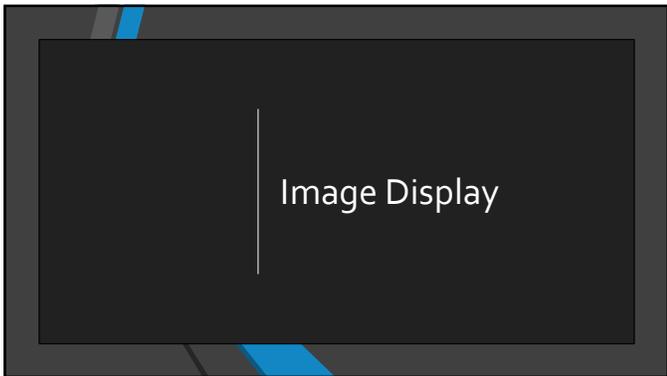




1



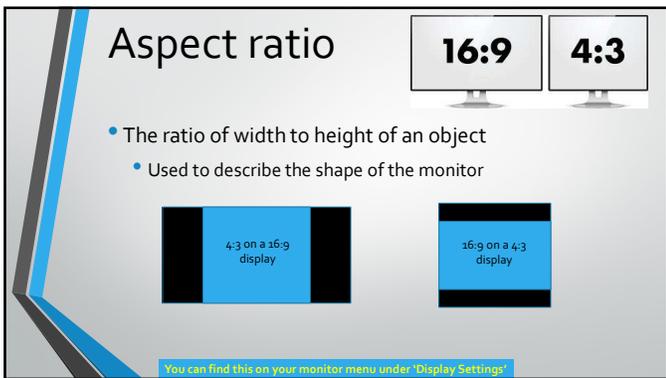
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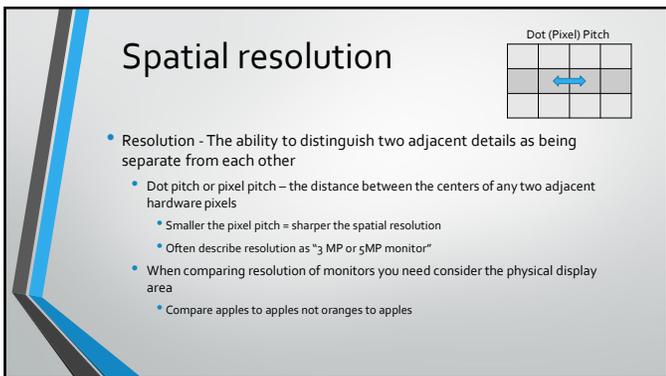
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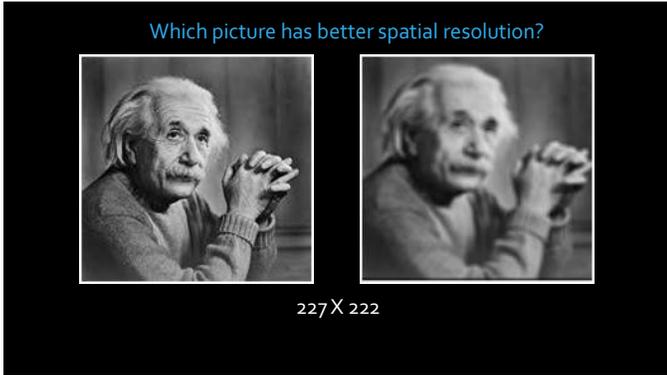
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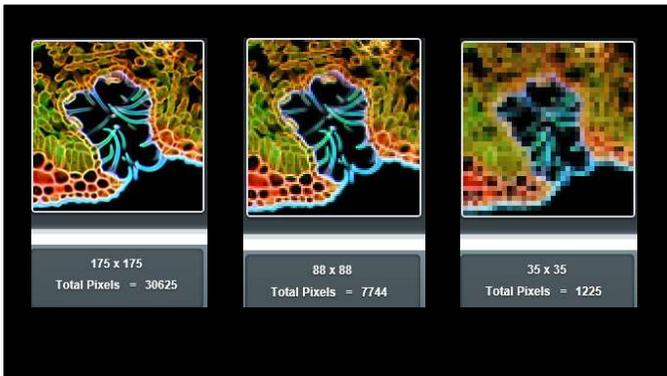
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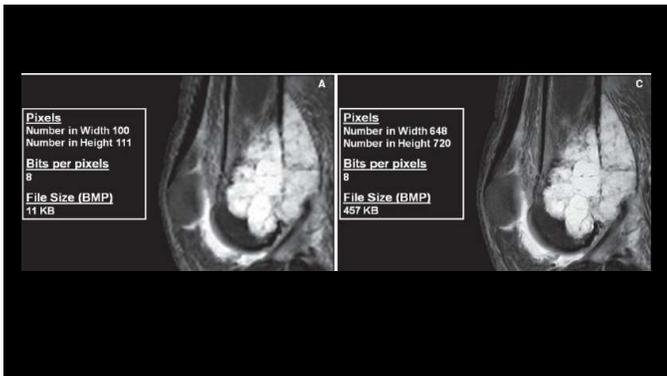
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8



9

Brightness

- The black level of a display screen. Although it may sound peculiar, the brightness adjusts the "black level" of the display system (how black the black is) –*Computer Desktop Encyclopedia*
- Photometer is used to measure the brightness output of an LCD
- American College of Radiology (ACR) requires a minimum brightness capability for radiologic display systems of 250 lumens



Too dark Good brightness Too bright

10

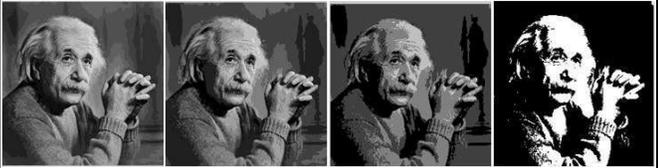
Contrast Ratio

- The difference between the darkest blacks and the brightest whites a given display can produce.
- Contrast ratio for LCD = 600:1, CRT = 3000:1
 - LCD - Inability to produce a "true black" due to backlight leakage



100% Contrast 75% Contrast 50% Contrast 25% Contrast 1% Contrast

12

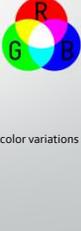


16 Gray Levels 8 Gray Levels 4 Gray Levels 2 Gray Levels

13

Color vs. Grayscale (monochrome)

- **Monochrome monitors**
 - Color images will appear as shades of gray
 - Has only one phosphor of color, but may have the ability to change the brightness causing the illusion of depth
 - Produces sharper text and image because 1 phosphor per pixel than color
- **Color monitors**
 - Monochrome images can be viewed on color monitors
 - Uses alternating intensities of red, green and blue to produce the different color variations
 - Uses 3 phosphors per pixel



15

What color would be seen in a color monitor?

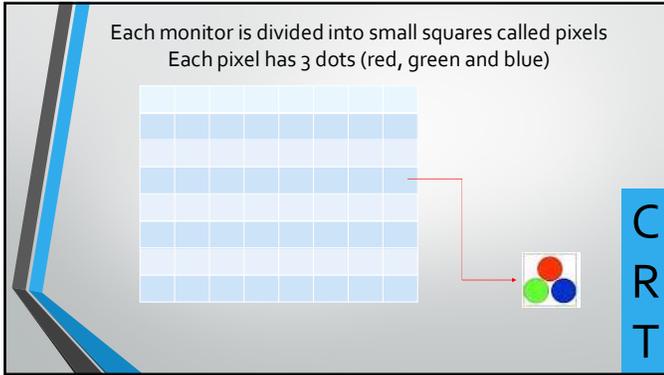
- If all 3 colors set at 0 = **BLACK**
- If all 3 colors set at 255 = **WHITE**
- If red was set at 255 and blue and green at 0 = **RED**

16

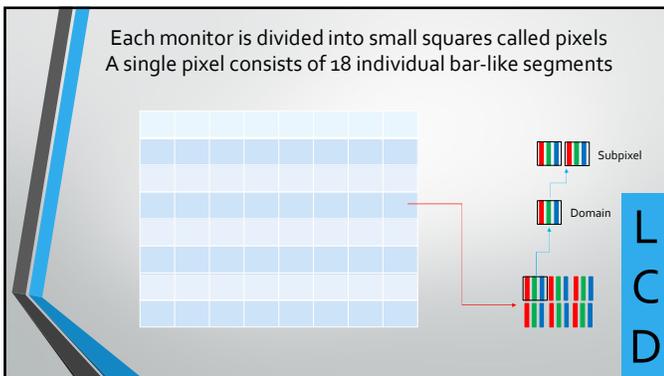
Pixels for Computers

- Pixel – multiple definitions
 - Carroll states it is “the smallest element of the matrix or device that can represent all pixel values within the system’s dynamic range”
- CRT – each triad of color (red, blue, and green) is considered one pixel
- LCD – a single pixel consists of 18 individual bar-like segments
- Hardware pixel in monitor – intersections of flat, transparent wires crossing over each other to form an overall square shape

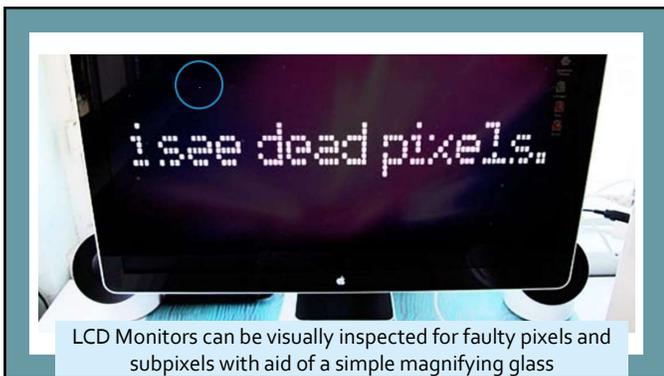
18



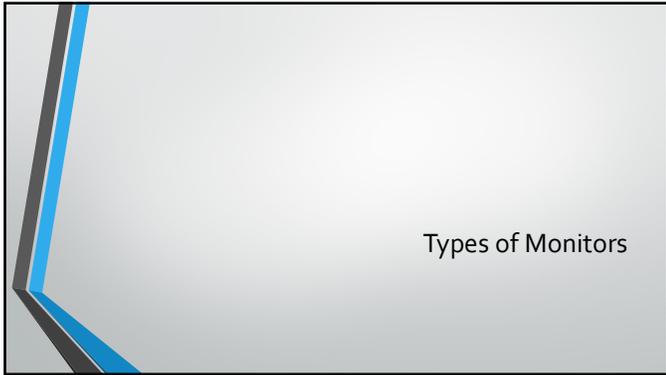
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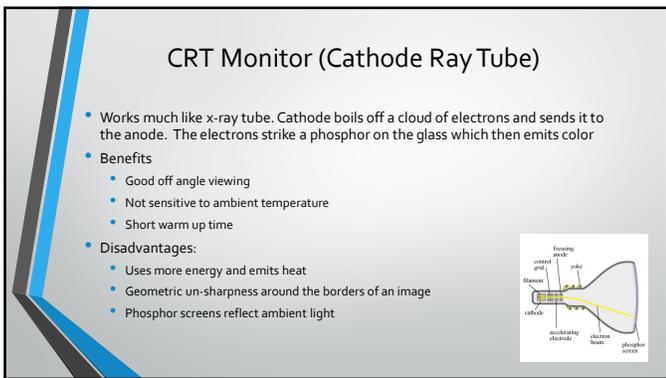
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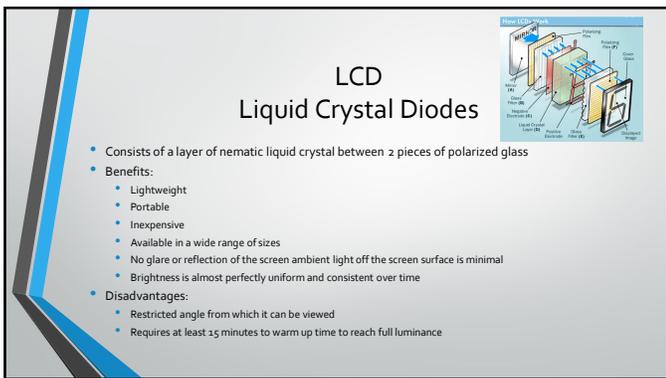
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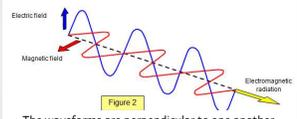
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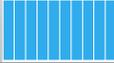
To understand the LCD monitor you must comprehend Light Polarization

- Like an x-ray, a ray of light is electromagnetic radiation that consists of a double wave

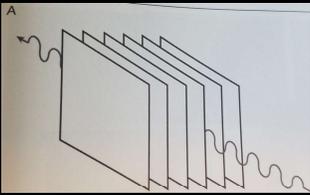


The waveforms are perpendicular to one another

- LCD Monitors use polarized glass
 - Polarized glass contains long chains of iodine molecules, all aligned parallel to each other
 - Just like a grid strips in a grid

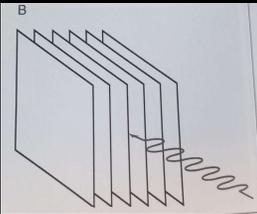


26



Electrical

The electrical component of the double wave can pass through a polarized glass with vertical string molecules because it vibrates parallel to it

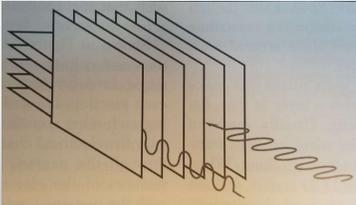


Magnetic

The magnetic component of the double wave cannot pass through a polarized glass with vertical string molecules because it vibrates perpendicular to it

27

What will happen if you layer 2 polarizing glass together so the string molecules are perpendicular to each other?



28

LCD – Light polarization

- LCD monitor consists of:
 - 2 thin sheets of glass
 - Each with a light polarizing layer that are perpendicular to the other sheet

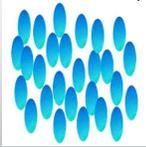
Perpendicular sheets = ALL light being blocked

Don't worry, the LCD process involves "tricking" these layers into allowing light to pass

29

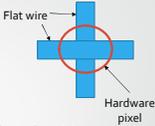
What are nematic liquid crystals?

- This is what is inserted between the polarizing glass sheets/lenses that plays the trick
- A crystalline arrangement of molecules that have a long linear shape and tend to align parallel to each other



30

Before we see the "trick", you need to know one more thing....



- In the polarizing glass there are a layer of thin, flat wires to conduct electricity
- These conductors are also aligned perpendicular to each other when the 2 polarized glass are together
- Each junction forms a single **hardware pixel**
 - Each electrode has a scratch on it
 - Scratches are perpendicular to one another
 - The crystals tend to line up with the "scratch" direction when no electric charge is present -- **known as "on" state**

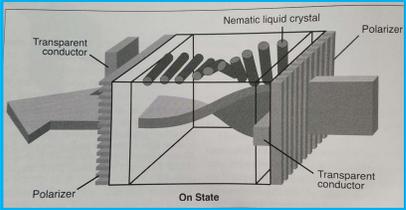
31

And **FINALLY**, Here is the Magic Trick.....



<https://www.youtube.com/watch?v=jiejNAUwcQ8>

32

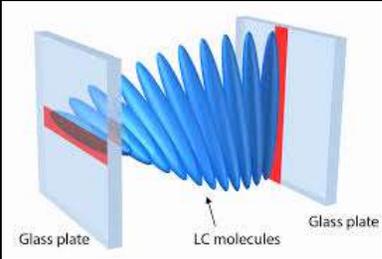


"ON" STATE

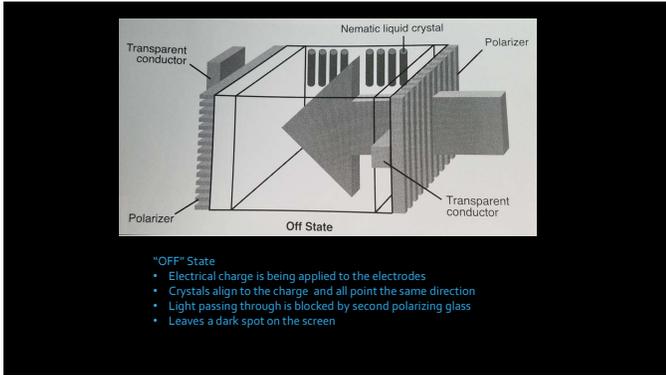
- Since the scratches are perpendicular, the liquid crystals line up in a spiral pattern that twists 90 degrees between the two glass plates
- This lets light waves pass through the nematic liquid crystal and follow the spiral
- Light is able to pass through the second glass plate to the viewer of the monitor

33

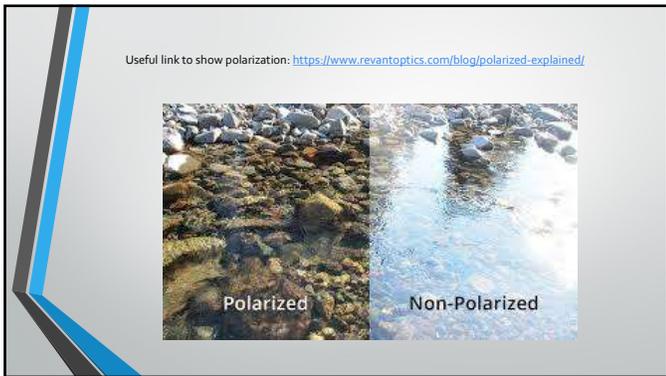
Just another way to look at it



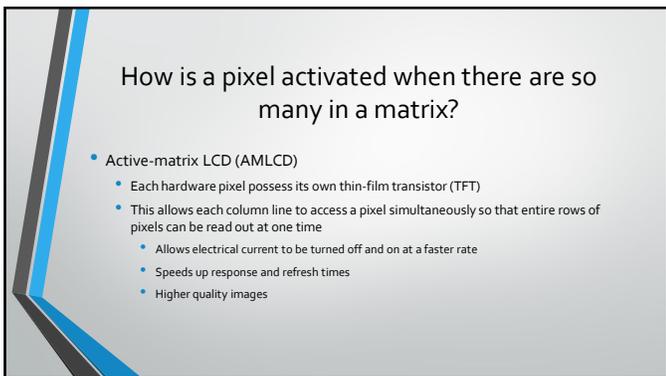
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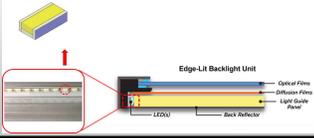
36



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More info on LCD Monitors

- As LCDs **do not** produce light by themselves—they need illumination to produce a visible image.
 - Without a **backlight**, an LCD display device will remain black, rendering it unviewable
- **Backlighting**
 - Types: Fluorescent bulbs or light-emitting diodes (LEDs)
 - LED - Most common



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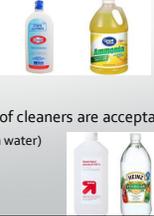
Care and Maintenance

39

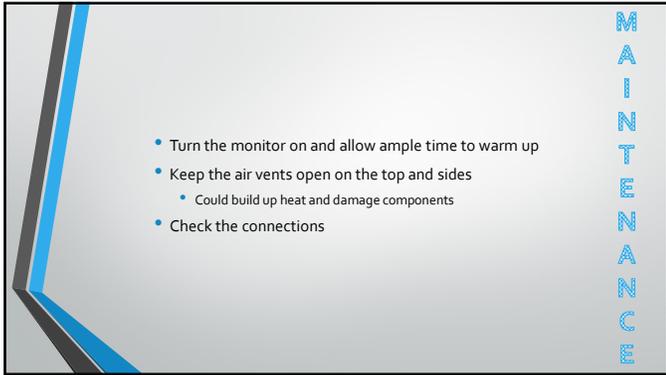
CARE

1. Apply cleaning solution to soft cloth
 - Do not spray solution directly on screen
 - Do not use paper towel can cause scratches
2. Wipe in one direction from top of screen to bottom

- The following cleaners should NOT be used: Acetone
 - Ethyl alcohol
 - Ethyl acid
 - Ammonia
 - Methyl chloride
- The following types of cleaners are acceptable: Water
 - Vinegar (mixed with water)
 - Isopropyl Alcohol
 - Petroleum Benzene



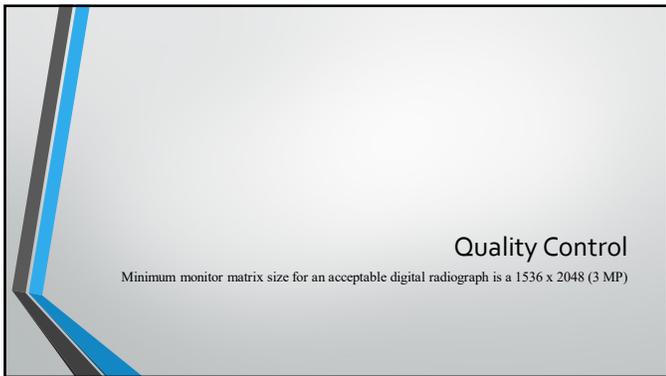
40



M-A-I-N-T-E-N-A-N-C-E

- Turn the monitor on and allow ample time to warm up
- Keep the air vents open on the top and sides
 - Could build up heat and damage components
- Check the connections

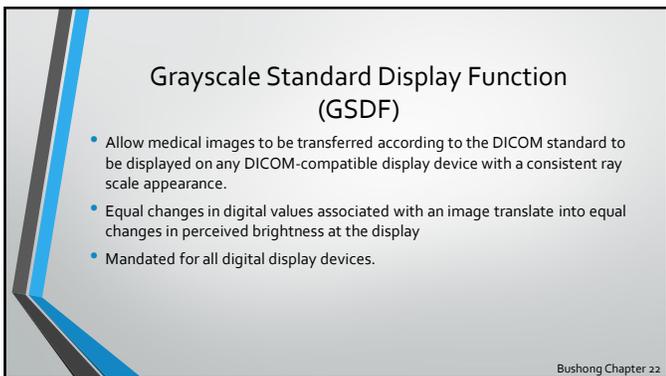
41



Quality Control

Minimum monitor matrix size for an acceptable digital radiograph is a 1536 x 2048 (3 MP)

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Grayscale Standard Display Function (GSDf)

- Allow medical images to be transferred according to the DICOM standard to be displayed on any DICOM-compatible display device with a consistent ray scale appearance.
- Equal changes in digital values associated with an image translate into equal changes in perceived brightness at the display
- Mandated for all digital display devices.

Bushong Chapter 22

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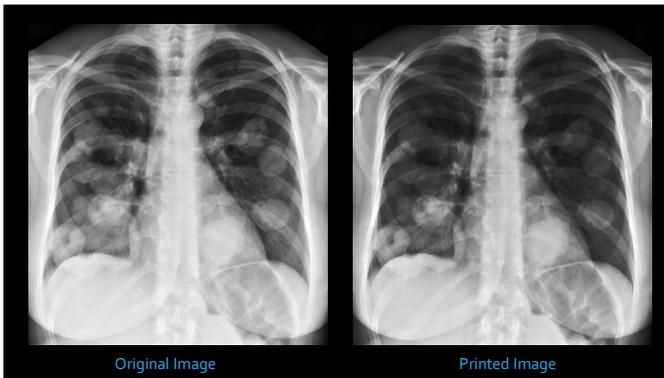
DICOM Grayscale Standard Display Function (GSDF) generates a display function matching the perceptual characteristics of a human observer.

Standard developed having human observer view monitor while luminance output of monitor changed in small steps from black to white and noting when they observed a **Just Noticeable Difference** (JND) in light output as the drive signal is changed.

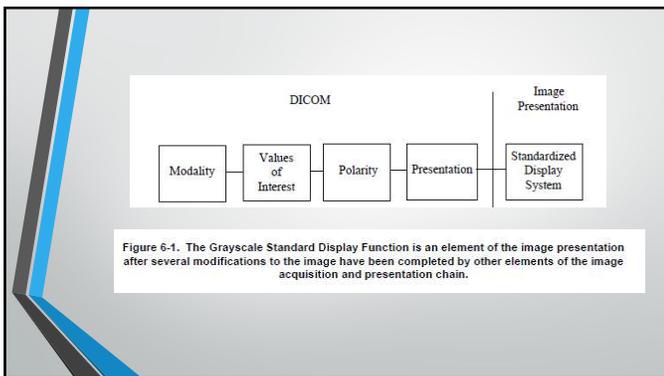
Most digital radiologic images are windowed to attempt to display 256 different shades of gray at any one time, (256 is approximate JND that humans can perceive)

The perceptual linearization implemented with the DICOM Grayscale Standard Display Function (GSDF) ensures that pixel values that are supposed to increase brightness in a linear fashion, say 6, 7, and 8, for example, actually appear that way to the human eye, despite the nonlinearity of our perception.

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Luminance

The rate of light (brightness) emitted from a source such as an LCD monitor

- **Maximum luminance** (*maximum brightness*)- checked at same monitor setting over a period of time with a photometer
- **Luminance response** – monitors ability to accurately display different shades of brightness from a test pattern
- **Luminance ratio** – compares maximum luminance to the minimum luminance
- **Luminance uniformity** – consistency of a single brightness level displayed across the area of the screen

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Luminance Ratio

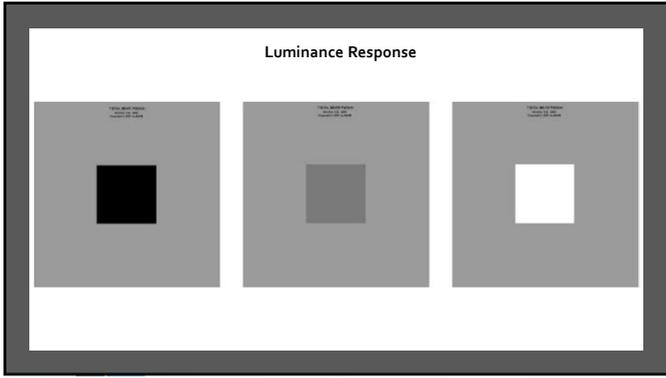
48

Luminance Response

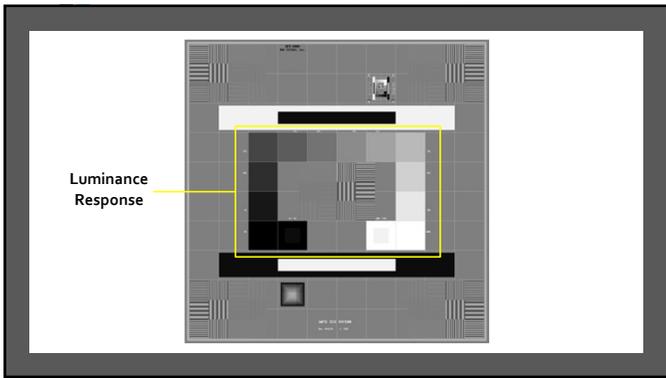
TGS-CT Pattern
Version 2.0, 10/11
Copyright © 2011 by Apple

A

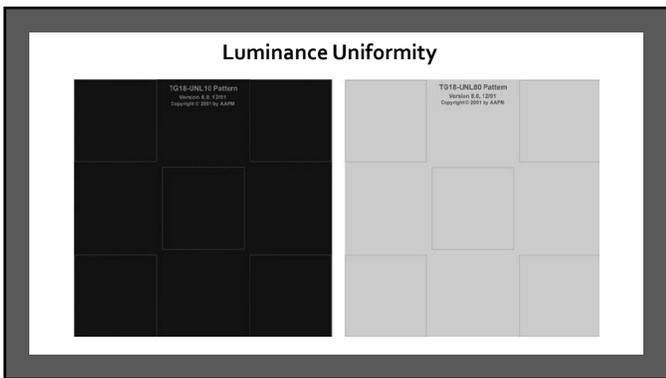
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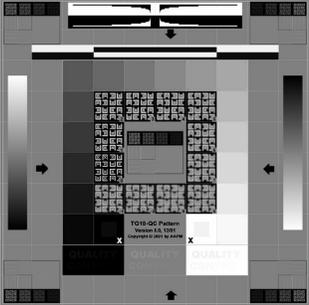
52

Resolution

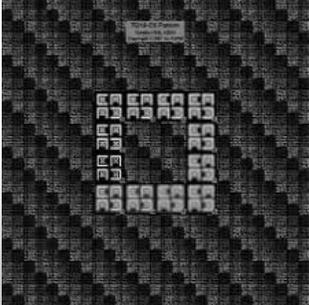
- ACR and AAPM minimum resolution for electronically displayed images of 2.5LP/mm
 - Generic SMPTE test pattern can be used
 - Check for blurring
- AAPM TG18 – QC and TG 18 CX provides an excellent check for resolution across the area of the display screen
 - Evaluate the CX pattern in the middle and in the corners
- Test can be done daily, weekly or monthly

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TG18 - QC

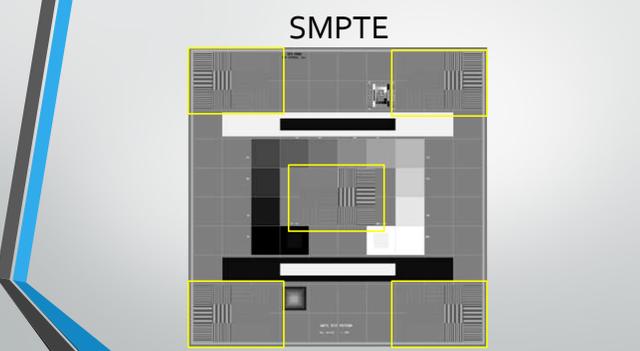


TG18 - CX



54

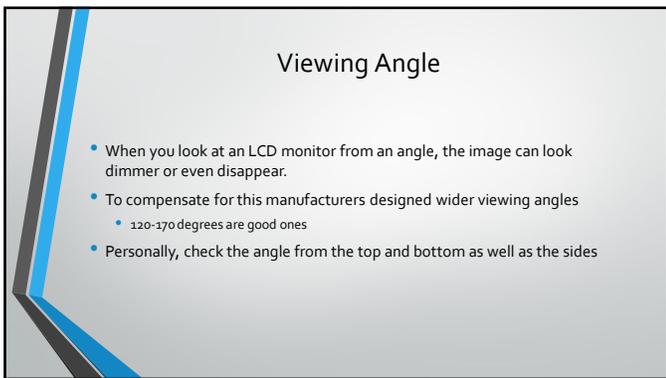
SMPTE



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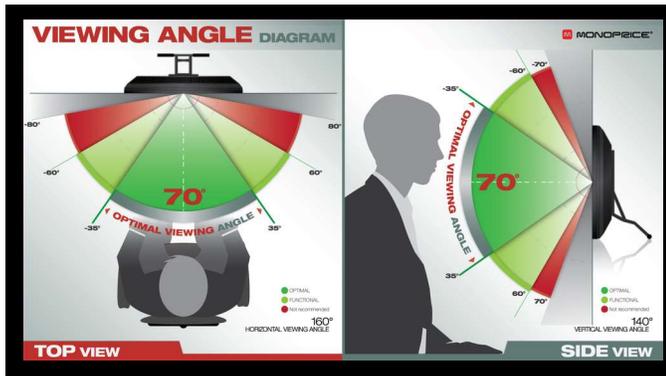
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Ambient Lighting

Illuminance – the rate of light striking a surface

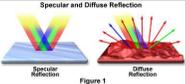


Figure 1

- The effect of ambient room lighting on the surface of and LCD monitor screen, including **reflectance** off the screen, and the resulting reduction in visible contrast of the image, is a result of **illuminance**
- Diffuse reflectance
 - The cumulative effect of room lighting across the area of the monitor screen
- Specular reflectance
 - The reflection of actual light sources such as a light bulb or window

The ambient lighting within the room must be dimmed to a point where both types of reflectance are below any noticeable level, that would impede full visibility of the image and image contrast

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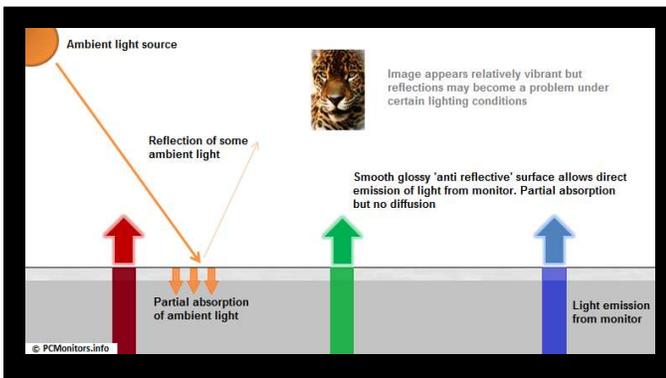
QC Aspect or Ambient Light

- While diagnosis is taking place, the maximum ambient lighting in a reading room should never be more than 25 lux
 - Approximately 1/4 the typical brightness of normal office lighting (75-100 lux)

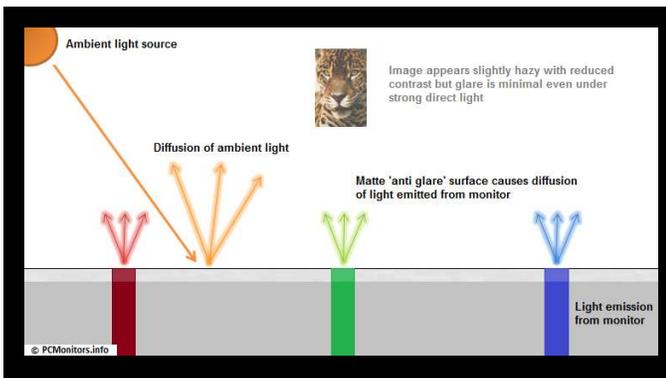
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Laser Film

- Produces a hard copies of radiographs, CT and MRIs
- Use helium-neon laser or solid state diode laser to write digital data onto special film
- Heat from laser makes area on film turn black and form an image
- Laser printers can be directly networked into PACS

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CD and DVD

- 1958 – optical discs invented
- CD – has microscopic groove from inner track to outer track
 - Typical storage is 700 MB
- 1990s – second generation of optical disc
 - DVD (digital versatile disk or digital video disc)
 - Typical storage is 5GB
- 2006 – third generation
 - Blue ray disc – allows high definition
 - Typical storage is 25GB

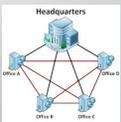
69

Data Management

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Network Connectivity

- LAN – Local Area Network
 - Computerized communications network generally contained within a single building or business
 - Devices share one server
- WAN – Wide Area Network
 - Extends to other businesses or locations that may be at great distances
 - Publically or commercially owned
 - Uses transmission services provided by common carriers (phone or cable companies)



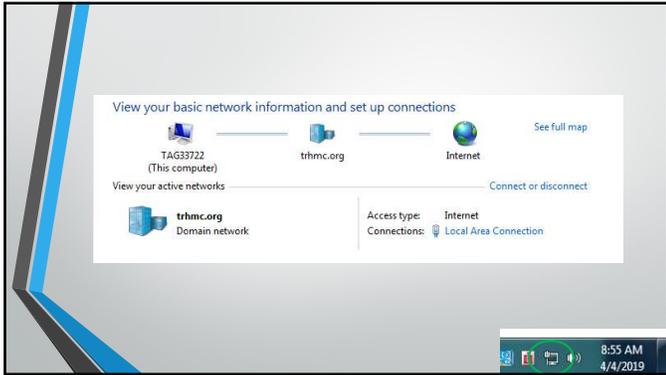
76

Computer Network

- Every computer within a network has a unique internet protocol or IP address
 - Ex. 172.811.3.1
- Every computer must have a network interface card
- Router
 - Connects 2 or more networks
 - Wireless routers – allow "point-of-care" access to a network for physicians and other caregivers via tablet or laptop



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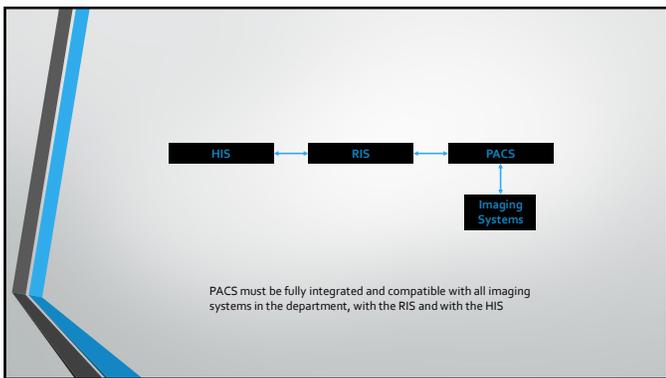
78

Type of LAN

RIS and HIS

- Radiology Information System
 - Data system for patient-related functions in the department, such as scheduling of x-ray appointments, tracking of patients, storage and distribution of reports
 - Makes info accessible from different locations within the radiology department
 - Assigns the **accession number**
- Hospital/Health Information System
 - Performs same functions for the entire institution (patient's general medical file)
 - Assigns a unique identifying number for each patient (**MRN**)

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Picture Archiving and Communications System (PACS)

- Comprehensive computer network that is responsible for the electronic storage and distribution of medical images.
- Makes radiographs, CT and MRI scans, US and Nuclear Med images for a particular patient available within the network
- Allows Radiologists and Technologist to access these images from various locations, improving the efficiency of communication

Soon to be Called....
Medical image management and processing system (MIMPS)

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PACS

- Digital acquisition (Picture)
- Display workstations
- Storage devices (Archiving)
- Components are interconnected by a network (Communication)

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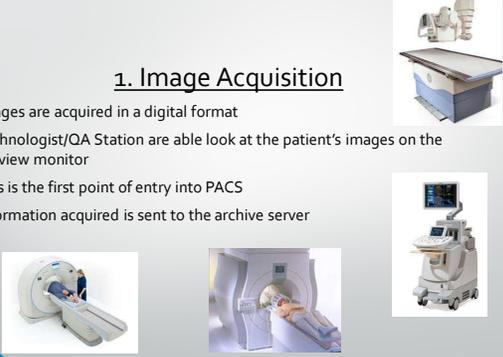
Components of PACS

- Image acquisition
- Display workstations
- Archive servers

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1. Image Acquisition

- Images are acquired in a digital format
- Technologist/OA Station are able look at the patient's images on the preview monitor
- This is the first point of entry into PACS
- Information acquired is sent to the archive server



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2. Display Workstations

Any computer used to view digital images

- Radiologists
- Physicians, surgeons, nurses & patients
- Technologists

- Most interactive part of PACS
- Used inside and out of Radiology
- Has PACS application software that allows minor image-manipulation

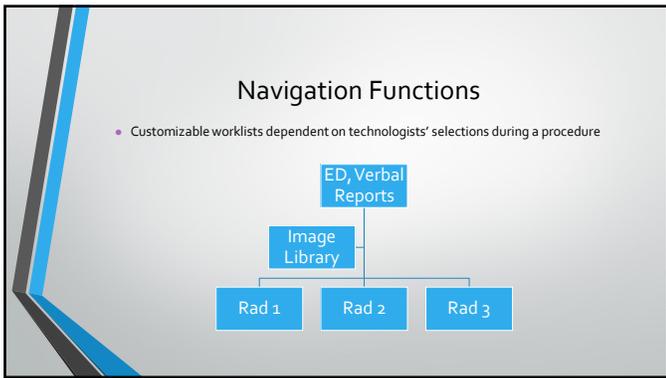


85

Common Workstation Functions

- Navigation Functions
- Hanging Protocol
- Study Navigation
- Image Manipulation & Enhancement
- Image Management

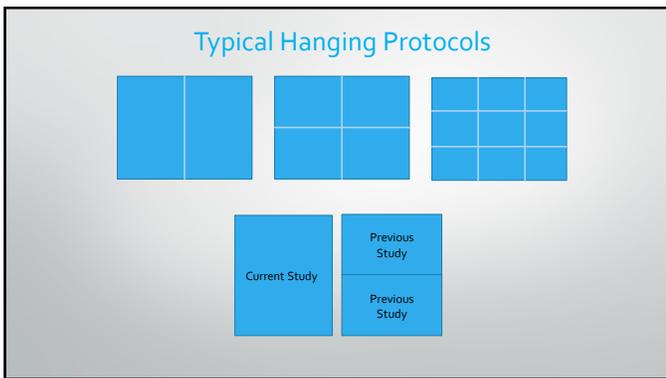
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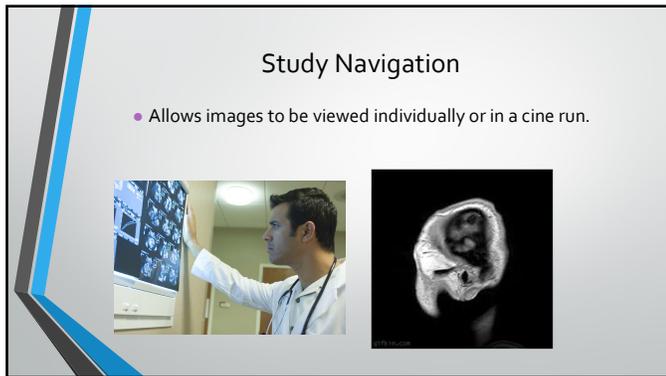
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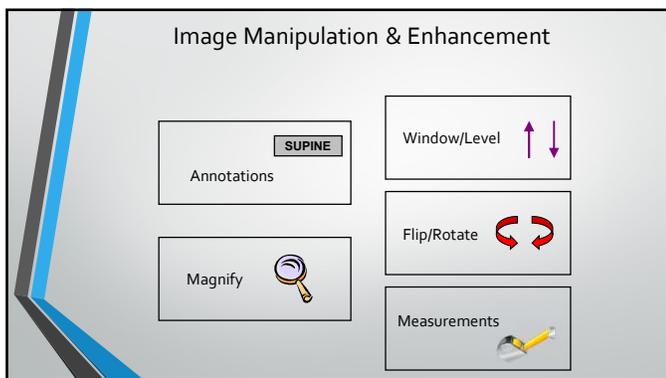
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Image Management Functions

- Patient demographics
 - Edit patient information for proper correlation with previous studies, billing, etc.
- Query / Retrieve
 - Locate images based on patient demographics
- Hardcopy images
 - Either CD or plain film
 - Usually only image library has this function

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3. Archive Servers

- File room of PACS
- Contains all historic and current data



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PACS Archiving

- Consist of:
 - Image manager/controller
 - Image storage/server



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Image Manager

- Contains master database of everything in the archive
- Controls the receipt, retrieval and distribution of the images it stores
- Controls all the DICOM processes running within the archive
- Communicates with RIS and HIS
- Can populate image information into the EMR

MANAGER

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Image Storage/Archive Server

- Physical storage device for archive system
- Network of servers
- Setup in tiers
 - Short-term
 - Long-term

In the United States, storage requirement of a patient's images is from five to seven years.

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Short Term Storage

- RAID
 - several magnetic disks or hard drives that are linked together in an array

RAID 5 is the most common level used for a PACS archive because it provides adequate redundancy and fault tolerance

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Reading Hospital

- Short-term storage is done on servers located in IMS but maintained by Philips
 - Philips monitors the system through remote access
 - All backups and drive redundancy are handled by Philips

100

Long Term Storage

- RAID
- Optical disk
- Tape
- Magnetic disk

101

Cloud-Based Storage

- Offsite storage and servers supported by a secure network
- 3rd party vendor
- Shifts disaster recovery process to the vendor along with maintenance and storage equipment purchase
- You pay for the service and storage space

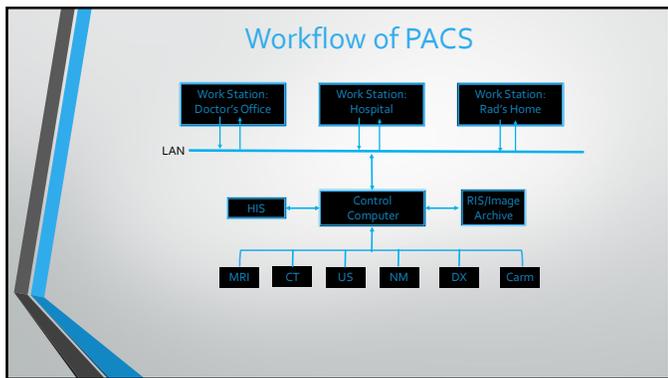
102

Reading Hospital:

- Prior to EPIC - \$1 million budget for record storage
- Legally obligated to retain films:
 - Pediatrics
 - Mammo
 - All other films



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Summary of PACS Functions

- Main function: Act as a *database*
 - Generate and sort according to status (i.e. pending, completed)
 - Various queries – users can search for specific information
- Manipulation – at any workstation
- Storage

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Vendor Neutral Archives (VNA)

- Allows for images and data from different systems and in different formats to be stored using a singular system on a common infrastructure
- May be used as replacements to existing PACS to avoid very expensive transition costs
- Used to consolidate a number of systems that exist within a single facility or across a system of facilities

106

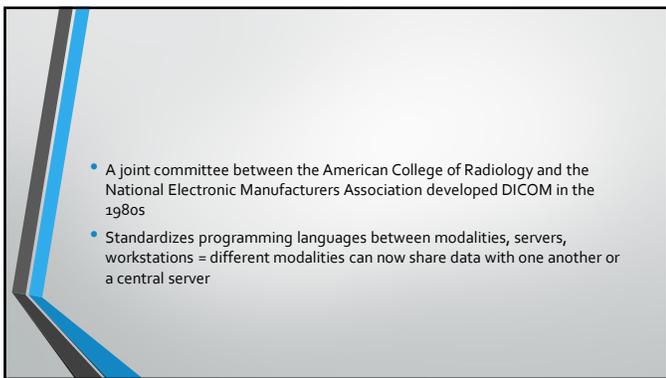
PACS Emergency Contingency Plan

- A backup copy of ALL archived records should be maintained either by the hospital or an Application Service Provider
- RH PACS Downtime Procedure Policy - <https://trh.elucid.com/documents/view/12114/33066/3>

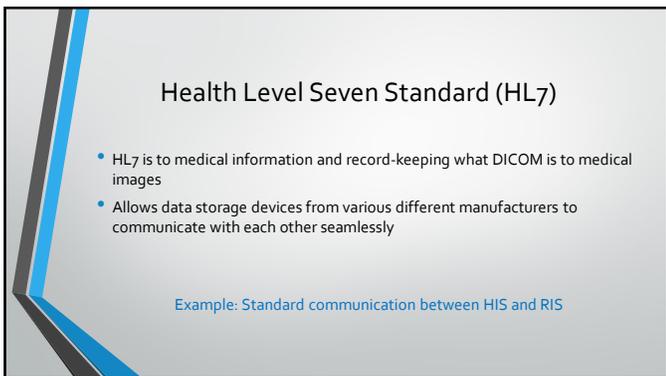
107



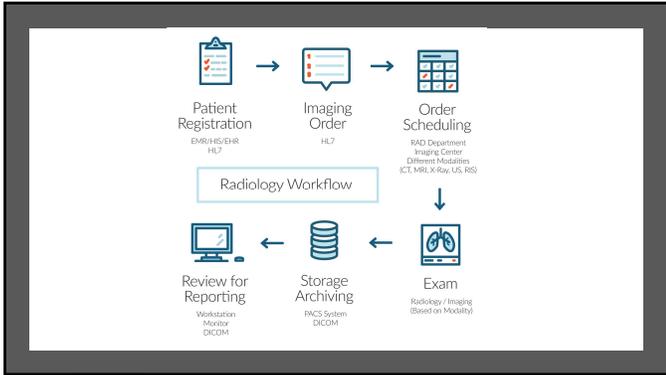
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112



113



114

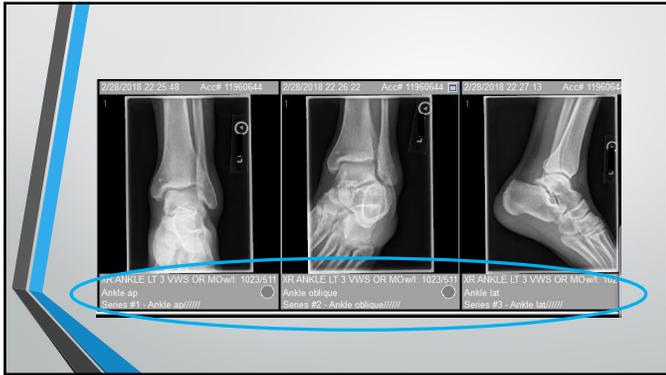
DICOM Header

- A summary of critical identification and study information such as:
 - Date and time of procedure
 - Number of images taken
 - Body part, position
 - Technique used
 - Image format and receptor size
 - Parameters used to digitally process the image
- All this information is stored as **metadata**
 - Should appear in a bar at the top of the screen for each image
 - Shows summary of essential metadata for the image

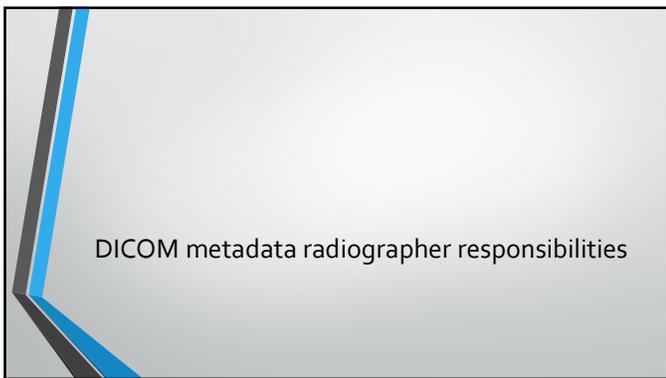
115

Group Tag	Element Tag	Tag Description	Value
0010	0011	Private Tag	MURKIN
0010	0020	Patient ID	12345
0010	0030	Patient's Birth Date	00000000
0010	0040	Patient's Sex	M
0010	1030	Patient's Weight	0
0010	2165	Private Tag	None
0010	2166	Private Tag	None
0010	4000	Patient Comments	
0018	0015	Body Part Examined	THORAX
0018	1000	Device Serial Number	00000000
0018	1020	Software Version(s)	1.0.1.120
0018	1164	Image Field Source	0.16
0018	1508	Positioner Type	COLLIMIN
0018	5100	Patient Position	ANTERIOR - POSTERIOR
0018	7004	Detector Type	DIRECT
0018	7006	Detector Description	
0018	7014	Detector Serial	1.1.1
0020	0000	Study Instance UID	1.2.825.0.1.3680043.2.1330.1000001.1.2213256752.2712337879
0020	000E	Series Instance UID	1.2.825.0.1.3680043.2.1330.1000001.4.2213256752.27123318877
0020	0010	Study ID	None
0020	0011	Series Number	1
0020	0019	Instance Number	29
0020	0020	Patient Orientation	N
0020	0060	Laterality	L
0020	0062	Private Tag	U
0020	4000	Image Comments	
0028	0002	Samples per Pixel	1

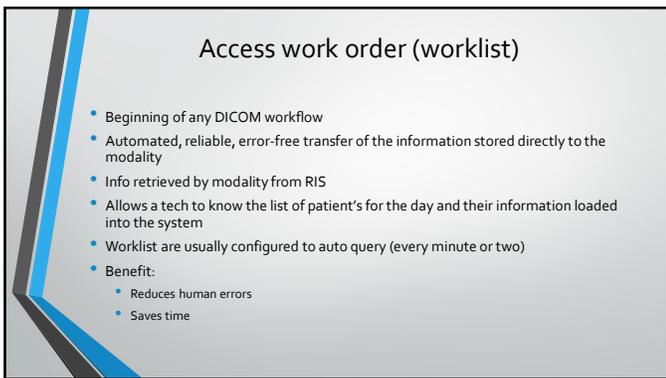
116



117



118



119

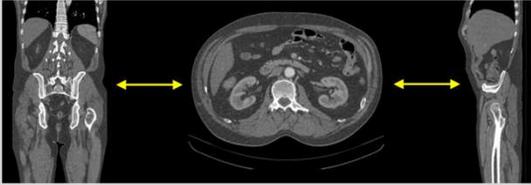
Post Processing – Image operation and manipulation

- Image operation activities
- Multiplanar Reconstruction
- Maximum and Minimum Intensity Projection
- Volume Rendering Technique (VRT)
- Shaded Surface Display (3D technology)
- CAD

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Multiplanar Reconstruction

- Creates multiple planes of view from a single scan



<https://www.youtube.com/watch?v=H1nPmSVijag>

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Maximum & Minimum Intensity Projections

- Enhancement of small vessels (MIP) and air-filled structures (MinIP)

MinIP – Minimum Intensity Projections

MIP – Maximum Intensity Projections

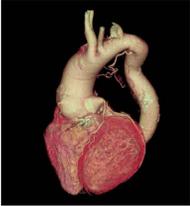


MinIP AIP MIP

122

Volume Rendering Technique (VRT)

- Assists in differentiating between anatomical structures by adding color shades based on pixel intensity



123

Shaded Surface Display (SSD)

- Creates a 3D, moveable image based on the pixel intensity of choice



124

CAD (Computer Aided Diagnosis/Detection)

- used as a "second opinion" in assisting radiologists' image interpretations
 - complementary tools that draw the radiologists' attention to certain image areas that need further evaluation
- Uses algorithms
- Used in Mammography at RH



Source: Appl Radiol © 2004 Anderson Publishing, Ltd

125

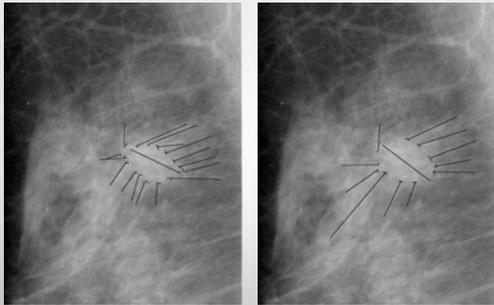
Annotation Issues: Annotations and Mark Ups

- *Image annotation* – describes the meaning in images
- *Image markup* – visual presentation of the annotation
- AIM Project (Annotation and Image Mark up project)
 - The model contains information about who created the annotation, the equipment with which the annotation was created, when the annotation was created, and the image(s) to which the annotation refers.
 - Once the annotation is defined in the AIM, sophisticated queries are now easily found
 - "Find all studies that contain enhancing right middle lobe lung masses that measure between 5 and 6 cm"

126

- Other concerns are
 - What is more accurate tool to use --- stylus or mouse for marking or measurements?
 - Human error
 - Legal issues

127



Mouse Stylus

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Case number	Annotation time for mouse (s)	Annotation time for stylus (s)
1	109	86
2	121	71
3	108	70
4	78	74
5	109	91
6	55	57
7	78	77
8	90	54
9	113	60
10	89	85
11	101	98
12	81	41

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Image Transmission

- Concerns of medical data overload
 - CT may produce 300 to 500 images and a CT angiography runoff study may include 1,500 to 2,000 images
- In teleradiology, the header of the DICOM image is first transmitted followed by the compressed image data and then at the receiving end, images are reconstructed from low quality to high (or perfect) quality
- Facilities will compress images to send, this allow it to be sent more efficiently
 - Lossless compression have been defined as "visually acceptable" images by the medical imaging community

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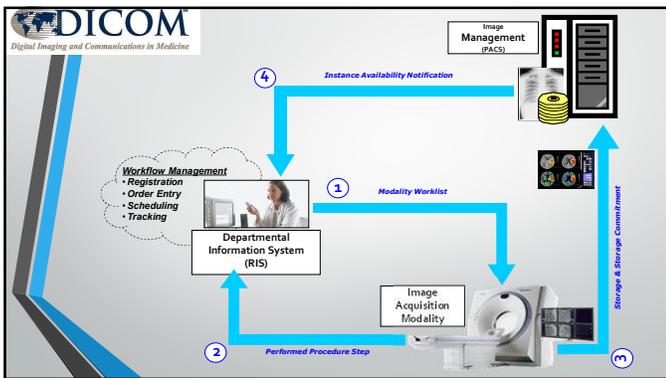
HIPAA

- Health Insurance Portability and Accountability Act of 1996 (HIPAA) Privacy Rule is to ensure you have rights over your own health information, no matter what form it is in.
- The government also created the HIPAA Security Rule to require specific protections to safeguard your electronic health information.
- Federal law requires doctors, hospitals, and other health care providers to notify you of a "breach."
- Facilities should implement high-grade security and encryption in their systems in order to protect records from hackers or theft
- Adhering to HIPAA guidelines often means subjecting software developments to a legal team who can determine whether or not the software falls within HIPAA regulations for security and confidentiality

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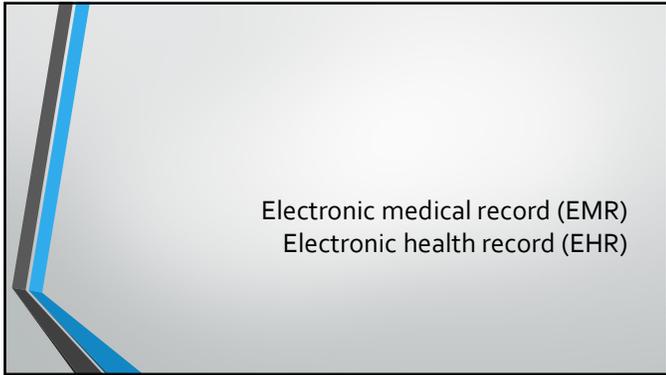
133

DICOM Services for Acquisition Workflow Management

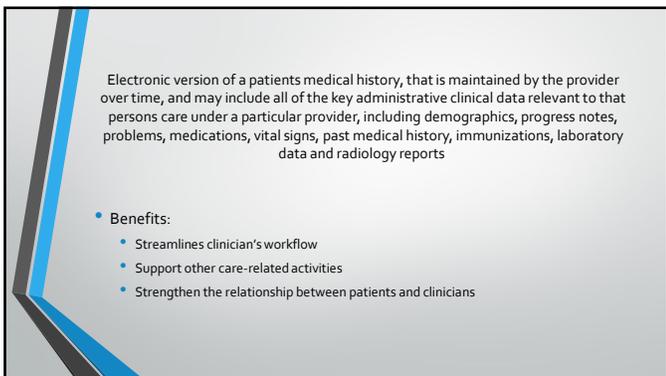
- Improve Interoperability of Imaging Equipment
- Ensure Data Consistency
- Facilitate Reliable Data Management
- Improve Process Efficiency
- Better Quality of Imaging Services

DICOM
Digital Imaging and Communications in Medicine

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137

- Any system which allows remote transmission and viewing of radiographic images via modems over phone or cable lines
- Makes it possible for images to be sent great distances for a specialist to collaborate with a radiologist, and for images stored at a hospital to be accessed almost instantly by doctors at their individual clinics
 - Example: transmit images to radiologist's home during off hours





1



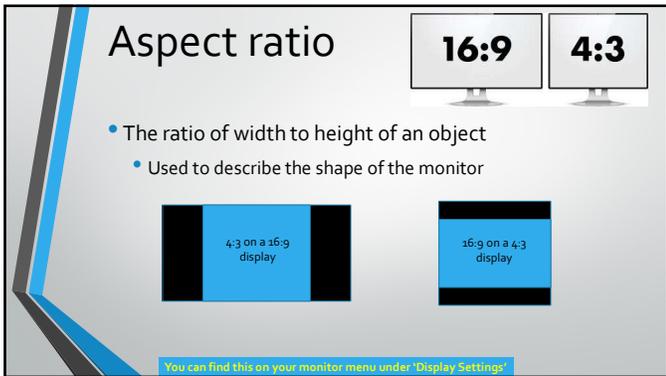
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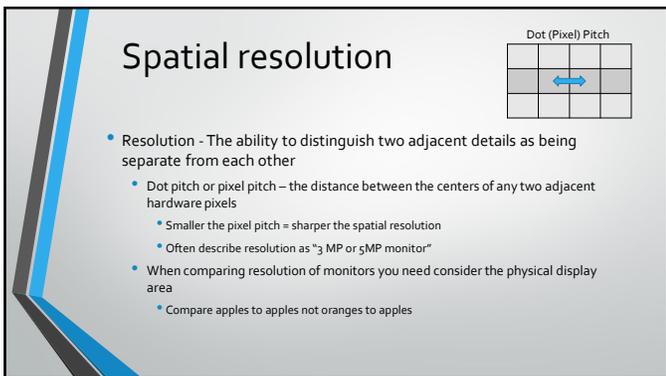
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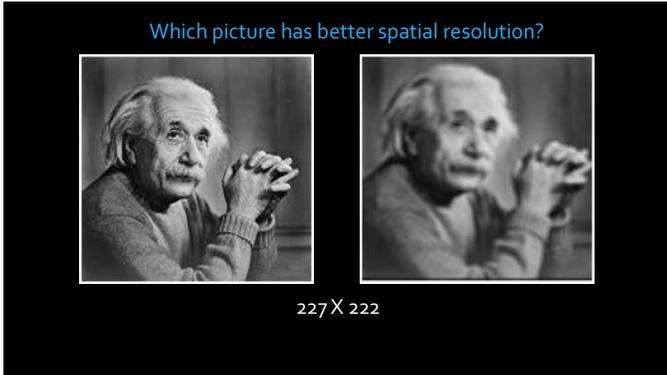
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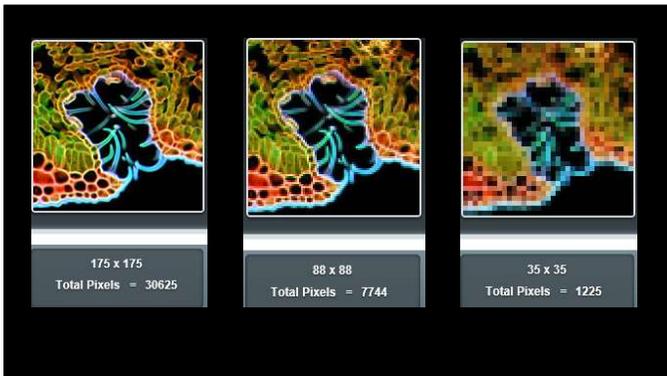
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6



7



8



9

Brightness

- The black level of a display screen. Although it may sound peculiar, the brightness adjusts the "black level" of the display system (how black the black is) –*Computer Desktop Encyclopedia*
- Photometer is used to measure the brightness output of an LCD
- American College of Radiology (ACR) requires a minimum brightness capability for radiologic display systems of 250 lumens



Too dark Good brightness Too bright

10

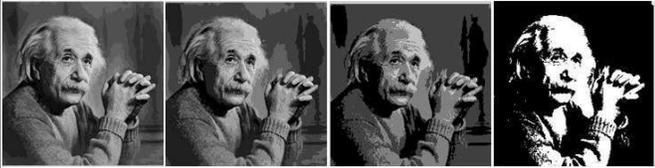
Contrast Ratio

- The difference between the darkest blacks and the brightest whites a given display can produce.
- Contrast ratio for LCD = 600:1, CRT = 3000:1
 - LCD - Inability to produce a "true black" due to backlight leakage



100% Contrast 75% Contrast 50% Contrast 25% Contrast 1% Contrast

12

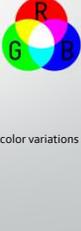


16 Gray Levels 8 Gray Levels 4 Gray Levels 2 Gray Levels

13

Color vs. Grayscale (monochrome)

- **Monochrome monitors**
 - Color images will appear as shades of gray
 - Has only one phosphor of color, but may have the ability to change the brightness causing the illusion of depth
 - Produces sharper text and image because 1 phosphor per pixel than color
- **Color monitors**
 - Monochrome images can be viewed on color monitors
 - Uses alternating intensities of red, green and blue to produce the different color variations
 - Uses 3 phosphors per pixel



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What color would be seen in a color monitor?

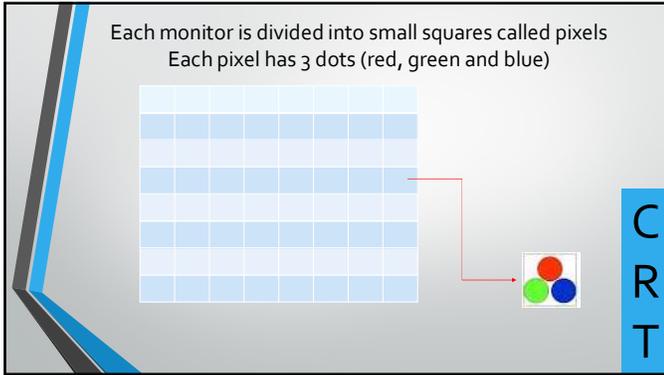
- If all 3 colors set at 0 = **BLACK**
- If all 3 colors set at 255 = **WHITE**
- If red was set at 255 and blue and green at 0 = **RED**

16

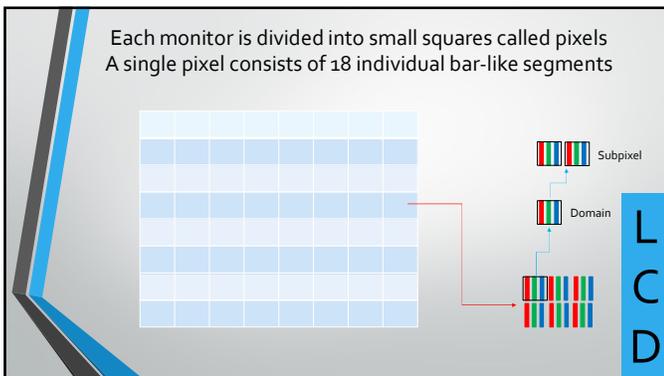
Pixels for Computers

- Pixel – multiple definitions
 - Carroll states it is “the smallest element of the matrix or device that can represent all pixel values within the system’s dynamic range”
- CRT – each triad of color (red, blue, and green) is considered one pixel
- LCD – a single pixel consists of 18 individual bar-like segments
- Hardware pixel in monitor – intersections of flat, transparent wires crossing over each other to form an overall square shape

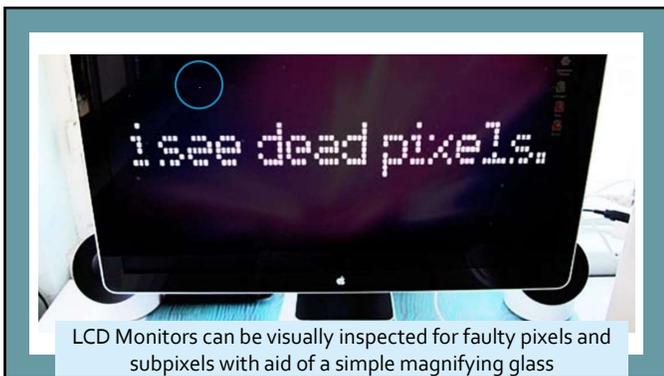
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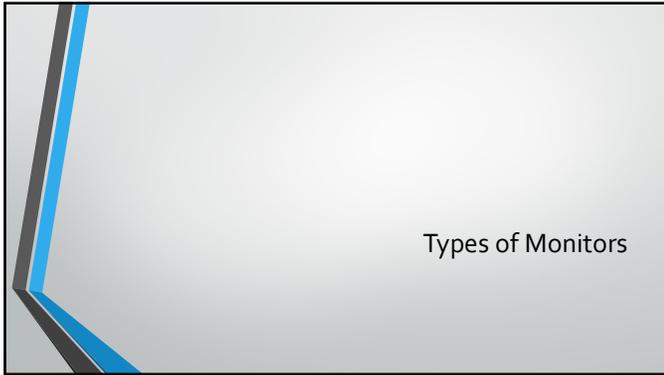
19



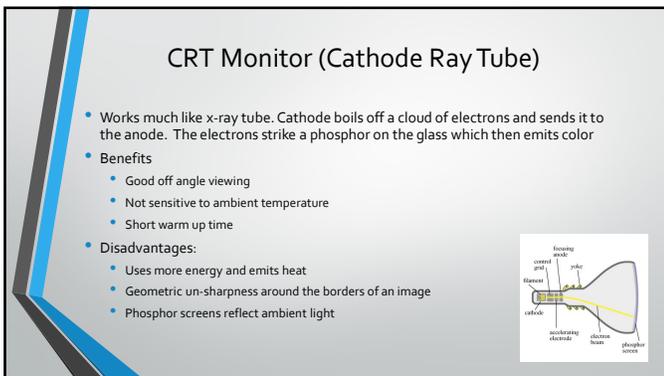
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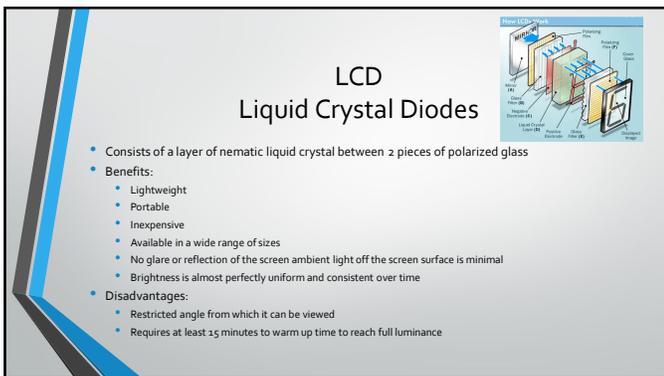
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23



24



25

To understand the LCD monitor you must comprehend Light Polarization

- Like an x-ray, a ray of light is electromagnetic radiation that consists of a double wave

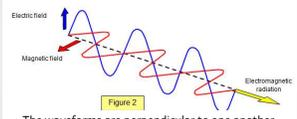
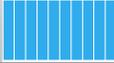
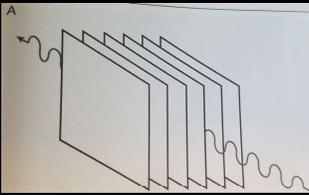


Figure 2
The waveforms are perpendicular to one another

- LCD Monitors use polarized glass
 - Polarized glass contains long chains of iodine molecules, all aligned parallel to each other
 - Just like a grid strips in a grid

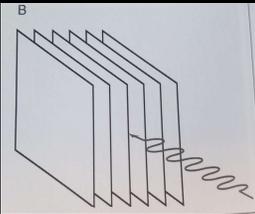


26



Electrical

The electrical component of the double wave can pass through a polarized glass with vertical string molecules because it vibrates parallel to it

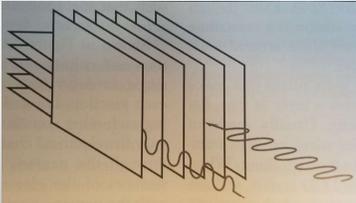


Magnetic

The magnetic component of the double wave cannot pass through a polarized glass with vertical string molecules because it vibrates perpendicular to it

27

What will happen if you layer 2 polarizing glass together so the string molecules are perpendicular to each other?



28

LCD – Light polarization

- LCD monitor consists of:
 - 2 thin sheets of glass
 - Each with a light polarizing layer that are perpendicular to the other sheet

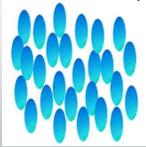
Perpendicular sheets = ALL light being blocked

Don't worry, the LCD process involves "tricking" these layers into allowing light to pass

29

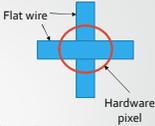
What are nematic liquid crystals?

- This is what is inserted between the polarizing glass sheets/lenses that plays the trick
- A crystalline arrangement of molecules that have a long linear shape and tend to align parallel to each other



30

Before we see the "trick", you need to know one more thing....



- In the polarizing glass there are a layer of thin, flat wires to conduct electricity
- These conductors are also aligned perpendicular to each other when the 2 polarized glass are together
- Each junction forms a single **hardware pixel**
 - Each electrode has a scratch on it
 - Scratches are perpendicular to one another
 - The crystals tend to line up with the "scratch" direction when no electric charge is present -- **known as "on" state**

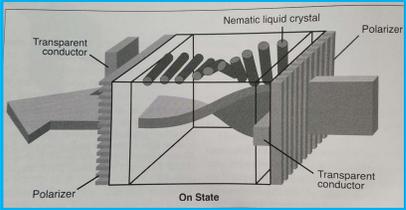
31

And **FINALLY**, Here is the Magic Trick.....



<https://www.youtube.com/watch?v=jiejNAUwcQ8>

32

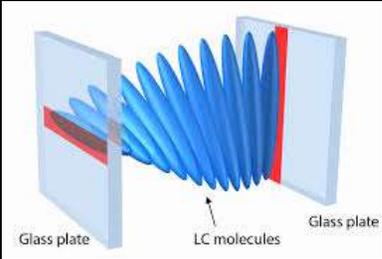


"ON" STATE

- Since the scratches are perpendicular, the liquid crystals line up in a spiral pattern that twists 90 degrees between the two glass plates
- This lets light waves pass through the nematic liquid crystal and follow the spiral
- Light is able to pass through the second glass plate to the viewer of the monitor

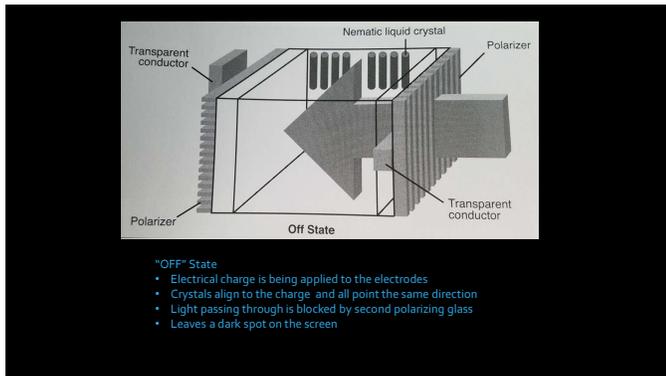
33

Just another way to look at it



Glass plate LC molecules Glass plate

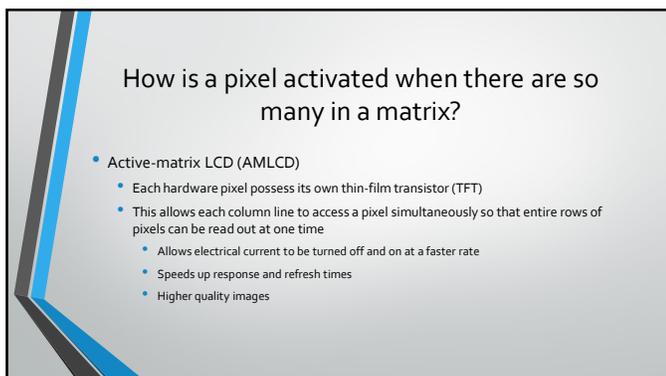
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35



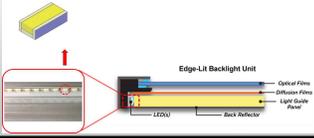
36



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More info on LCD Monitors

- As LCDs **do not** produce light by themselves—they need illumination to produce a visible image.
 - Without a **backlight**, an LCD display device will remain black, rendering it unviewable
- **Backlighting**
 - Types: Fluorescent bulbs or light-emitting diodes (LEDs)
 - LED - Most common



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Care and Maintenance

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CARE

1. Apply cleaning solution to soft cloth
 - Do not spray solution directly on screen
 - Do not use paper towel can cause scratches
2. Wipe in one direction from top of screen to bottom

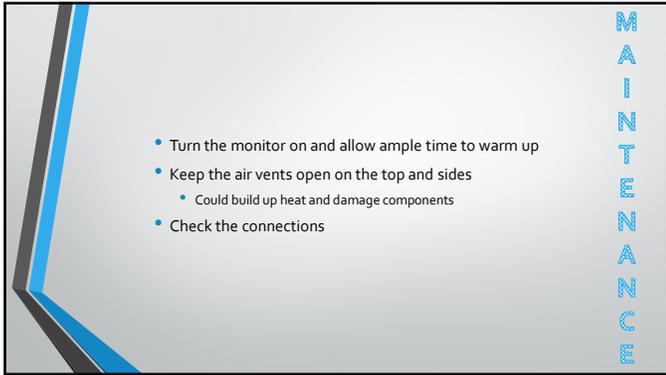
- The following cleaners should NOT be used: Acetone
 - Ethyl alcohol
 - Ethyl acid
 - Ammonia
 - Methyl chloride



- The following types of cleaners are acceptable: Water
 - Vinegar (mixed with water)
 - Isopropyl Alcohol
 - Petroleum Benzene



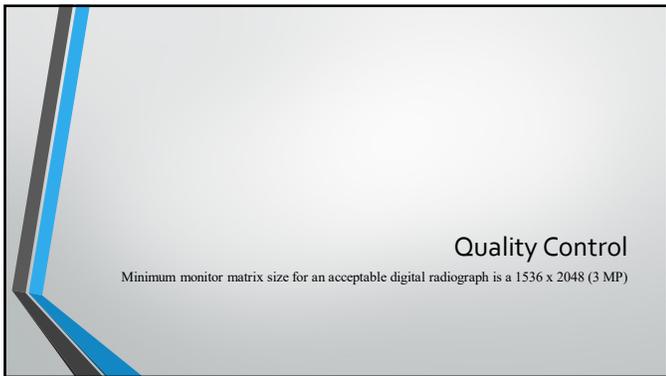
40



M-A-I-N-T-E-N-A-N-C-E

- Turn the monitor on and allow ample time to warm up
- Keep the air vents open on the top and sides
 - Could build up heat and damage components
- Check the connections

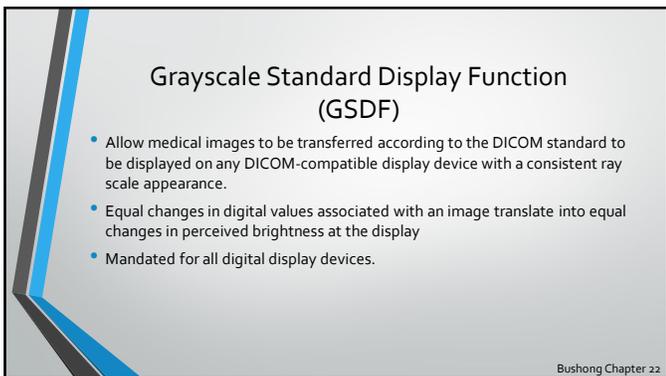
41



Quality Control

Minimum monitor matrix size for an acceptable digital radiograph is a 1536 x 2048 (3 MP)

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Grayscale Standard Display Function (GSDf)

- Allow medical images to be transferred according to the DICOM standard to be displayed on any DICOM-compatible display device with a consistent ray scale appearance.
- Equal changes in digital values associated with an image translate into equal changes in perceived brightness at the display
- Mandated for all digital display devices.

Bushong Chapter 22

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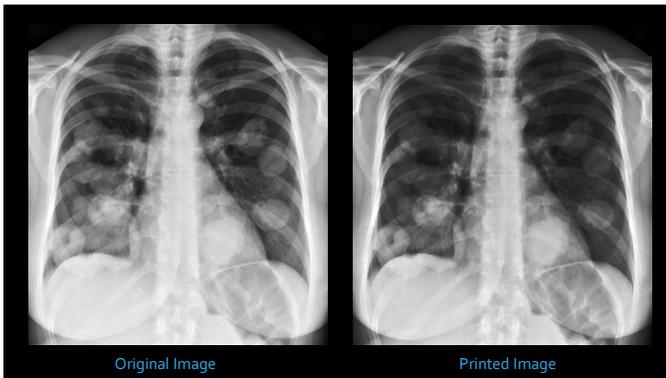
DICOM Grayscale Standard Display Function (GSDF) generates a display function matching the perceptual characteristics of a human observer.

Standard developed having human observer view monitor while luminance output of monitor changed in small steps from black to white and noting when they observed a **Just Noticeable Difference** (JND) in light output as the drive signal is changed.

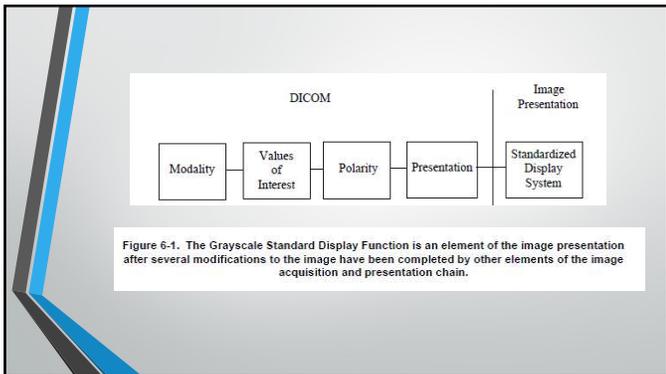
Most digital radiologic images are windowed to attempt to display 256 different shades of gray at any one time, (256 is approximate JND that humans can perceive)

The perceptual linearization implemented with the DICOM Grayscale Standard Display Function (GSDF) ensures that pixel values that are supposed to increase brightness in a linear fashion, say 6, 7, and 8, for example, actually appear that way to the human eye, despite the nonlinearity of our perception.

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Luminance

The rate of light (brightness) emitted from a source such as an LCD monitor

- **Maximum luminance** (*maximum brightness*)- checked at same monitor setting over a period of time with a photometer
- **Luminance response** – monitors ability to accurately display different shades of brightness from a test pattern
- **Luminance ratio** – compares maximum luminance to the minimum luminance
- **Luminance uniformity** – consistency of a single brightness level displayed across the area of the screen

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Luminance Ratio

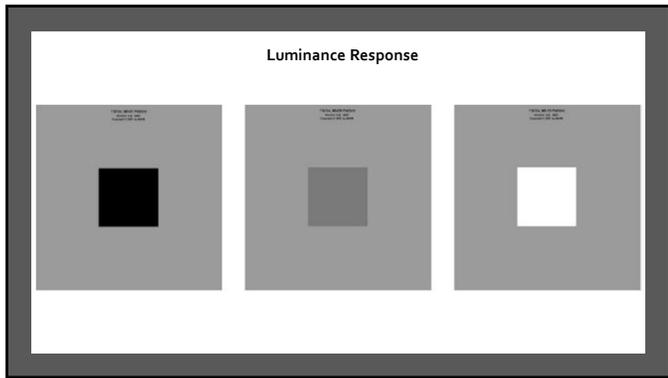
48

Luminance Response

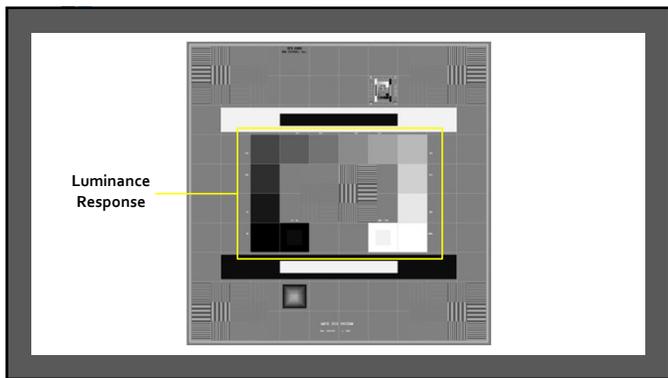
TDS-CT Patterns
Version 2.0, 10/11
Copyright © 2011 by iMAGIX

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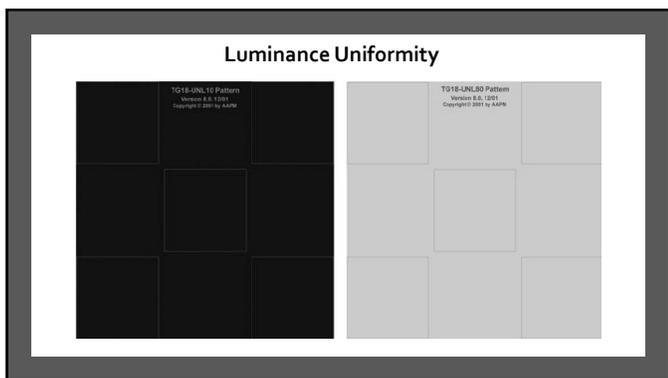
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50



51



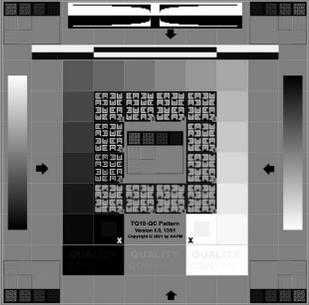
52

Resolution

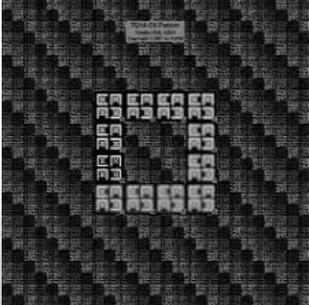
- ACR and AAPM minimum resolution for electronically displayed images of 2.5LP/mm
 - Generic SMPTE test pattern can be used
 - Check for blurring
- AAPM TG18 – QC and TG 18 CX provides an excellent check for resolution across the area of the display screen
 - Evaluate the CX pattern in the middle and in the corners
- Test can be done daily, weekly or monthly

53

TG18 - QC

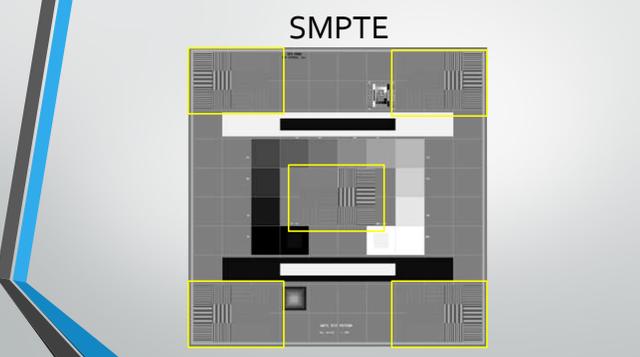


TG18 - CX

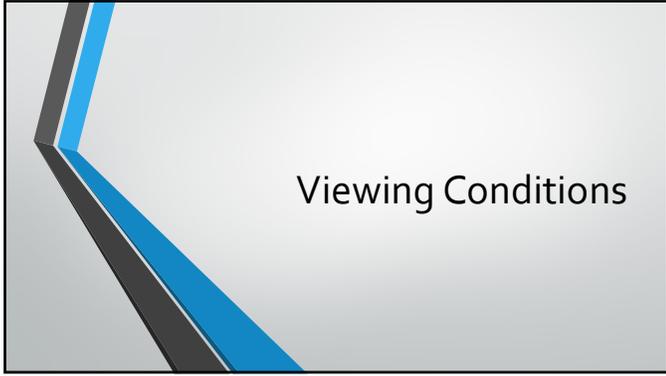


54

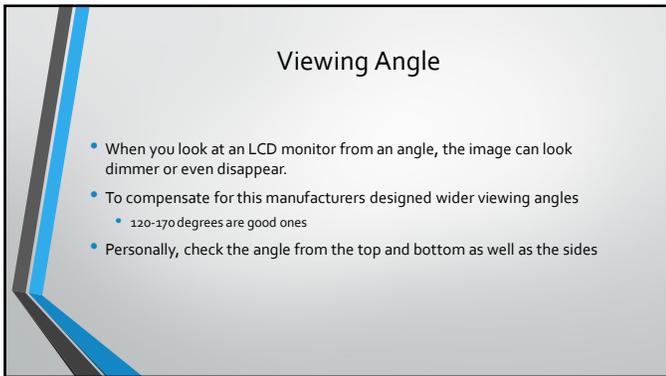
SMPTE



55



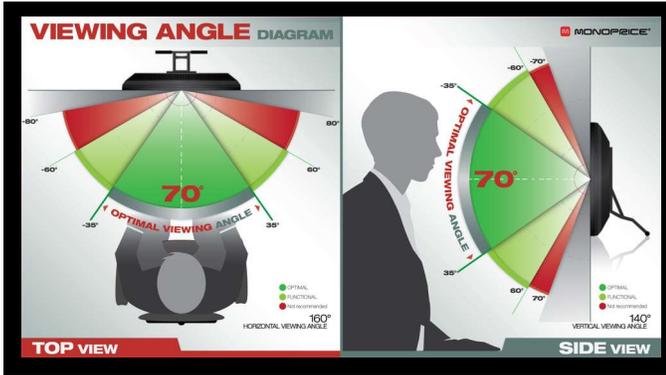
57



58



59



60

Ambient Lighting

Illuminance – the rate of light striking a surface

- The effect of ambient room lighting on the surface of and LCD monitor screen, including **reflectance** off the screen, and the resulting reduction in visible contrast of the image, is a result of **illuminance**
- Diffuse reflectance
 - The cumulative effect of room lighting across the area of the monitor screen
- Specular reflectance
 - The reflection of actual light sources such as a light bulb or window

The ambient lighting within the room must be dimmed to a point where both types of reflectance are below any noticeable level, that would impede full visibility of the image and image contrast

62

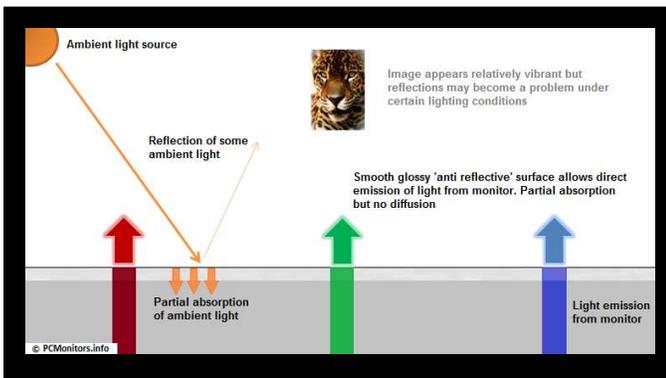
QC Aspect or Ambient Light

- While diagnosis is taking place, the maximum ambient lighting in a reading room should never be more than 25 lux
 - Approximately 1/4 the typical brightness of normal office lighting (75-100 lux)

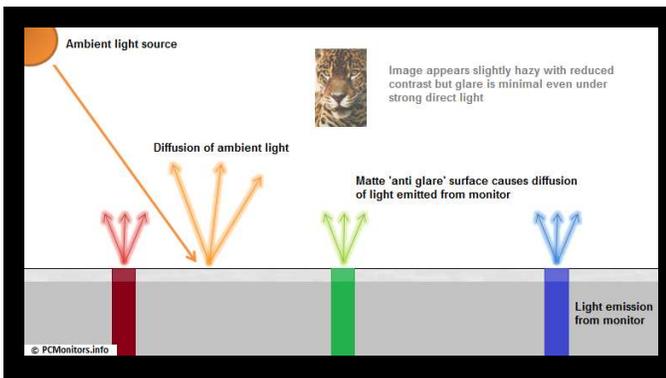
63



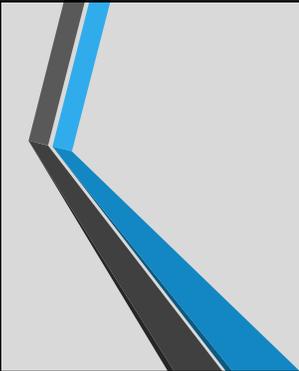
64



65

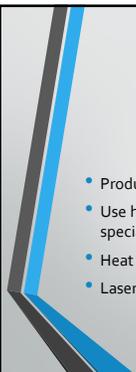


66



Hard Copy

67



Laser Film



- Produces a hard copies of radiographs, CT and MRIs
- Use helium-neon laser or solid state diode laser to write digital data onto special film
- Heat from laser makes area on film turn black and form an image
- Laser printers can be directly networked into PACS

68



CD and DVD

- 1958 – optical discs invented
- CD – has microscopic groove from inner track to outer track
 - Typical storage is 700 MB
- 1990s – second generation of optical disc
 - DVD (digital versatile disk or digital video disc)
 - Typical storage is 5GB
- 2006 – third generation
 - Blue ray disc – allows high definition
 - Typical storage is 25GB



69

Data Management

75

Network Connectivity

- LAN – Local Area Network
 - Computerized communications network generally contained within a single building or business
 - Devices share one server
- WAN – Wide Area Network
 - Extends to other businesses or locations that may be at great distances
 - Publically or commercially owned
 - Uses transmission services provided by common carriers (phone or cable companies)



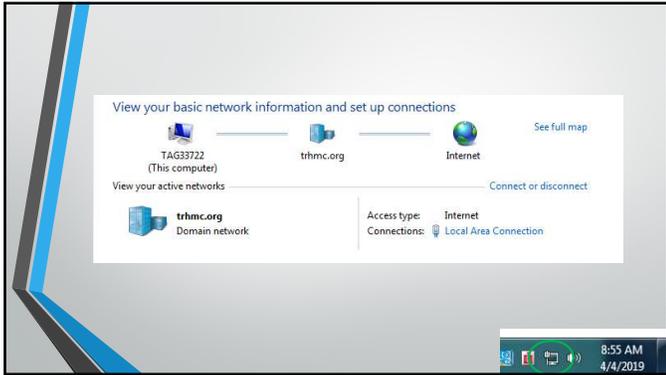
76

Computer Network

- Every computer within a network has a unique internet protocol or IP address
 - Ex. 172.811.3.1
- Every computer must have a network interface card
- Router
 - Connects 2 or more networks
 - Wireless routers – allow "point-of-care" access to a network for physicians and other caregivers via tablet or laptop



77



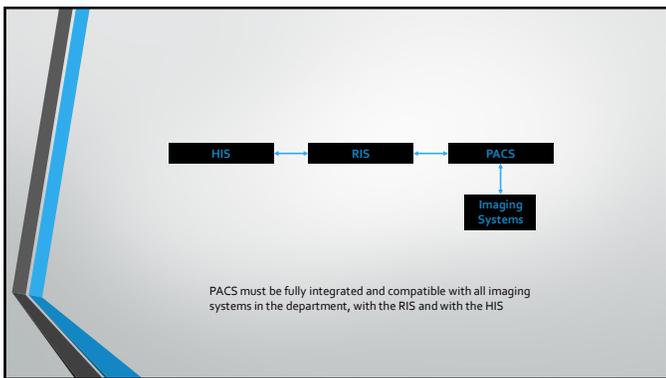
78

Type of LAN

RIS and HIS

- Radiology Information System
 - Data system for patient-related functions in the department, such as scheduling of x-ray appointments, tracking of patients, storage and distribution of reports
 - Makes info accessible from different locations within the radiology department
 - Assigns the **accession number**
- Hospital/Health Information System
 - Performs same functions for the entire institution (patient's general medical file)
 - Assigns a unique identifying number for each patient (**MRN**)

79



80

Picture Archiving and Communications System (PACS)

- Comprehensive computer network that is responsible for the electronic storage and distribution of medical images.
- Makes radiographs, CT and MRI scans, US and Nuclear Med images for a particular patient available within the network
- Allows Radiologists and Technologist to access these images from various locations, improving the efficiency of communication

Soon to be Called....
Medical image management and processing system (MIMPS)

81

PACS

- Digital acquisition (Picture)
- Display workstations
- Storage devices (Archiving)
- Components are interconnected by a network (Communication)

82

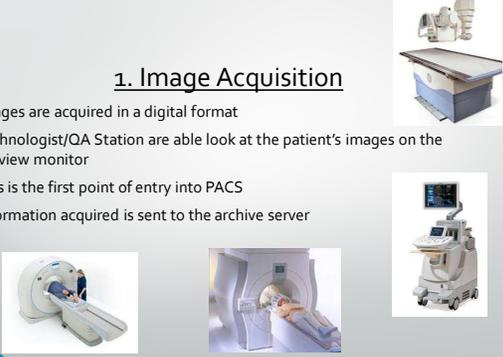
Components of PACS

- Image acquisition
- Display workstations
- Archive servers

83

1. Image Acquisition

- Images are acquired in a digital format
- Technologist/OA Station are able look at the patient's images on the preview monitor
- This is the first point of entry into PACS
- Information acquired is sent to the archive server



84

2. Display Workstations

Any computer used to view digital images

- Radiologists
- Physicians, surgeons, nurses & patients
- Technologists

- Most interactive part of PACS
- Used inside and out of Radiology
- Has PACS application software that allows minor image-manipulation

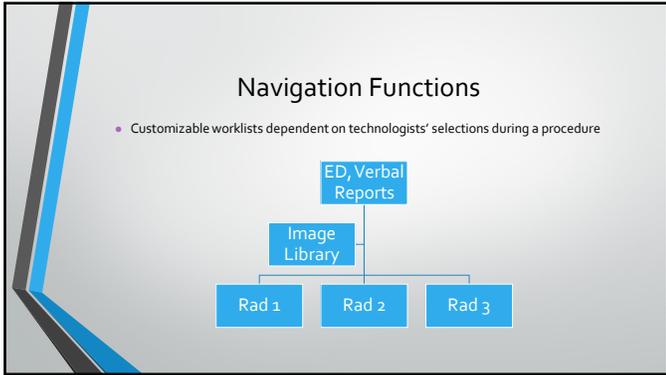


85

Common Workstation Functions

- Navigation Functions
- Hanging Protocol
- Study Navigation
- Image Manipulation & Enhancement
- Image Management

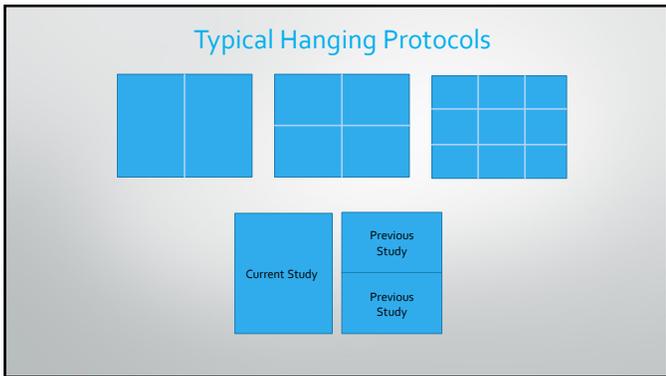
86



87



88



89

Study Navigation

- Allows images to be viewed individually or in a cine run.



90

Image Manipulation & Enhancement

Annotations **SUPINE**

Magnify 

Window/Level 

Flip/Rotate 

Measurements 

91

Key Images



92

Image Management Functions

- Patient demographics
 - Edit patient information for proper correlation with previous studies, billing, etc.
- Query / Retrieve
 - Locate images based on patient demographics
- Hardcopy images
 - Either CD or plain film
 - Usually only image library has this function

93

3. Archive Servers

- File room of PACS
- Contains all historic and current data



94

PACS Archiving

- Consist of:
 - Image manager/controller
 - Image storage/server



95

Image Manager

- Contains master database of everything in the archive
- Controls the receipt, retrieval and distribution of the images it stores
- Controls all the DICOM processes running within the archive
- Communicates with RIS and HIS
- Can populate image information into the EMR

MANAGER

96

97

Image Storage/Archive Server

- Physical storage device for archive system
- Network of servers
- Setup in tiers
 - Short-term
 - Long-term

In the United States, storage requirement of a patient's images is from five to seven years.

98

Short Term Storage

- RAID
 - several magnetic disks or hard drives that are linked together in an array

RAID 5 is the most common level used for a PACS archive because it provides adequate redundancy and fault tolerance

99

Reading Hospital

- Short-term storage is done on servers located in IMS but maintained by Philips
 - Philips monitors the system through remote access
 - All backups and drive redundancy are handled by Philips

100

Long Term Storage

- RAID
- Optical disk
- Tape
- Magnetic disk

101

Cloud-Based Storage

- Offsite storage and servers supported by a secure network
- 3rd party vendor
- Shifts disaster recovery process to the vendor along with maintenance and storage equipment purchase
- You pay for the service and storage space

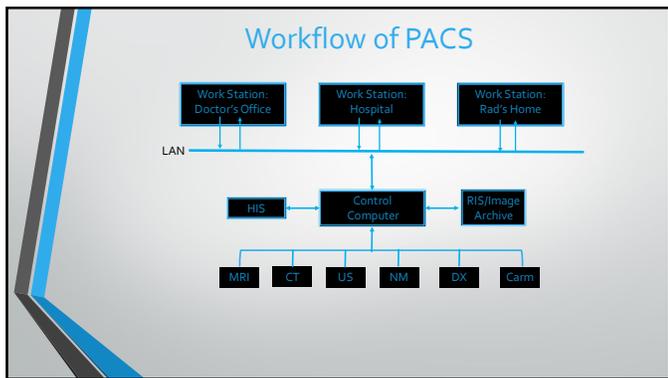
102

Reading Hospital:

- Prior to EPIC - \$1 million budget for record storage
- Legally obligated to retain films:
 - Pediatrics
 - Mammo
 - All other films



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104

Summary of PACS Functions

- Main function: Act as a *database*
 - Generate and sort according to status (i.e. pending, completed)
 - Various queries – users can search for specific information
- Manipulation – at any workstation
- Storage

105

Vendor Neutral Archives (VNA)

- Allows for images and data from different systems and in different formats to be stored using a singular system on a common infrastructure
- May be used as replacements to existing PACS to avoid very expensive transition costs
- Used to consolidate a number of systems that exist within a single facility or across a system of facilities

106

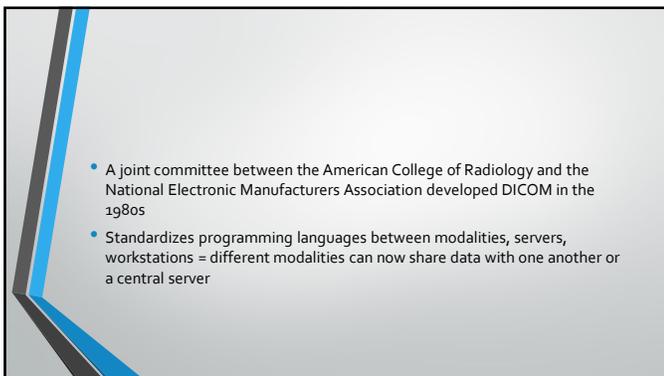
PACS Emergency Contingency Plan

- A backup copy of ALL archived records should be maintained either by the hospital or an Application Service Provider
- RH PACS Downtime Procedure Policy - <https://trh.elucid.com/documents/view/12114/33066/3>

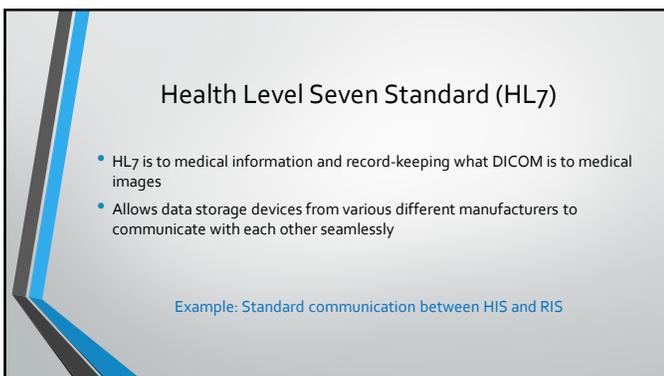
107



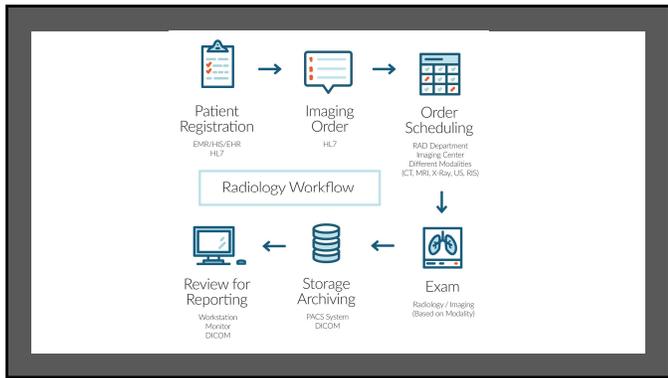
111



112



113



114

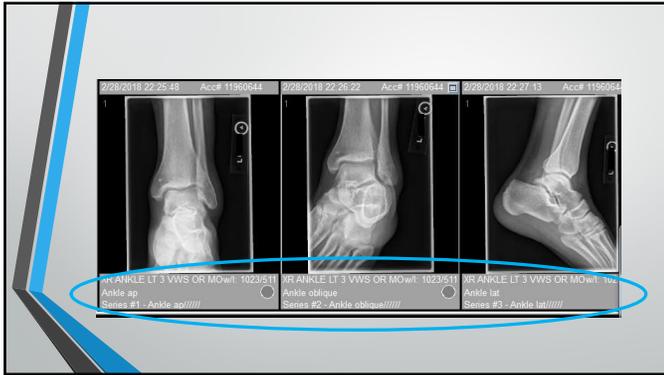
DICOM Header

- A summary of critical identification and study information such as:
 - Date and time of procedure
 - Number of images taken
 - Body part, position
 - Technique used
 - Image format and receptor size
 - Parameters used to digitally process the image
- All this information is stored as **metadata**
 - Should appear in a bar at the top of the screen for each image
 - Shows summary of essential metadata for the image

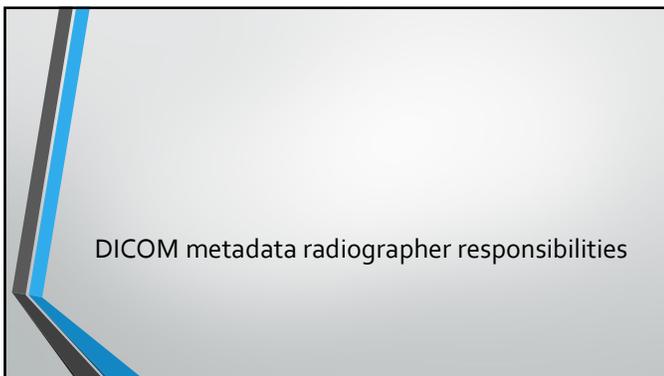
115

Group Tag	Element Tag	Tag Description	Value
0010	0011	Private Tag	MURKIN
0010	0020	Patient ID	12345
0010	0030	Patient's Birth Date	00000000
0010	0040	Patient's Sex	M
0010	1030	Patient's Weight	0
0010	2165	Private Tag	None
0010	2166	Private Tag	None
0010	4000	Patient Comments	
0018	0015	Body Part Examined	THORAX
0018	1000	Device Serial Number	00000000
0018	1020	Software Version(s)	1.0.1.120
0018	1164	Image Field Source	0.16
0018	1508	Positioner Type	COLLIMIN
0018	5100	Patient Position	ANTERIOR - POSTERIOR
0018	7004	Detector Type	DIRECT
0018	7006	Detector Description	
0018	7014	Detector Serial	1.1.1
0020	0020	Study Instance UID	1.2.826.0.1.3680043.2.1330.1000001.1.2213256762.2712337879
0020	000E	Series Instance UID	1.2.826.0.1.3680043.2.1330.1000001.4.2213256762.27123318877
0020	0010	Study ID	None
0020	0011	Series Number	1
0020	0019	Instance Number	29
0020	0020	Patient Orientation	N
0020	0060	Laterality	L
0020	0062	Private Tag	U
0020	4000	Image Comments	
0028	0002	Samples per Pixel	1

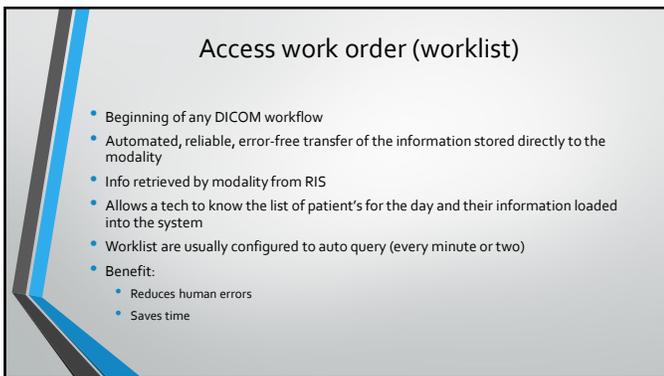
116



117



118



119

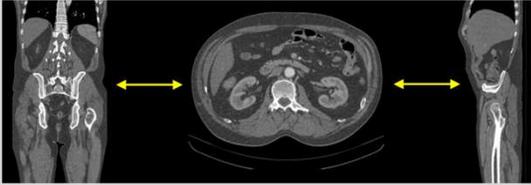
Post Processing – Image operation and manipulation

- Image operation activities
- Multiplanar Reconstruction
- Maximum and Minimum Intensity Projection
- Volume Rendering Technique (VRT)
- Shaded Surface Display (3D technology)
- CAD

120

Multiplanar Reconstruction

- Creates multiple planes of view from a single scan



<https://www.youtube.com/watch?v=H1nPMSVijag>

121

Maximum & Minimum Intensity Projections

- Enhancement of small vessels (MIP) and air-filled structures (MinIP)

MinIP – Minimum Intensity Projections

MIP – Maximum Intensity Projections



MinIP AIP MIP

122

Volume Rendering Technique (VRT)

- Assists in differentiating between anatomical structures by adding color shades based on pixel intensity



123

Shaded Surface Display (SSD)

- Creates a 3D, moveable image based on the pixel intensity of choice



124

CAD (Computer Aided Diagnosis/Detection)

- used as a "second opinion" in assisting radiologists' image interpretations
 - complementary tools that draw the radiologists' attention to certain image areas that need further evaluation
- Uses algorithms
- Used in Mammography at RH



Source: Appl Radiol © 2004 Anderson Publishing, Ltd

125

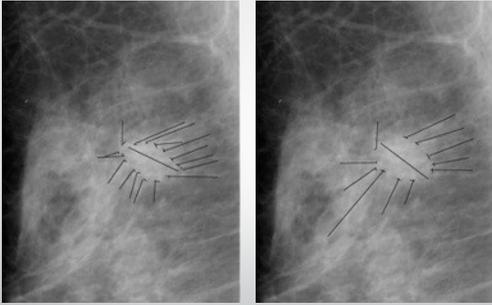
Annotation Issues: Annotations and Mark Ups

- *Image annotation* – describes the meaning in images
- *Image markup* – visual presentation of the annotation
- AIM Project (Annotation and Image Mark up project)
 - The model contains information about who created the annotation, the equipment with which the annotation was created, when the annotation was created, and the image(s) to which the annotation refers.
 - Once the annotation is defined in the AIM, sophisticated queries are now easily found
 - "Find all studies that contain enhancing right middle lobe lung masses that measure between 5 and 6 cm"

126

- Other concerns are
 - What is more accurate tool to use --- stylus or mouse for marking or measurements?
 - Human error
 - Legal issues

127



Mouse Stylus

128

Case number	Annotation time for mouse (s)	Annotation time for stylus (s)
1	109	86
2	121	71
3	108	70
4	78	74
5	109	91
6	55	57
7	78	77
8	90	54
9	113	60
10	89	85
11	101	98
12	81	41

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Image Transmission

- Concerns of medical data overload
 - CT may produce 300 to 500 images and a CT angiography runoff study may include 1,500 to 2,000 images
- In teleradiology, the header of the DICOM image is first transmitted followed by the compressed image data and then at the receiving end, images are reconstructed from low quality to high (or perfect) quality
- Facilities will compress images to send, this allow it to be sent more efficiently
 - Lossless compression have been defined as "visually acceptable" images by the medical imaging community

130

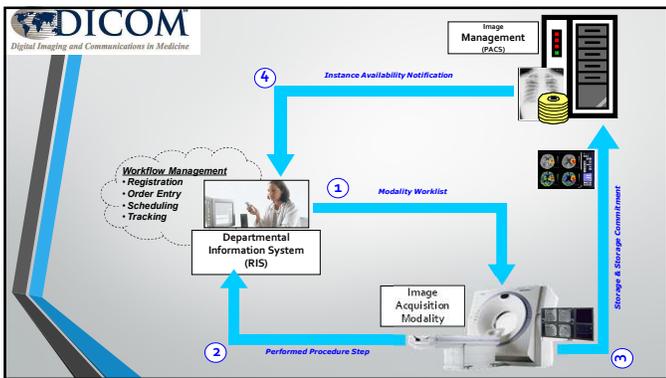
HIPAA

- Health Insurance Portability and Accountability Act of 1996 (HIPAA) Privacy Rule is to ensure you have rights over your own health information, no matter what form it is in.
- The government also created the HIPAA Security Rule to require specific protections to safeguard your electronic health information.
- Federal law requires doctors, hospitals, and other health care providers to notify you of a "breach."
- Facilities should implement high-grade security and encryption in their systems in order to protect records from hackers or theft
- Adhering to HIPAA guidelines often means subjecting software developments to a legal team who can determine whether or not the software falls within HIPAA regulations for security and confidentiality

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132



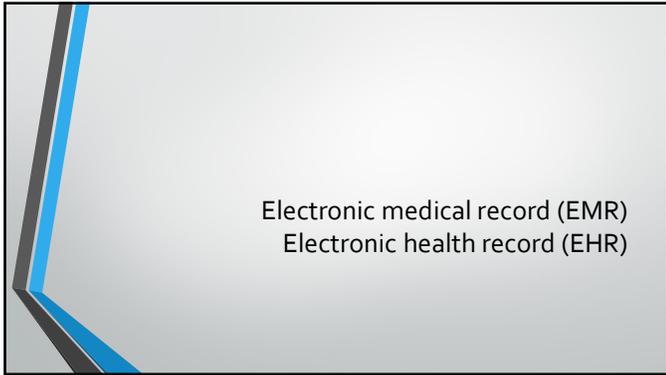
133

DICOM Services for Acquisition Workflow Management

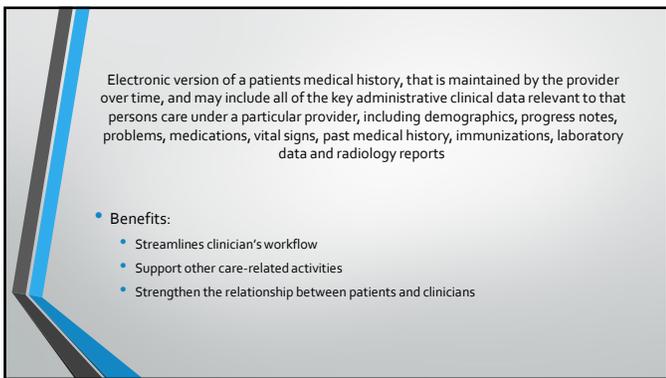
- Improve Interoperability of Imaging Equipment
- Ensure Data Consistency
- Facilitate Reliable Data Management
- Improve Process Efficiency
- Better Quality of Imaging Services

DICOM
Digital Imaging and Communications in Medicine

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135



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137

- Any system which allows remote transmission and viewing of radiographic images via modems over phone or cable lines
- Makes it possible for images to be sent great distances for a specialist to collaborate with a radiologist, and for images stored at a hospital to be accessed almost instantly by doctors at their individual clinics
 - Example: transmit images to radiologist's home during off hours





1



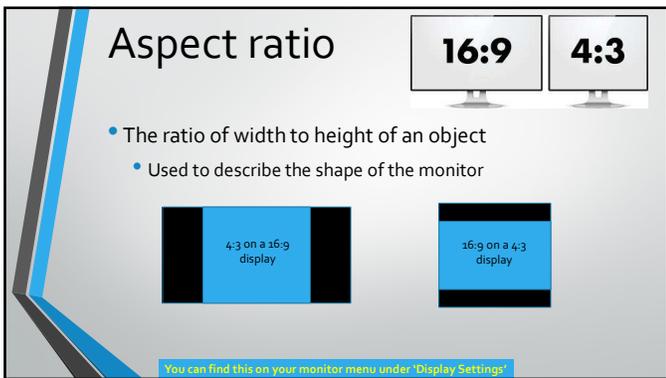
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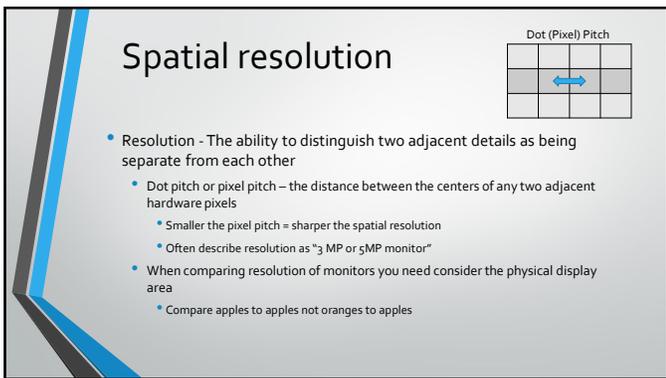
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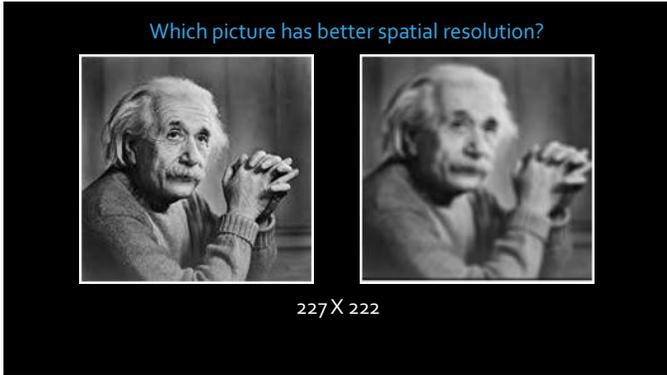
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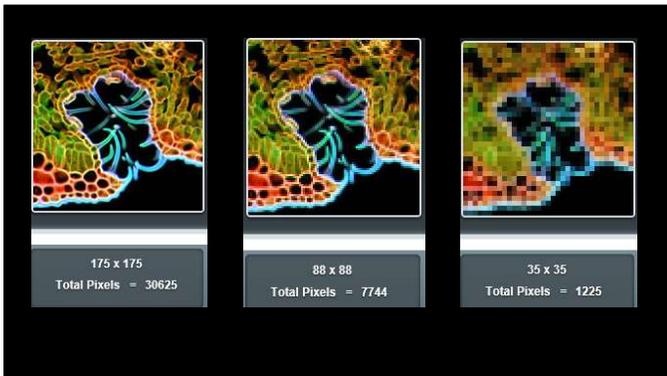
5



6



7



8



9

Brightness

- The black level of a display screen. Although it may sound peculiar, the brightness adjusts the "black level" of the display system (how black the black is) –*Computer Desktop Encyclopedia*
- Photometer is used to measure the brightness output of an LCD
- American College of Radiology (ACR) requires a minimum brightness capability for radiologic display systems of 250 lumens



Too dark Good brightness Too bright

10

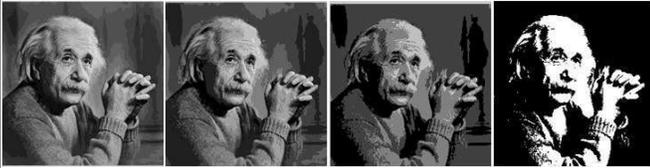
Contrast Ratio

- The difference between the darkest blacks and the brightest whites a given display can produce.
- Contrast ratio for LCD = 600:1, CRT = 3000:1
 - LCD - Inability to produce a "true black" due to backlight leakage



100% Contrast 75% Contrast 50% Contrast 25% Contrast 1% Contrast

12

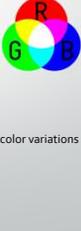


16 Gray Levels 8 Gray Levels 4 Gray Levels 2 Gray Levels

13

Color vs. Grayscale (monochrome)

- **Monochrome monitors**
 - Color images will appear as shades of gray
 - Has only one phosphor of color, but may have the ability to change the brightness causing the illusion of depth
 - Produces sharper text and image because 1 phosphor per pixel than color
- **Color monitors**
 - Monochrome images can be viewed on color monitors
 - Uses alternating intensities of red, green and blue to produce the different color variations
 - Uses 3 phosphors per pixel



15

What color would be seen in a color monitor?

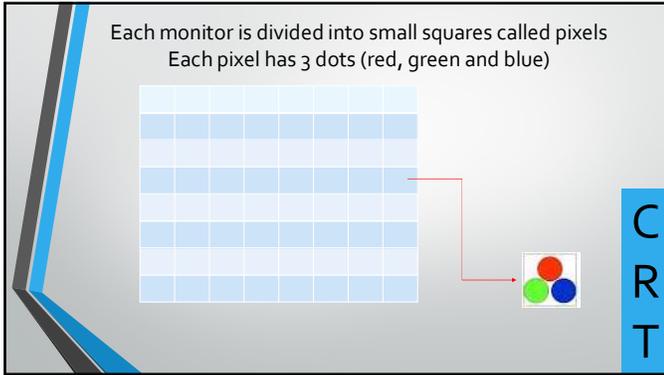
- If all 3 colors set at 0 = **BLACK**
- If all 3 colors set at 255 = **WHITE**
- If red was set at 255 and blue and green at 0 = **RED**

16

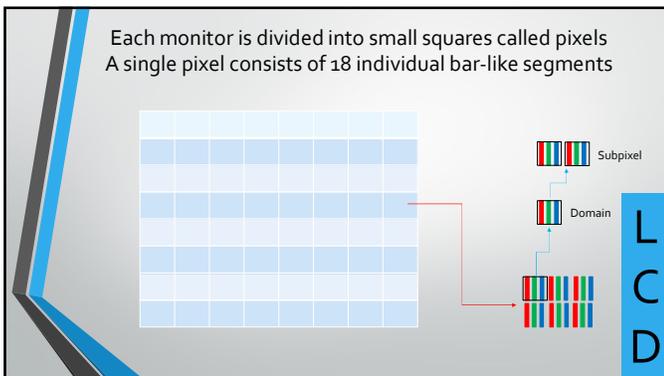
Pixels for Computers

- Pixel – multiple definitions
 - Carroll states it is “the smallest element of the matrix or device that can represent all pixel values within the system’s dynamic range”
- CRT – each triad of color (red, blue, and green) is considered one pixel
- LCD – a single pixel consists of 18 individual bar-like segments
- Hardware pixel in monitor – intersections of flat, transparent wires crossing over each other to form an overall square shape

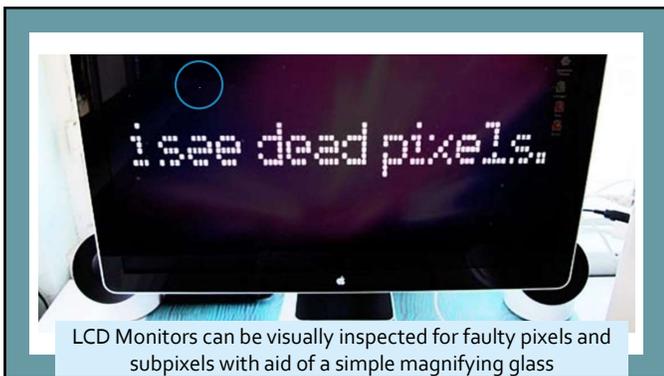
18



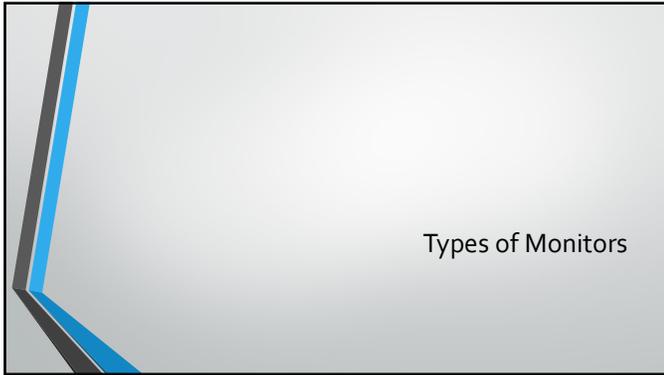
19



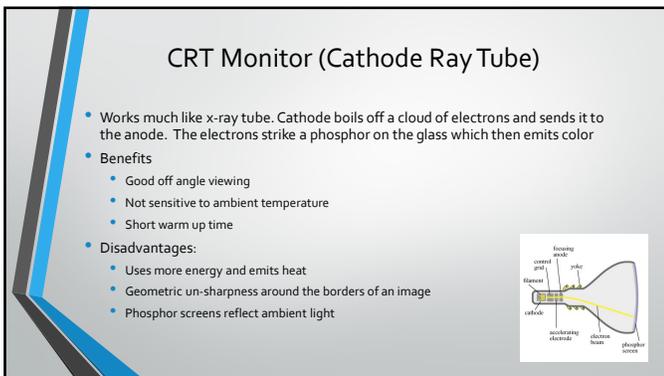
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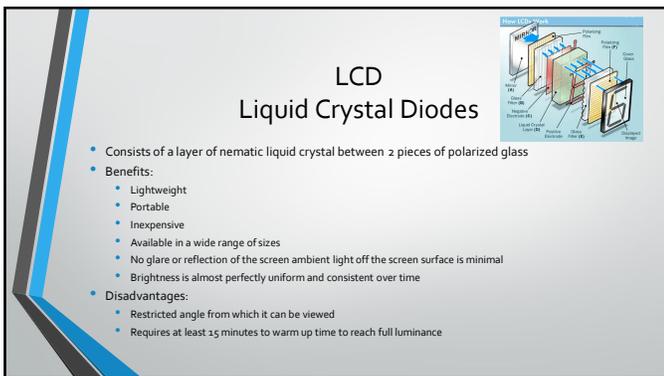
21



23



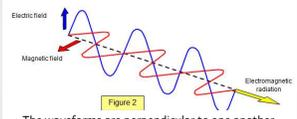
24



25

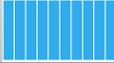
To understand the LCD monitor you must comprehend Light Polarization

- Like an x-ray, a ray of light is electromagnetic radiation that consists of a double wave

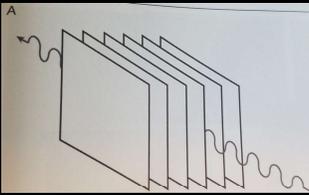


The waveforms are perpendicular to one another

- LCD Monitors use polarized glass
 - Polarized glass contains long chains of iodine molecules, all aligned parallel to each other
 - Just like a grid strips in a grid

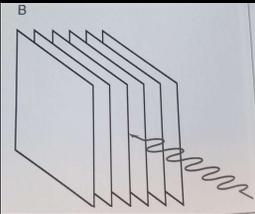


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Electrical

The electrical component of the double wave can pass through a polarized glass with vertical string molecules because it vibrates parallel to it

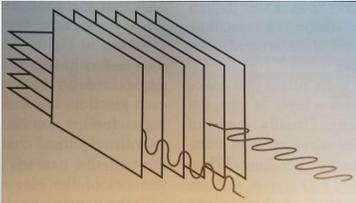


Magnetic

The magnetic component of the double wave cannot pass through a polarized glass with vertical string molecules because it vibrates perpendicular to it

27

What will happen if you layer 2 polarizing glass together so the string molecules are perpendicular to each other?



28

LCD – Light polarization

- LCD monitor consists of:
 - 2 thin sheets of glass
 - Each with a light polarizing layer that are perpendicular to the other sheet

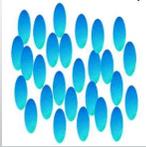
Perpendicular sheets = ALL light being blocked

Don't worry, the LCD process involves "tricking" these layers into allowing light to pass

29

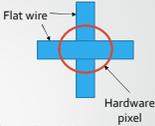
What are nematic liquid crystals?

- This is what is inserted between the polarizing glass sheets/lenses that plays the trick
- A crystalline arrangement of molecules that have a long linear shape and tend to align parallel to each other



30

Before we see the "trick", you need to know one more thing....



- In the polarizing glass there are a layer of thin, flat wires to conduct electricity
- These conductors are also aligned perpendicular to each other when the 2 polarized glass are together
- Each junction forms a single **hardware pixel**
 - Each electrode has a scratch on it
 - Scratches are perpendicular to one another
 - The crystals tend to line up with the "scratch" direction when no electric charge is present -- **known as "on" state**

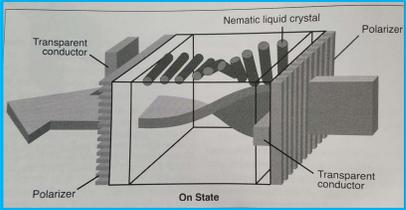
31

And **FINALLY**, Here is the Magic Trick.....



<https://www.youtube.com/watch?v=jiejNAUwcQ8>

32

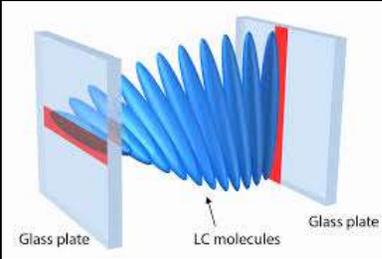


"ON" STATE

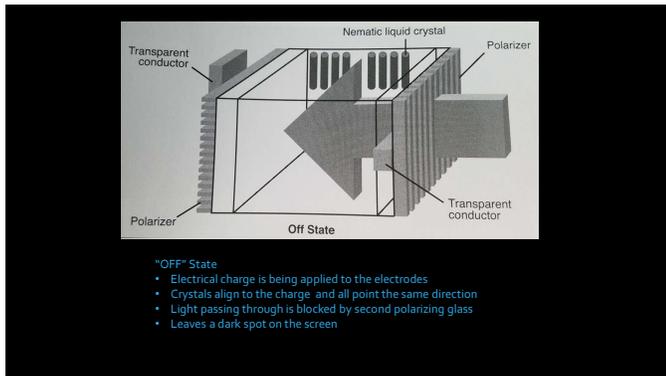
- Since the scratches are perpendicular, the liquid crystals line up in a spiral pattern that twists 90 degrees between the two glass plates
- This lets light waves pass through the nematic liquid crystal and follow the spiral
- Light is able to pass through the second glass plate to the viewer of the monitor

33

Just another way to look at it



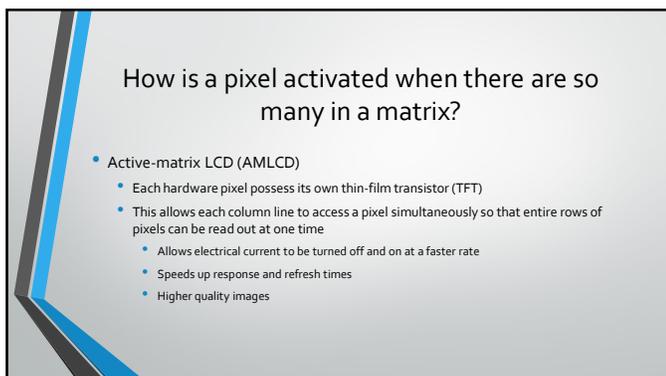
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35



36



37

More info on LCD Monitors

- As LCDs **do not** produce light by themselves—they need illumination to produce a visible image.
 - Without a **backlight**, an LCD display device will remain black, rendering it unviewable
- **Backlighting**
 - Types: Fluorescent bulbs or light-emitting diodes (LEDs)
 - LED - Most common

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Care and Maintenance

39

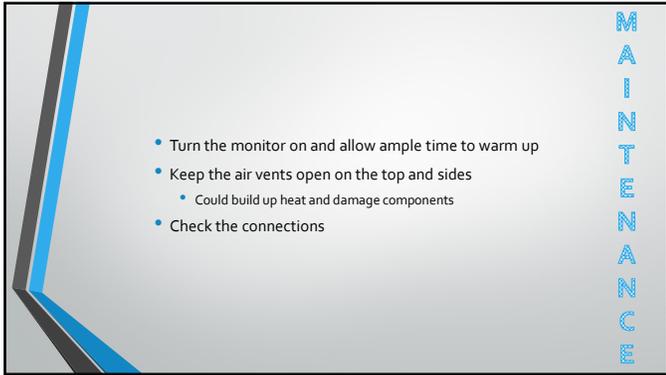
CARE

1. Apply cleaning solution to soft cloth
 - Do not spray solution directly on screen
 - Do not use paper towel can cause scratches
2. Wipe in one direction from top of screen to bottom

- The following cleaners should NOT be used: Acetone
 - Ethyl alcohol
 - Ethyl acid
 - Ammonia
 - Methyl chloride

- The following types of cleaners are acceptable: Water
 - Vinegar (mixed with water)
 - Isopropyl Alcohol
 - Petroleum Benzene

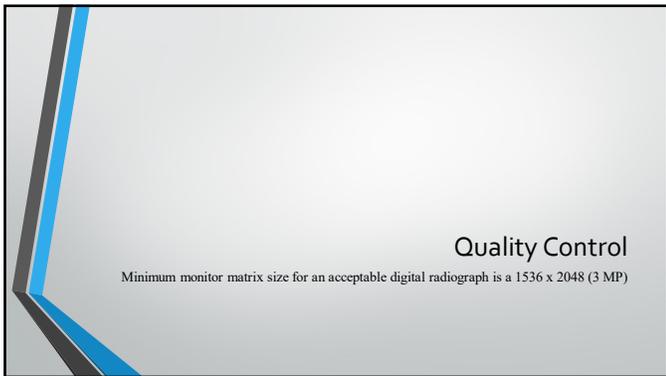
40



M-A-I-N-T-E-N-A-N-C-E

- Turn the monitor on and allow ample time to warm up
- Keep the air vents open on the top and sides
 - Could build up heat and damage components
- Check the connections

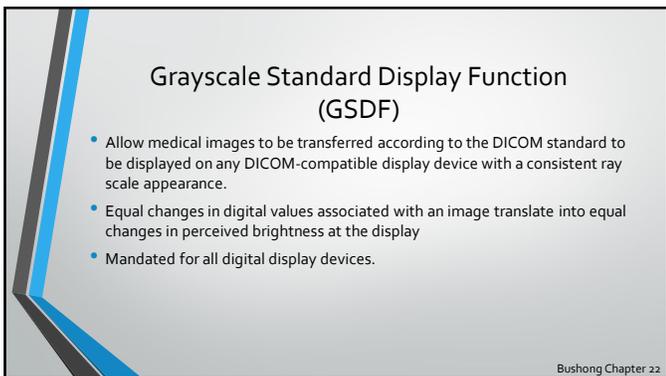
41



Quality Control

Minimum monitor matrix size for an acceptable digital radiograph is a 1536 x 2048 (3 MP)

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Grayscale Standard Display Function (GSDf)

- Allow medical images to be transferred according to the DICOM standard to be displayed on any DICOM-compatible display device with a consistent ray scale appearance.
- Equal changes in digital values associated with an image translate into equal changes in perceived brightness at the display
- Mandated for all digital display devices.

Bushong Chapter 22

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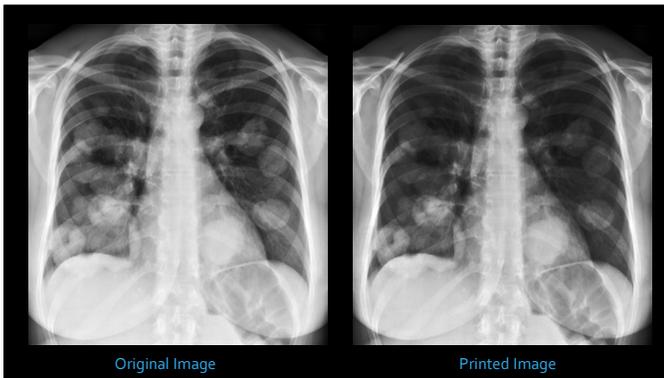
DICOM Grayscale Standard Display Function (GSDF) generates a display function matching the perceptual characteristics of a human observer.

Standard developed having human observer view monitor while luminance output of monitor changed in small steps from black to white and noting when they observed a **Just Noticeable Difference** (JND) in light output as the drive signal is changed.

Most digital radiologic images are windowed to attempt to display 256 different shades of gray at any one time, (256 is approximate JND that humans can perceive)

The perceptual linearization implemented with the DICOM Grayscale Standard Display Function (GSDF) ensures that pixel values that are supposed to increase brightness in a linear fashion, say 6, 7, and 8, for example, actually appear that way to the human eye, despite the nonlinearity of our perception.

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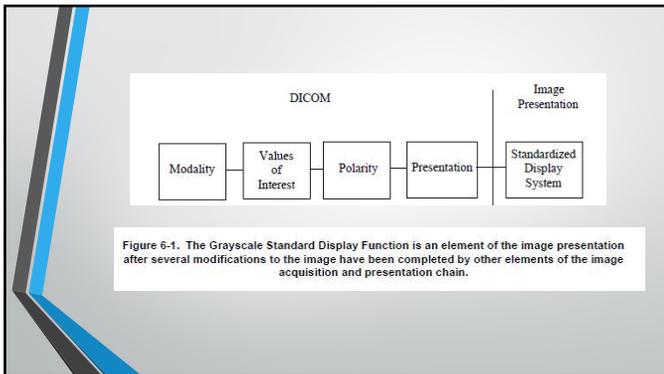


Figure 6-1. The Grayscale Standard Display Function is an element of the image presentation after several modifications to the image have been completed by other elements of the image acquisition and presentation chain.

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Luminance

The rate of light (brightness) emitted from a source such as an LCD monitor

- **Maximum luminance** (*maximum brightness*)- checked at same monitor setting over a period of time with a photometer
- **Luminance response** – monitors ability to accurately display different shades of brightness from a test pattern
- **Luminance ratio** – compares maximum luminance to the minimum luminance
- **Luminance uniformity** – consistency of a single brightness level displayed across the area of the screen

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Luminance Ratio

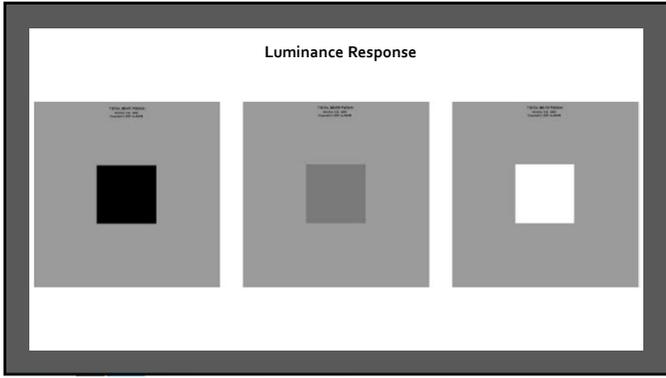
48

Luminance Response

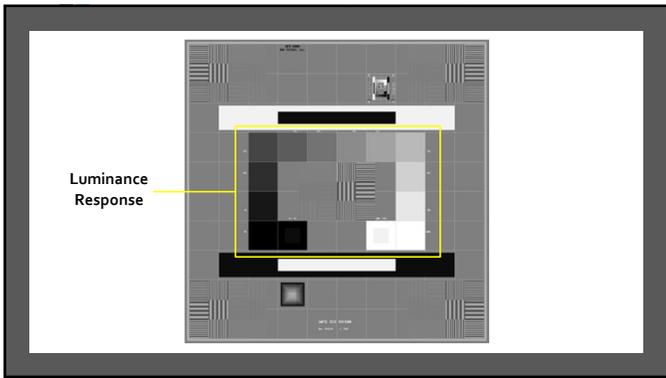
TG18-CT Pattern
Version 2.0, 10/11
Copyright © 2011 by Luster

A

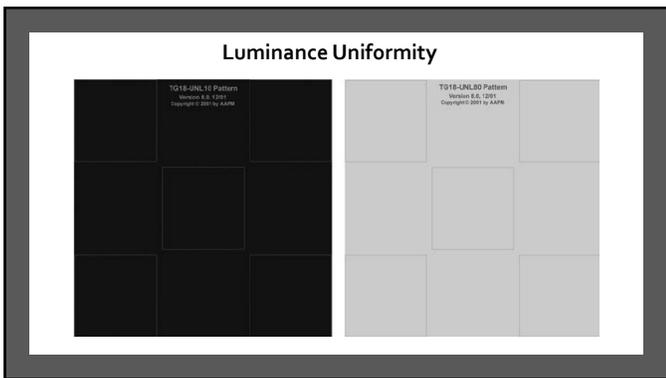
49



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51



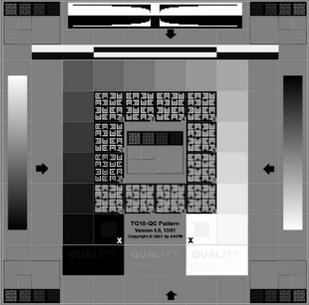
52

Resolution

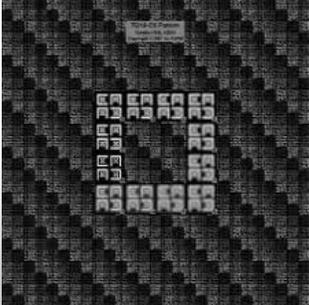
- ACR and AAPM minimum resolution for electronically displayed images of 2.5LP/mm
 - Generic SMPTE test pattern can be used
 - Check for blurring
- AAPM TG18 – QC and TG 18 CX provides an excellent check for resolution across the area of the display screen
 - Evaluate the CX pattern in the middle and in the corners
- Test can be done daily, weekly or monthly

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TG18 - QC

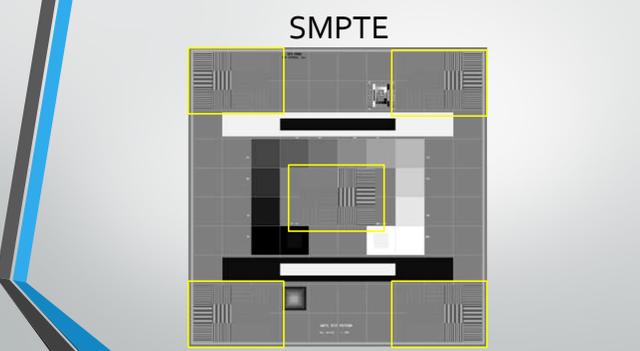


TG18 - CX

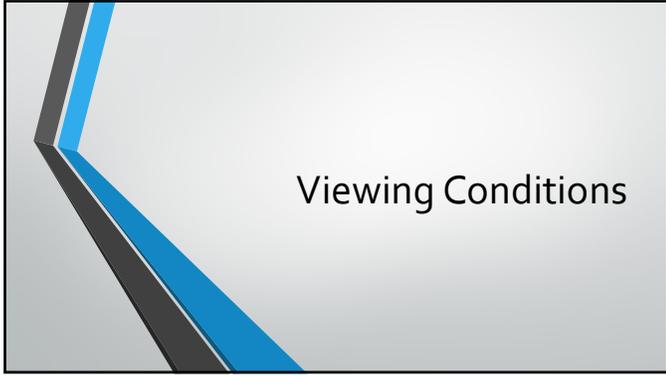


54

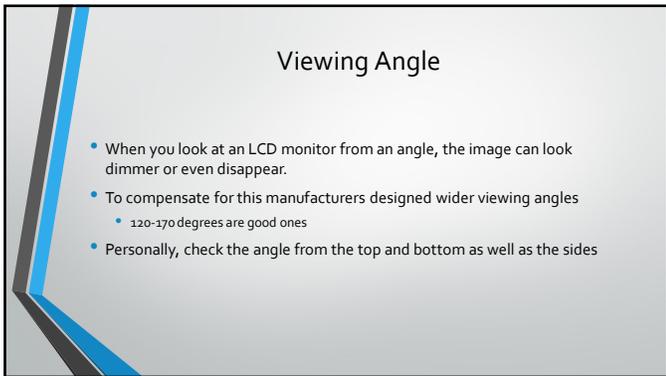
SMPTE



55



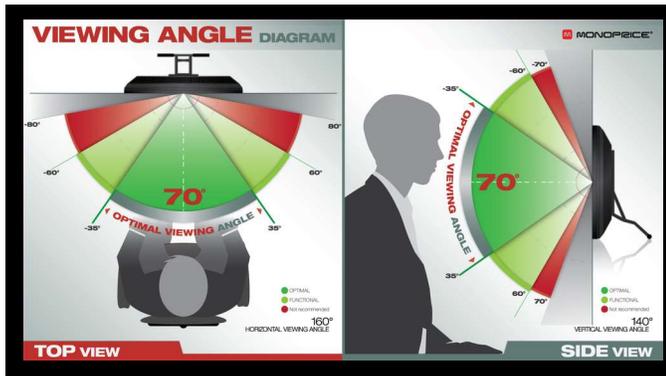
57



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Ambient Lighting

Illuminance – the rate of light striking a surface

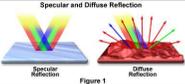


Figure 1

- The effect of ambient room lighting on the surface of and LCD monitor screen, including **reflectance** off the screen, and the resulting reduction in visible contrast of the image, is a result of **illuminance**
- Diffuse reflectance
 - The cumulative effect of room lighting across the area of the monitor screen
- Specular reflectance
 - The reflection of actual light sources such as a light bulb or window

The ambient lighting within the room must be dimmed to a point where both types of reflectance are below any noticeable level, that would impede full visibility of the image and image contrast

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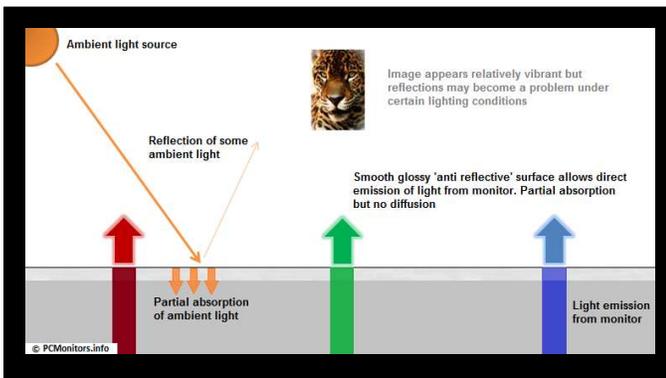
QC Aspect or Ambient Light

- While diagnosis is taking place, the maximum ambient lighting in a reading room should never be more than 25 lux
 - Approximately ¼ the typical brightness of normal office lighting (75-100 lux)

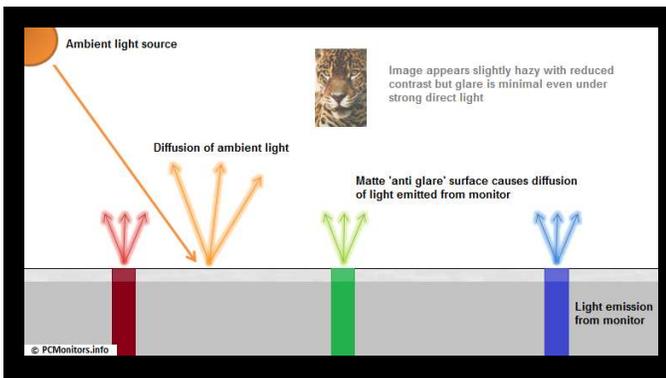
63



64



65



66



67

Laser Film

- Produces a hard copies of radiographs, CT and MRIs
- Use helium-neon laser or solid state diode laser to write digital data onto special film
- Heat from laser makes area on film turn black and form an image
- Laser printers can be directly networked into PACS

68

CD and DVD

- 1958 – optical discs invented
- CD – has microscopic groove from inner track to outer track
 - Typical storage is 700 MB
- 1990s – second generation of optical disc
 - DVD (digital versatile disk or digital video disc)
 - Typical storage is 5GB
- 2006 – third generation
 - Blue ray disc – allows high definition
 - Typical storage is 25GB

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Data Management

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Network Connectivity

- LAN – Local Area Network
 - Computerized communications network generally contained within a single building or business
 - Devices share one server
- WAN – Wide Area Network
 - Extends to other businesses or locations that may be at great distances
 - Publically or commercially owned
 - Uses transmission services provided by common carriers (phone or cable companies)



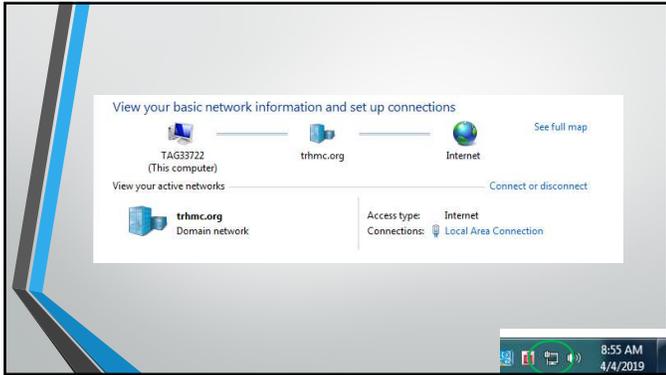
76

Computer Network

- Every computer within a network has a unique internet protocol or IP address
 - Ex. 172.811.3.1
- Every computer must have a network interface card
- Router
 - Connects 2 or more networks
 - Wireless routers – allow "point-of-care" access to a network for physicians and other caregivers via tablet or laptop



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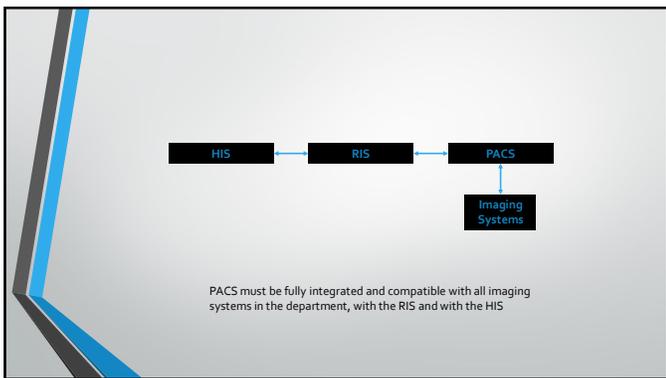
78

Type of LAN

RIS and HIS

- Radiology Information System
 - Data system for patient-related functions in the department, such as scheduling of x-ray appointments, tracking of patients, storage and distribution of reports
 - Makes info accessible from different locations within the radiology department
 - Assigns the **accession number**
- Hospital/Health Information System
 - Performs same functions for the entire institution (patient's general medical file)
 - Assigns a unique identifying number for each patient (**MRN**)

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Picture Archiving and Communications System (PACS)

- Comprehensive computer network that is responsible for the electronic storage and distribution of medical images.
- Makes radiographs, CT and MRI scans, US and Nuclear Med images for a particular patient available within the network
- Allows Radiologists and Technologist to access these images from various locations, improving the efficiency of communication

Soon to be Called....
Medical image management and processing system (MIMPS)

81

PACS

- Digital acquisition (Picture)
- Display workstations
- Storage devices (Archiving)
- Components are interconnected by a network (Communication)

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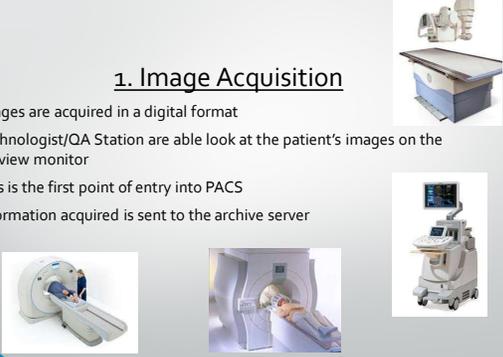
Components of PACS

- Image acquisition
- Display workstations
- Archive servers

83

1. Image Acquisition

- Images are acquired in a digital format
- Technologist/OA Station are able look at the patient's images on the preview monitor
- This is the first point of entry into PACS
- Information acquired is sent to the archive server



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2. Display Workstations

Any computer used to view digital images

- Radiologists
- Physicians, surgeons, nurses & patients
- Technologists

- Most interactive part of PACS
- Used inside and out of Radiology
- Has PACS application software that allows minor image-manipulation

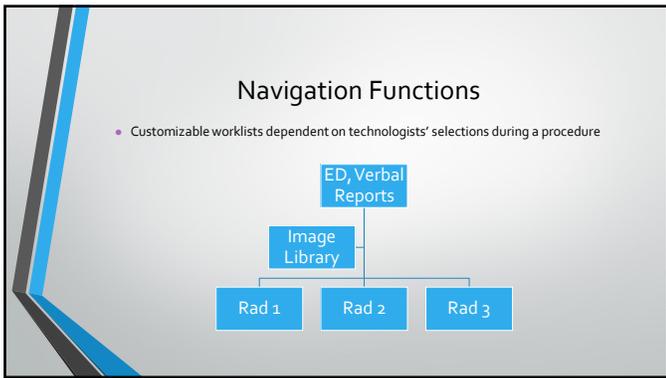


85

Common Workstation Functions

- Navigation Functions
- Hanging Protocol
- Study Navigation
- Image Manipulation & Enhancement
- Image Management

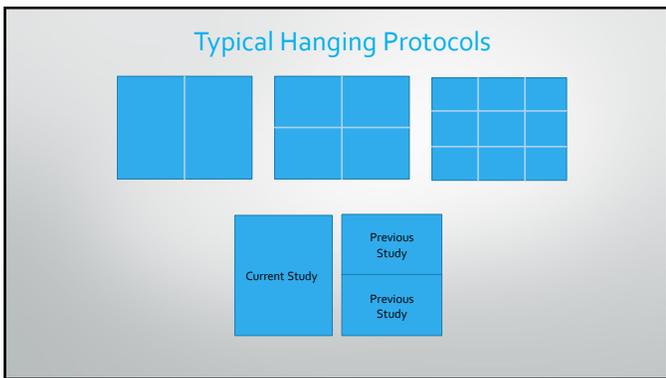
86



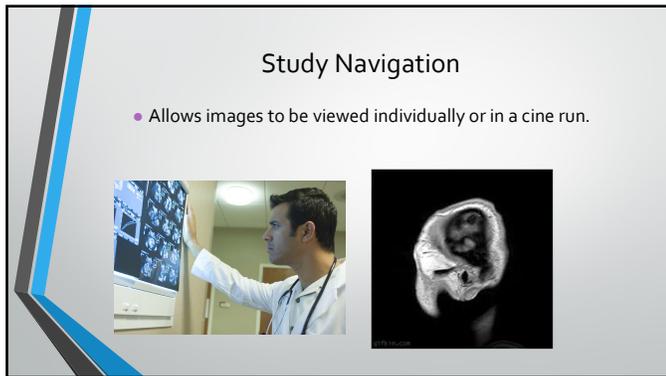
87



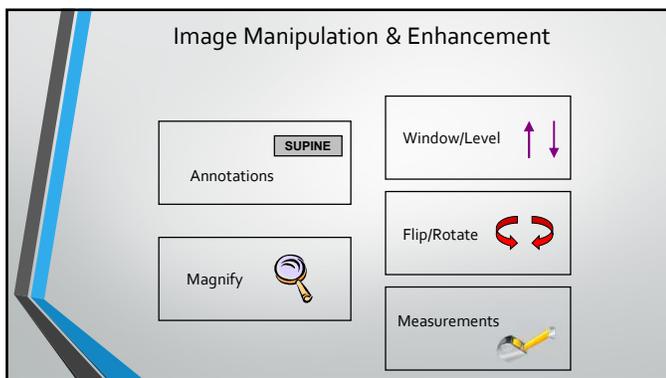
88



89



90



91



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Image Management Functions

- Patient demographics
 - Edit patient information for proper correlation with previous studies, billing, etc.
- Query / Retrieve
 - Locate images based on patient demographics
- Hardcopy images
 - Either CD or plain film
 - Usually only image library has this function

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3. Archive Servers

- File room of PACS
- Contains all historic and current data



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PACS Archiving

- Consist of:
 - Image manager/controller
 - Image storage/server



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Image Manager

- Contains master database of everything in the archive
- Controls the receipt, retrieval and distribution of the images it stores
- Controls all the DICOM processes running within the archive
- Communicates with RIS and HIS
- Can populate image information into the EMR

MANAGER

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Image Storage/Archive Server

- Physical storage device for archive system
- Network of servers
- Setup in tiers
 - Short-term
 - Long-term

In the United States, storage requirement of a patient's images is from five to seven years.

98

Short Term Storage

- RAID
 - several magnetic disks or hard drives that are linked together in an array

RAID 5 is the most common level used for a PACS archive because it provides adequate redundancy and fault tolerance

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Reading Hospital

- Short-term storage is done on servers located in IMS but maintained by Philips
 - Philips monitors the system through remote access
 - All backups and drive redundancy are handled by Philips

100

Long Term Storage

- RAID
- Optical disk
- Tape
- Magnetic disk

101

Cloud-Based Storage

- Offsite storage and servers supported by a secure network
- 3rd party vendor
- Shifts disaster recovery process to the vendor along with maintenance and storage equipment purchase
- You pay for the service and storage space

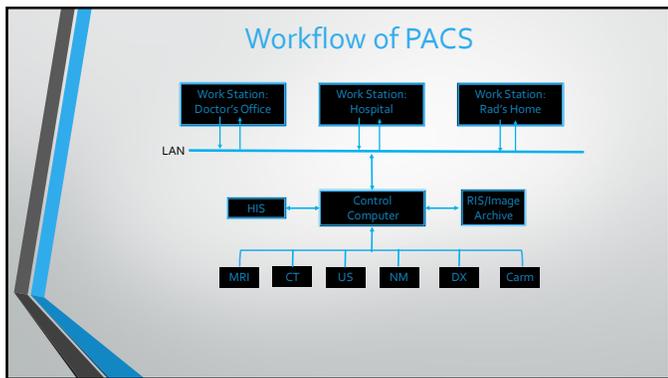
102

Reading Hospital:

- Prior to EPIC - \$1 million budget for record storage
- Legally obligated to retain films:
 - Pediatrics
 - Mammo
 - All other films



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Summary of PACS Functions

- Main function: Act as a *database*
 - Generate and sort according to status (i.e. pending, completed)
 - Various queries – users can search for specific information
- Manipulation – at any workstation
- Storage

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Vendor Neutral Archives (VNA)

- Allows for images and data from different systems and in different formats to be stored using a singular system on a common infrastructure
- May be used as replacements to existing PACS to avoid very expensive transition costs
- Used to consolidate a number of systems that exist within a single facility or across a system of facilities

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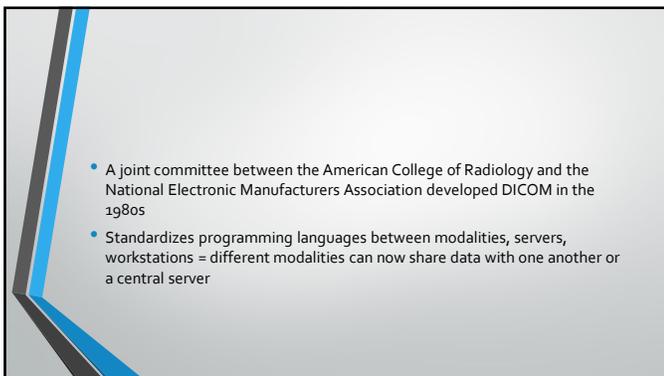
PACS Emergency Contingency Plan

- A backup copy of ALL archived records should be maintained either by the hospital or an Application Service Provider
- RH PACS Downtime Procedure Policy - <https://trh.elucid.com/documents/view/12114/33066/3>

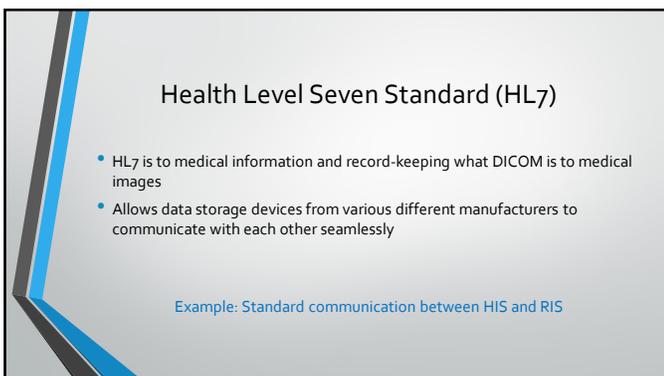
107



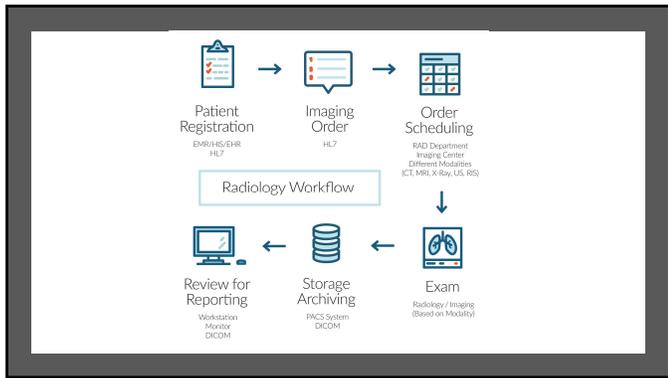
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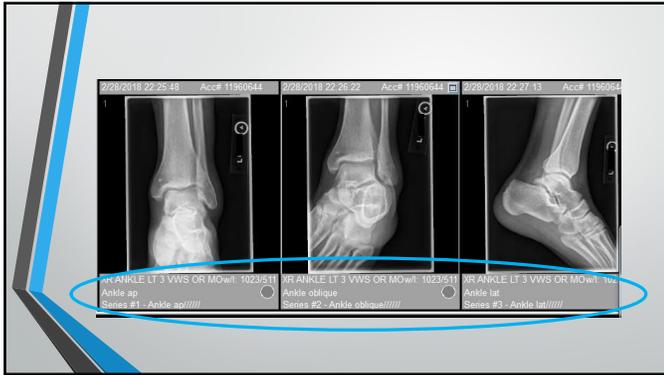
DICOM Header

- A summary of critical identification and study information such as:
 - Date and time of procedure
 - Number of images taken
 - Body part, position
 - Technique used
 - Image format and receptor size
 - Parameters used to digitally process the image
- All this information is stored as **metadata**
 - Should appear in a bar at the top of the screen for each image
 - Shows summary of essential metadata for the image

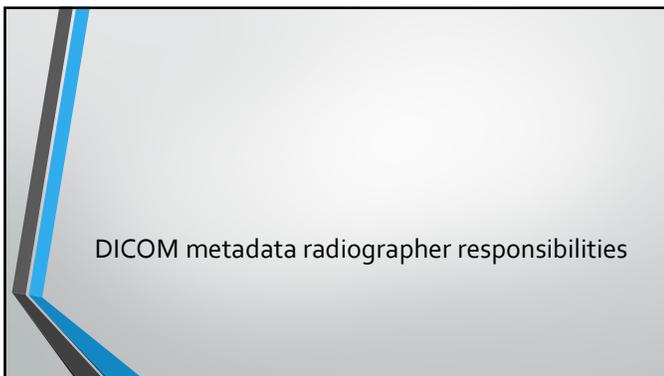
115

Group Tag	Element Tag	Tag Description	Value
0010	0011	Private Tag	MURKIN
0010	0020	Patient ID	12345
0010	0030	Patient's Birth Date	00000000
0010	0040	Patient's Sex	M
0010	1030	Patient's Weight	0
0010	2165	Private Tag	None
0010	2166	Private Tag	None
0010	4000	Patient Comments	
0018	0015	Body Part Examined	THORAX
0018	1000	Device Serial Number	00000000
0018	1020	Software Version(s)	1.0.1.120
0018	1164	Image Field Source	0.16
0018	1508	Positioner Type	COLLIMIN
0018	5100	Patient Position	ANTERIOR - POSTERIOR
0018	7004	Detector Type	DIRECT
0018	7006	Detector Description	
0018	7014	Detector Serial	1.1.1
0020	0020	Study Instance UID	1.2.826.0.1.3680043.2.1330.1000001.1.2213256762.2712337879
0020	000E	Series Instance UID	1.2.826.0.1.3680043.2.1330.1000001.4.2213256762.27123318877
0020	0010	Study ID	None
0020	0011	Series Number	1
0020	0019	Instance Number	29
0020	0020	Patient Orientation	N
0020	0060	Laterality	L
0020	0062	Private Tag	U
0020	4000	Image Comments	
0028	0002	Samples per Pixel	1

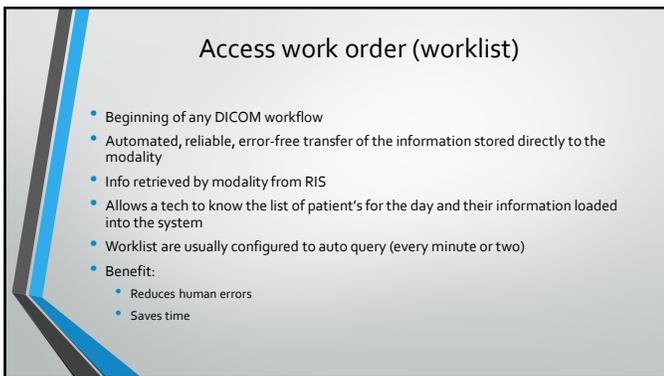
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119

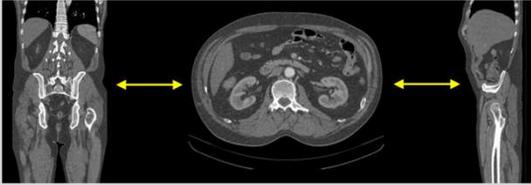
Post Processing – Image operation and manipulation

- Image operation activities
- Multiplanar Reconstruction
- Maximum and Minimum Intensity Projection
- Volume Rendering Technique (VRT)
- Shaded Surface Display (3D technology)
- CAD

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Multiplanar Reconstruction

- Creates multiple planes of view from a single scan



<https://www.youtube.com/watch?v=H1nPMSVijag>

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Maximum & Minimum Intensity Projections

- Enhancement of small vessels (MIP) and air-filled structures (MinIP)

MinIP – Minimum Intensity Projections

MIP – Maximum Intensity Projections



MinIP AIP MIP

122

Volume Rendering Technique (VRT)

- Assists in differentiating between anatomical structures by adding color shades based on pixel intensity



123

Shaded Surface Display (SSD)

- Creates a 3D, moveable image based on the pixel intensity of choice



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CAD (Computer Aided Diagnosis/Detection)

- used as a "second opinion" in assisting radiologists' image interpretations
 - complementary tools that draw the radiologists' attention to certain image areas that need further evaluation
- Uses algorithms
- Used in Mammography at RH



Source: Appl Radiol © 2004 Anderson Publishing, Ltd

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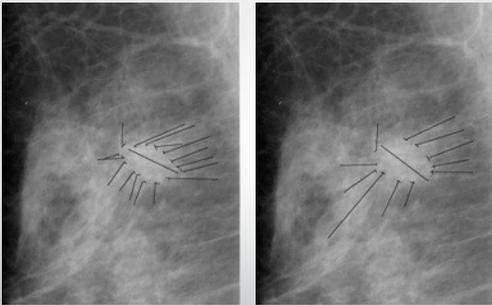
Annotation Issues: Annotations and Mark Ups

- *Image annotation* – describes the meaning in images
- *Image markup* – visual presentation of the annotation
- AIM Project (Annotation and Image Mark up project)
 - The model contains information about who created the annotation, the equipment with which the annotation was created, when the annotation was created, and the image(s) to which the annotation refers.
 - Once the annotation is defined in the AIM, sophisticated queries are now easily found
 - "Find all studies that contain enhancing right middle lobe lung masses that measure between 5 and 6 cm"

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- Other concerns are
 - What is more accurate tool to use --- stylus or mouse for marking or measurements?
 - Human error
 - Legal issues

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Mouse Stylus

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Case number	Annotation time for mouse (s)	Annotation time for stylus (s)
1	109	86
2	121	71
3	108	70
4	78	74
5	109	91
6	55	57
7	78	77
8	90	54
9	113	60
10	89	85
11	101	98
12	81	41

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Image Transmission

- Concerns of medical data overload
 - CT may produce 300 to 500 images and a CT angiography runoff study may include 1,500 to 2,000 images
- In teleradiology, the header of the DICOM image is first transmitted followed by the compressed image data and then at the receiving end, images are reconstructed from low quality to high (or perfect) quality
- Facilities will compress images to send, this allow it to be sent more efficiently
 - Lossless compression have been defined as "visually acceptable" images by the medical imaging community

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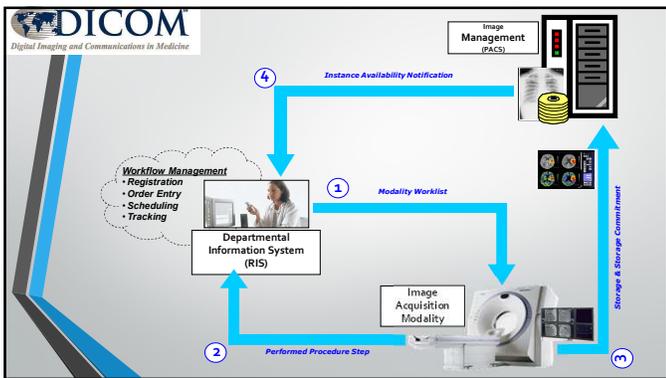
HIPAA

- Health Insurance Portability and Accountability Act of 1996 (HIPAA) Privacy Rule is to ensure you have rights over your own health information, no matter what form it is in.
- The government also created the HIPAA Security Rule to require specific protections to safeguard your electronic health information.
- Federal law requires doctors, hospitals, and other health care providers to notify you of a "breach."
- Facilities should implement high-grade security and encryption in their systems in order to protect records from hackers or theft
- Adhering to HIPAA guidelines often means subjecting software developments to a legal team who can determine whether or not the software falls within HIPAA regulations for security and confidentiality

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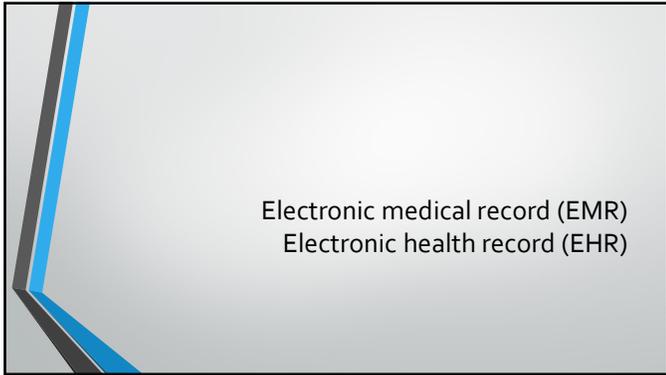
133

DICOM Services for Acquisition Workflow Management

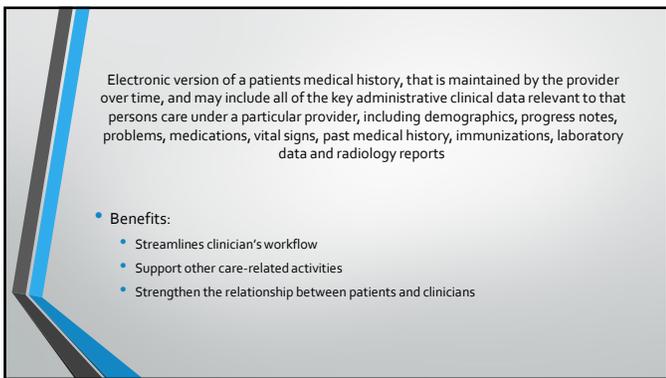
- Improve Interoperability of Imaging Equipment
- Ensure Data Consistency
- Facilitate Reliable Data Management
- Improve Process Efficiency
- Better Quality of Imaging Services

DICOM
Digital Imaging and Communications in Medicine

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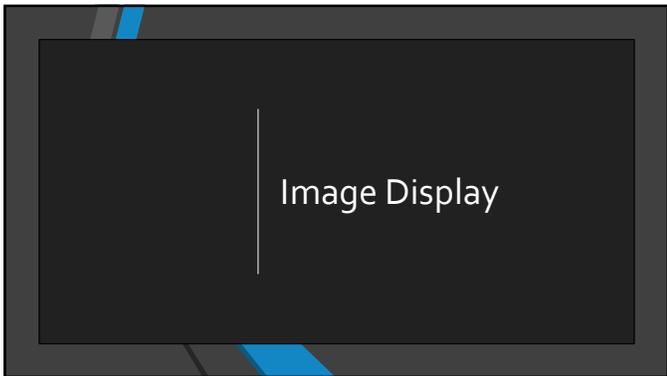
137

- Any system which allows remote transmission and viewing of radiographic images via modems over phone or cable lines
- Makes it possible for images to be sent great distances for a specialist to collaborate with a radiologist, and for images stored at a hospital to be accessed almost instantly by doctors at their individual clinics
 - Example: transmit images to radiologist's home during off hours





1



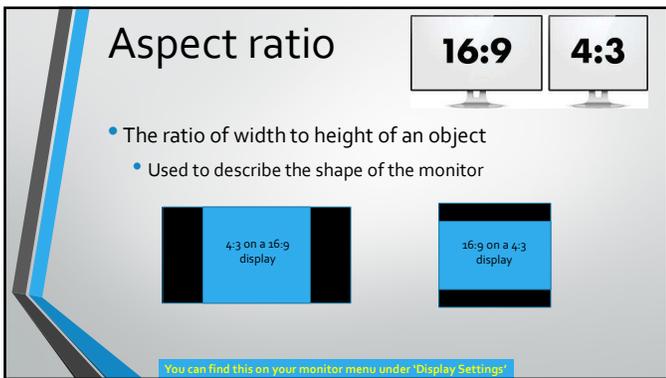
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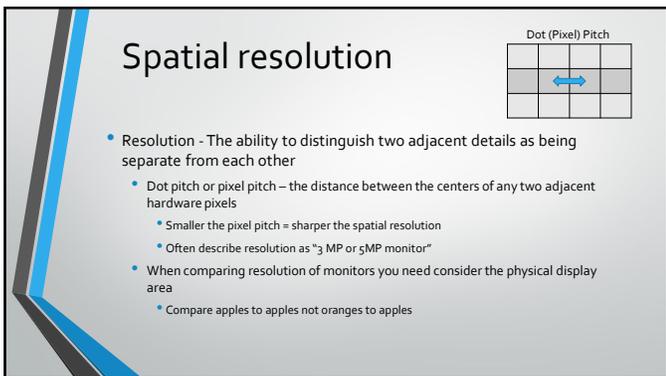
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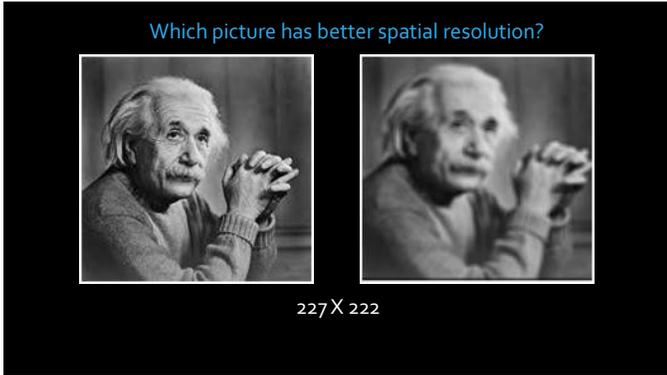
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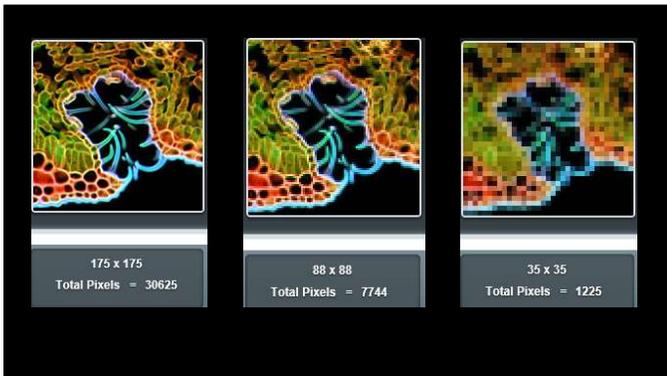
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9

Brightness

- The black level of a display screen. Although it may sound peculiar, the brightness adjusts the "black level" of the display system (how black the black is) –*Computer Desktop Encyclopedia*
- Photometer is used to measure the brightness output of an LCD
- American College of Radiology (ACR) requires a minimum brightness capability for radiologic display systems of 250 lumens



Too dark Good brightness Too bright

10

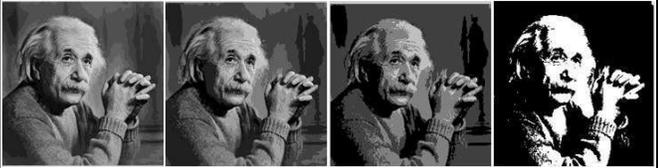
Contrast Ratio

- The difference between the darkest blacks and the brightest whites a given display can produce.
- Contrast ratio for LCD = 600:1, CRT = 3000:1
 - LCD - Inability to produce a "true black" due to backlight leakage



100% Contrast 75% Contrast 50% Contrast 25% Contrast 1% Contrast

12

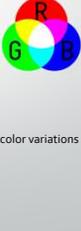


16 Gray Levels 8 Gray Levels 4 Gray Levels 2 Gray Levels

13

Color vs. Grayscale (monochrome)

- **Monochrome monitors**
 - Color images will appear as shades of gray
 - Has only one phosphor of color, but may have the ability to change the brightness causing the illusion of depth
 - Produces sharper text and image because 1 phosphor per pixel than color
- **Color monitors**
 - Monochrome images can be viewed on color monitors
 - Uses alternating intensities of red, green and blue to produce the different color variations
 - Uses 3 phosphors per pixel



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What color would be seen in a color monitor?

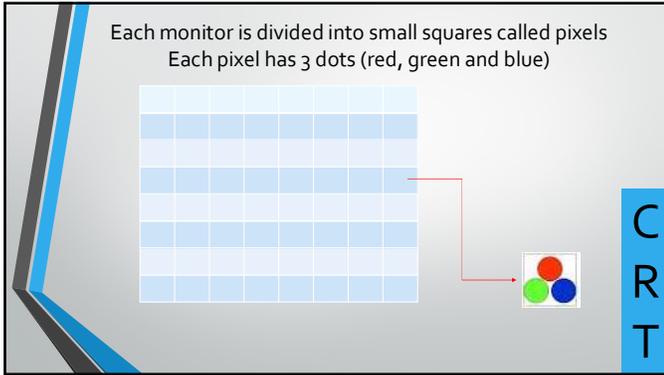
- If all 3 colors set at 0 = **BLACK**
- If all 3 colors set at 255 = **WHITE**
- If red was set at 255 and blue and green at 0 = **RED**

16

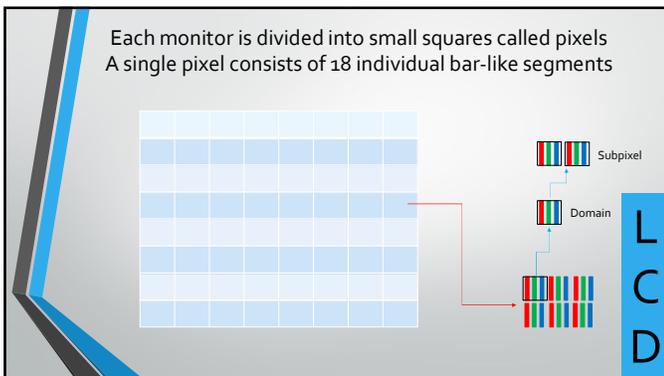
Pixels for Computers

- Pixel – multiple definitions
 - Carroll states it is “the smallest element of the matrix or device that can represent all pixel values within the system’s dynamic range”
- CRT – each triad of color (red, blue, and green) is considered one pixel
- LCD – a single pixel consists of 18 individual bar-like segments
- Hardware pixel in monitor – intersections of flat, transparent wires crossing over each other to form an overall square shape

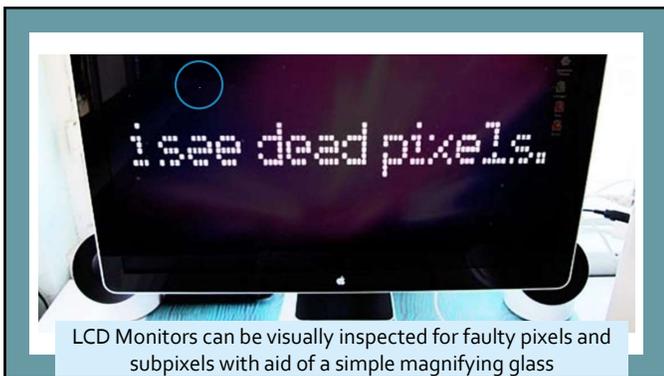
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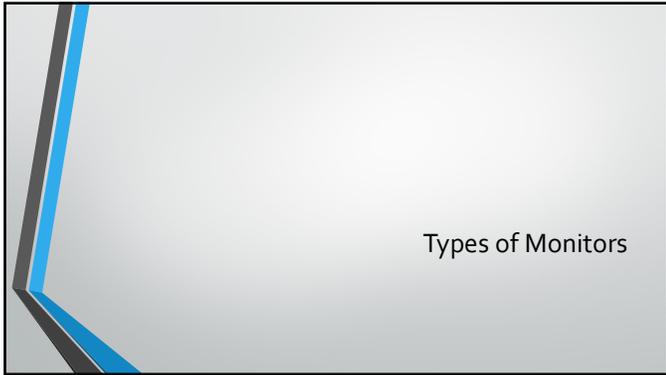
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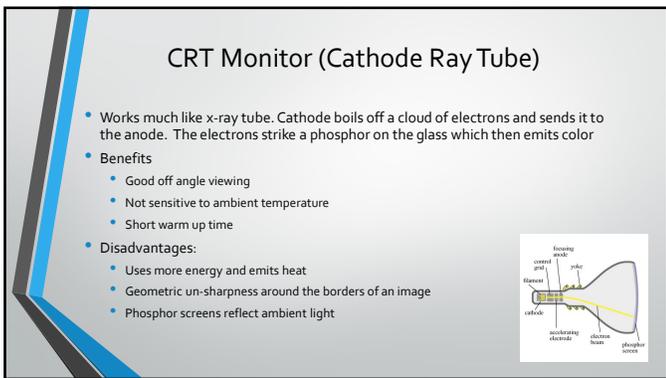
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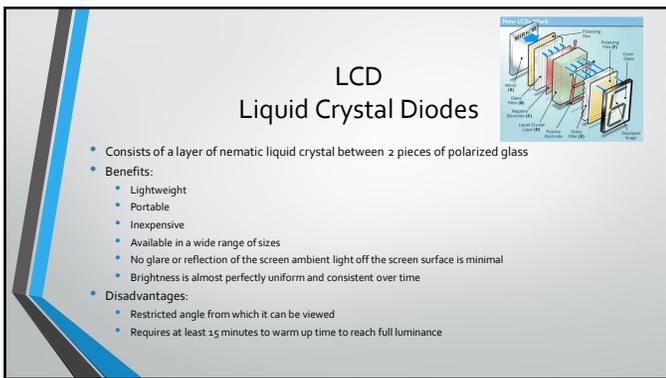
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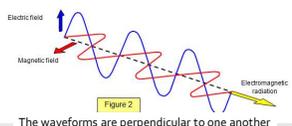
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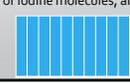
To understand the LCD monitor you must comprehend Light Polarization

- Like an x-ray, a ray of light is electromagnetic radiation that consists of a double wave

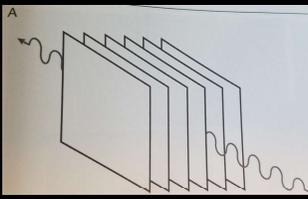


The waveforms are perpendicular to one another

- LCD Monitors use polarized glass
 - Polarized glass contains long chains of iodine molecules, all aligned parallel to each other
 - Just like a grid strips in a grid

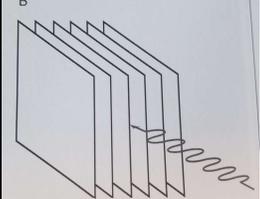


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Electrical

The electrical component of the double wave can pass through a polarized glass with vertical string molecules because it vibrates parallel to it

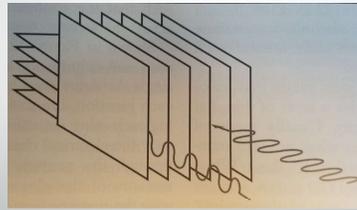


Magnetic

The magnetic component of the double wave cannot pass through a polarized glass with vertical string molecules because it vibrates perpendicular to it

27

What will happen if you layer 2 polarizing glass together so the string molecules are perpendicular to each other?



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LCD – Light polarization

- LCD monitor consists of:
 - 2 thin sheets of glass
 - Each with a light polarizing layer that are perpendicular to the other sheet

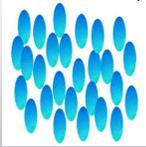
Perpendicular sheets = ALL light being blocked

Don't worry, the LCD process involves "tricking" these layers into allowing light to pass

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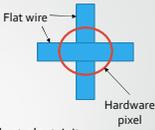
What are nematic liquid crystals?

- This is what is inserted between the polarizing glass sheets/lenses that plays the trick
- A crystalline arrangement of molecules that have a long linear shape and tend to align parallel to each other



30

Before we see the "trick", you need to know one more thing....



- In the polarizing glass there are a layer of thin, flat wires to conduct electricity
- These conductors are also aligned perpendicular to each other when the 2 polarized glass are together
- Each junction forms a single **hardware pixel**
 - Each electrode has a scratch on it
 - Scratches are perpendicular to one another
 - The crystals tend to line up with the "scratch" direction when no electric charge is present -- **known as "on" state**

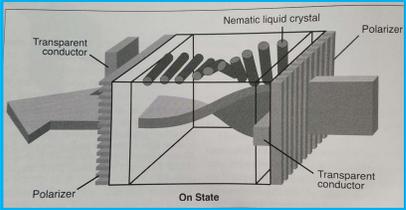
31

And **FINALLY**, Here is the Magic Trick.....



<https://www.youtube.com/watch?v=jiejNAUwcQ8>

32

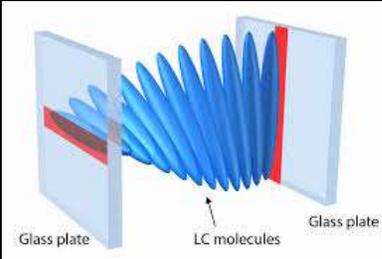


"ON" STATE

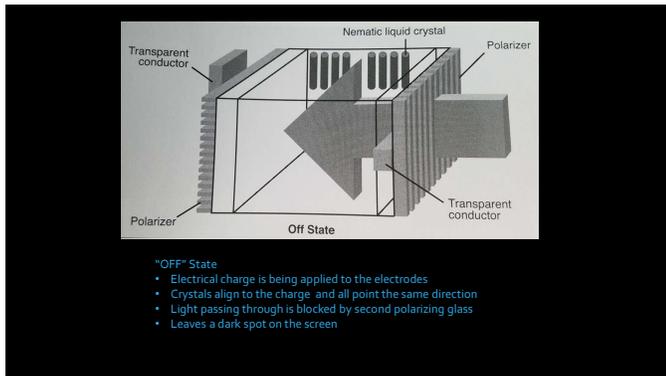
- Since the scratches are perpendicular, the liquid crystals line up in a spiral pattern that twists 90 degrees between the two glass plates
- This lets light waves pass through the nematic liquid crystal and follow the spiral
- Light is able to pass through the second glass plate to the viewer of the monitor

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Just another way to look at it



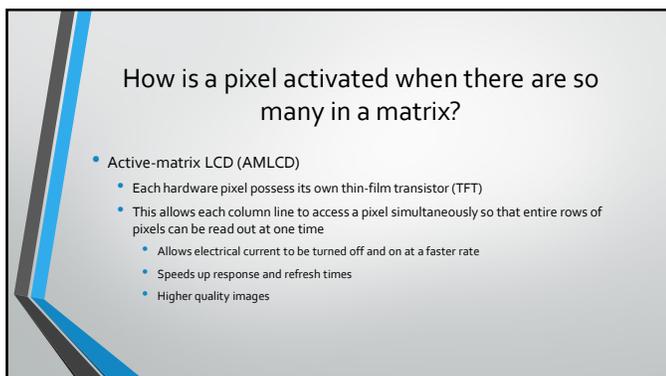
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More info on LCD Monitors

- As LCDs **do not** produce light by themselves—they need illumination to produce a visible image.
 - Without a **backlight**, an LCD display device will remain black, rendering it unviewable
- Backlighting**
 - Types: Fluorescent bulbs or light-emitting diodes (LEDs)
 - LED - Most common

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Care and Maintenance

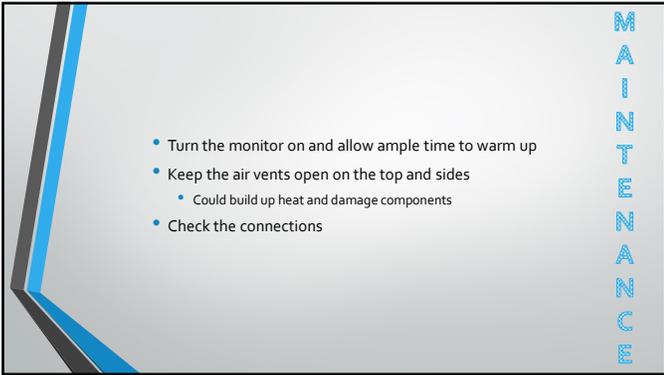
39

CARE

- Apply cleaning solution to soft cloth
 - Do not spray solution directly on screen
 - Do not use paper towel can cause scratches
- Wipe in one direction from top of screen to bottom

- The following cleaners should NOT be used: Acetone
 - Ethyl alcohol
 - Ethyl acid
 - Ammonia
 - Methyl chloride
- The following types of cleaners are acceptable: Water
 - Vinegar (mixed with water)
 - Isopropyl Alcohol
 - Petroleum Benzene

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• Turn the monitor on and allow ample time to warm up

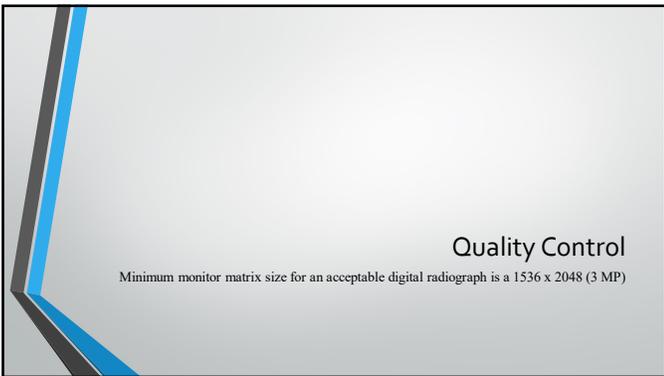
• Keep the air vents open on the top and sides

- Could build up heat and damage components

• Check the connections

M-A-I-N-T-E-N-A-N-C-E

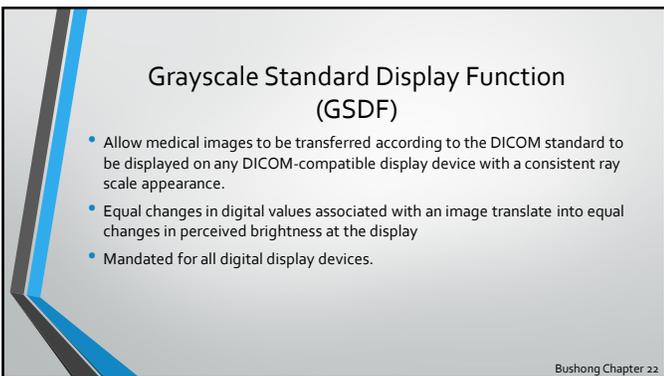
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Quality Control

Minimum monitor matrix size for an acceptable digital radiograph is a 1536 x 2048 (3 MP)

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Grayscale Standard Display Function (GSDf)

- Allow medical images to be transferred according to the DICOM standard to be displayed on any DICOM-compatible display device with a consistent ray scale appearance.
- Equal changes in digital values associated with an image translate into equal changes in perceived brightness at the display
- Mandated for all digital display devices.

Bushong Chapter 22

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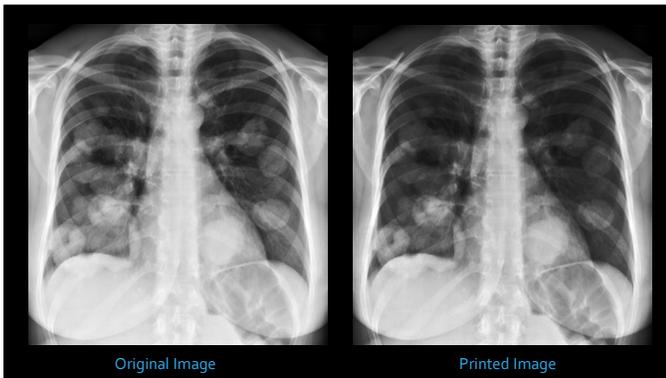
DICOM Grayscale Standard Display Function (GSDF) generates a display function matching the perceptual characteristics of a human observer.

Standard developed having human observer view monitor while luminance output of monitor changed in small steps from black to white and noting when they observed a **Just Noticeable Difference** (JND) in light output as the drive signal is changed.

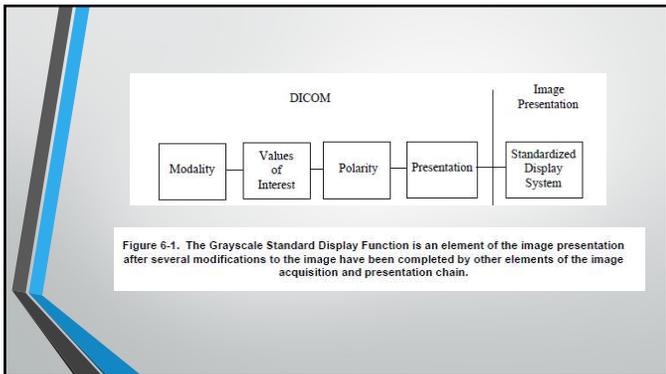
Most digital radiologic images are windowed to attempt to display 256 different shades of gray at any one time, (256 is approximate JND that humans can perceive)

The perceptual linearization implemented with the DICOM Grayscale Standard Display Function (GSDF) ensures that pixel values that are supposed to increase brightness in a linear fashion, say 6, 7, and 8, for example, actually appear that way to the human eye, despite the nonlinearity of our perception.

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Luminance

The rate of light (brightness) emitted from a source such as an LCD monitor

- **Maximum luminance** (*maximum brightness*)- checked at same monitor setting over a period of time with a photometer
- **Luminance response** – monitors ability to accurately display different shades of brightness from a test pattern
- **Luminance ratio** – compares maximum luminance to the minimum luminance
- **Luminance uniformity** – consistency of a single brightness level displayed across the area of the screen

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Luminance Ratio

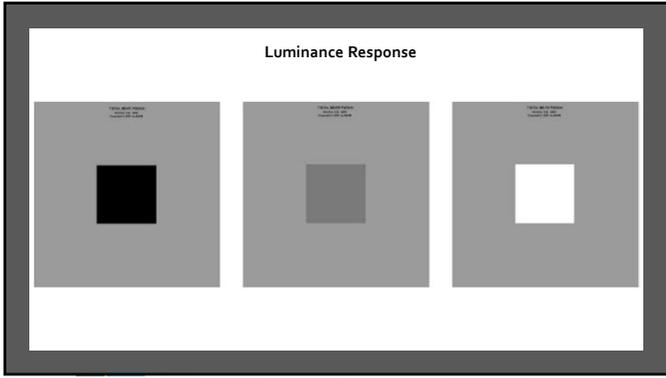
48

Luminance Response

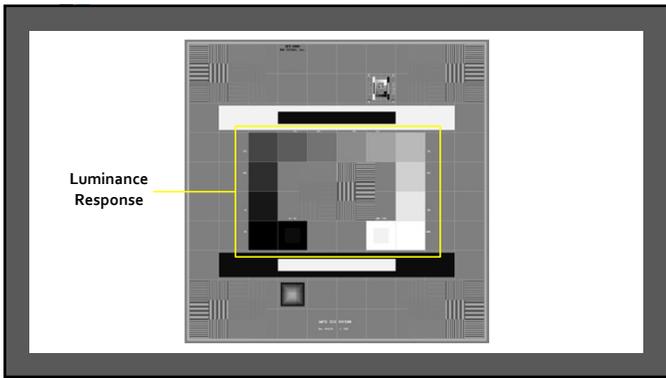
TDS-CT Patterns
Version 2.0, 10/11
Copyright © 2011 by Luster

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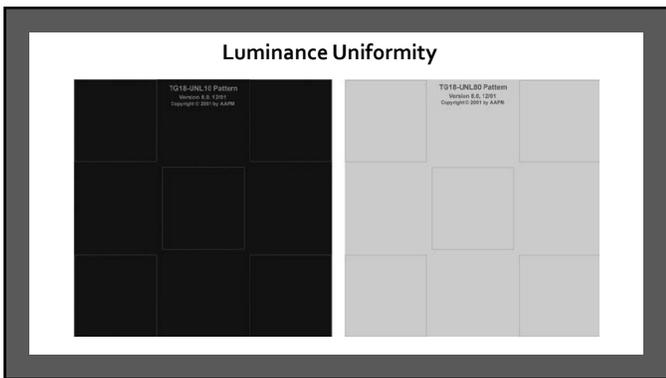
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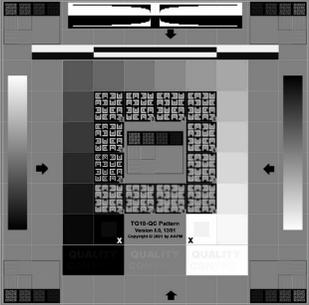
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Resolution

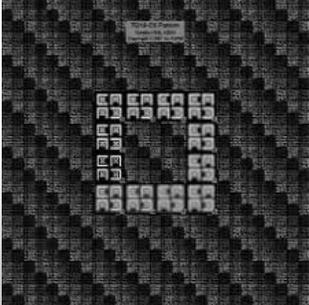
- ACR and AAPM minimum resolution for electronically displayed images of 2.5LP/mm
 - Generic SMPTE test pattern can be used
 - Check for blurring
- AAPM TG18 – QC and TG 18 CX provides an excellent check for resolution across the area of the display screen
 - Evaluate the CX pattern in the middle and in the corners
- Test can be done daily, weekly or monthly

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TG18 - QC

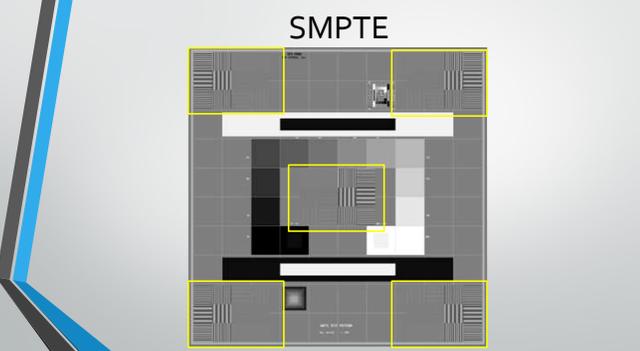


TG18 - CX

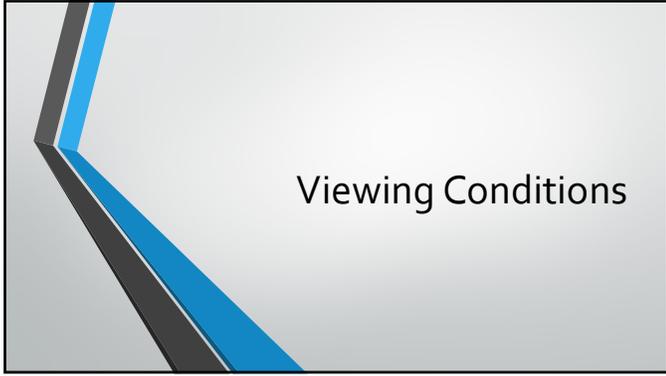


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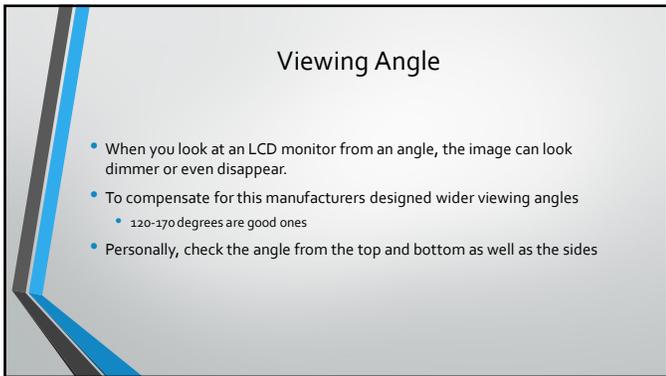
SMPTE



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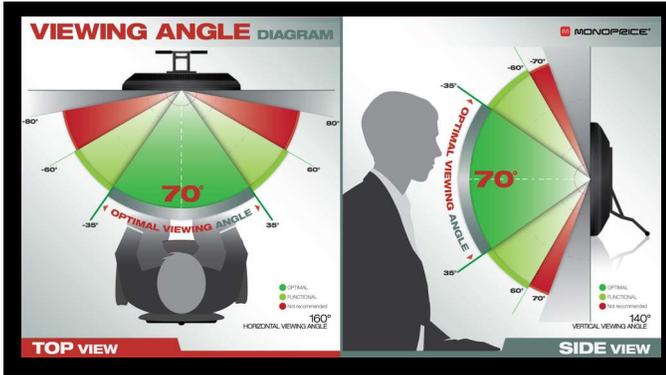
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Ambient Lighting

Illuminance – the rate of light striking a surface

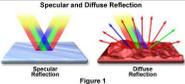


Figure 1

- The effect of ambient room lighting on the surface of and LCD monitor screen, including **reflectance** off the screen, and the resulting reduction in visible contrast of the image, is a result of **illuminance**
- Diffuse reflectance
 - The cumulative effect of room lighting across the area of the monitor screen
- Specular reflectance
 - The reflection of actual light sources such as a light bulb or window

The ambient lighting within the room must be dimmed to a point where both types of reflectance are below any noticeable level, that would impede full visibility of the image and image contrast

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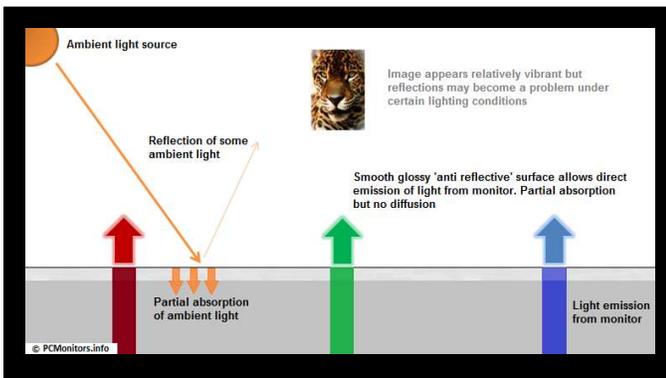
QC Aspect or Ambient Light

- While diagnosis is taking place, the maximum ambient lighting in a reading room should never be more than 25 lux
 - Approximately 1/4 the typical brightness of normal office lighting (75-100 lux)

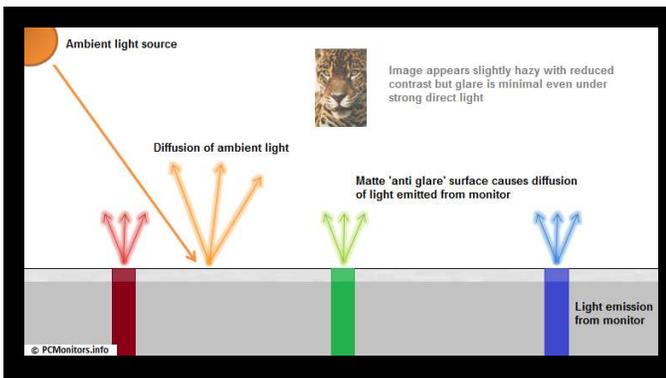
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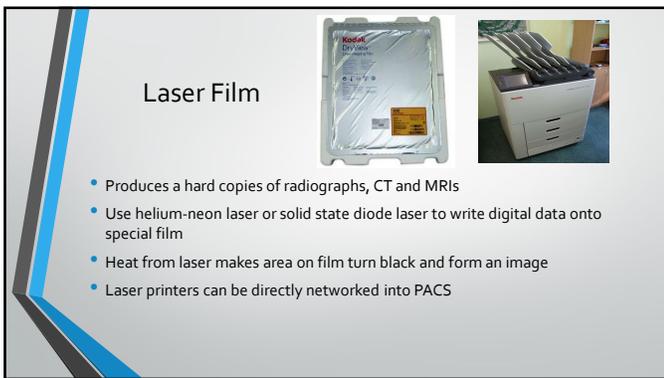
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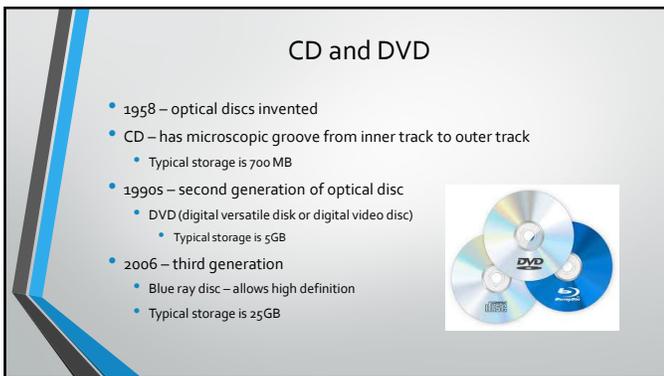
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Data Management

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Network Connectivity

- LAN – Local Area Network
 - Computerized communications network generally contained within a single building or business
 - Devices share one server
- WAN – Wide Area Network
 - Extends to other businesses or locations that may be at great distances
 - Publically or commercially owned
 - Uses transmission services provided by common carriers (phone or cable companies)



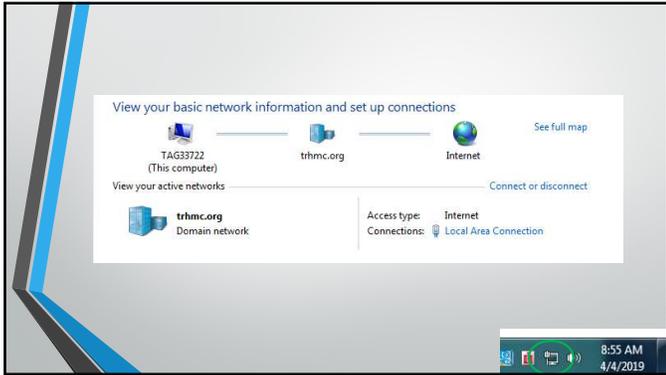
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Computer Network

- Every computer within a network has a unique internet protocol or IP address
 - Ex. 172.811.3.1
- Every computer must have a network interface card
- Router
 - Connects 2 or more networks
 - Wireless routers – allow "point-of-care" access to a network for physicians and other caregivers via tablet or laptop



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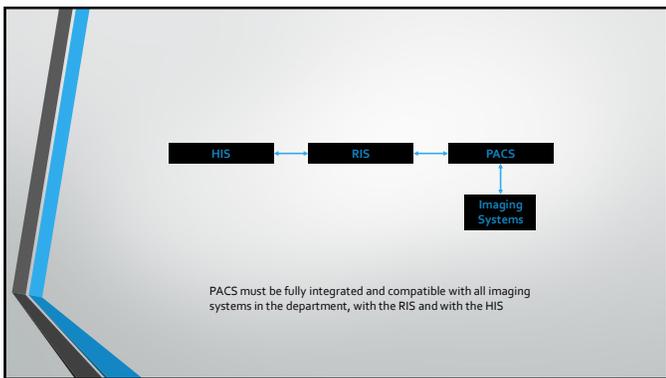
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Type of LAN

RIS and HIS

- Radiology Information System
 - Data system for patient-related functions in the department, such as scheduling of x-ray appointments, tracking of patients, storage and distribution of reports
 - Makes info accessible from different locations within the radiology department
 - Assigns the **accession number**
- Hospital/Health Information System
 - Performs same functions for the entire institution (patient's general medical file)
 - Assigns a unique identifying number for each patient (**MRN**)

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Picture Archiving and Communications System (PACS)

- Comprehensive computer network that is responsible for the electronic storage and distribution of medical images.
- Makes radiographs, CT and MRI scans, US and Nuclear Med images for a particular patient available within the network
- Allows Radiologists and Technologist to access these images from various locations, improving the efficiency of communication

Soon to be Called....
Medical image management and processing system (MIMPS)

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PACS

- Digital acquisition (Picture)
- Display workstations
- Storage devices (Archiving)
- Components are interconnected by a network (Communication)

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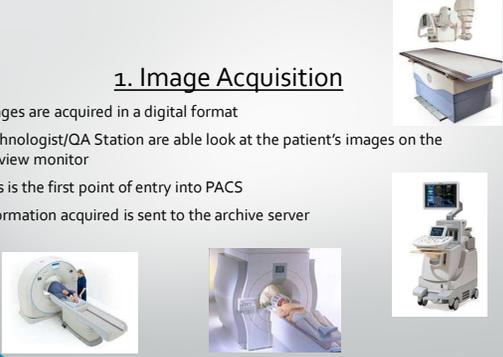
Components of PACS

- Image acquisition
- Display workstations
- Archive servers

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1. Image Acquisition

- Images are acquired in a digital format
- Technologist/OA Station are able look at the patient's images on the preview monitor
- This is the first point of entry into PACS
- Information acquired is sent to the archive server



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2. Display Workstations

Any computer used to view digital images

- Radiologists
- Physicians, surgeons, nurses & patients
- Technologists

- Most interactive part of PACS
- Used inside and out of Radiology
- Has PACS application software that allows minor image-manipulation

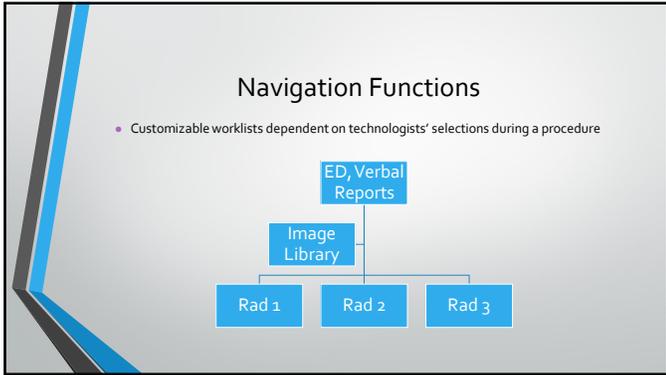


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Common Workstation Functions

- Navigation Functions
- Hanging Protocol
- Study Navigation
- Image Manipulation & Enhancement
- Image Management

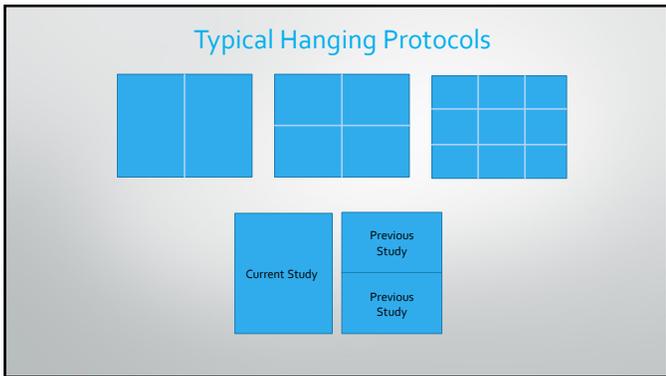
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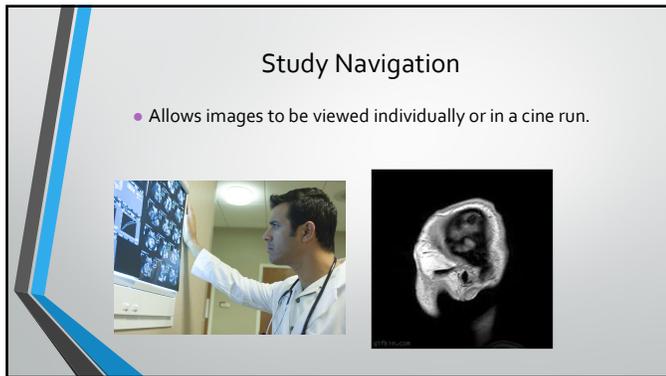
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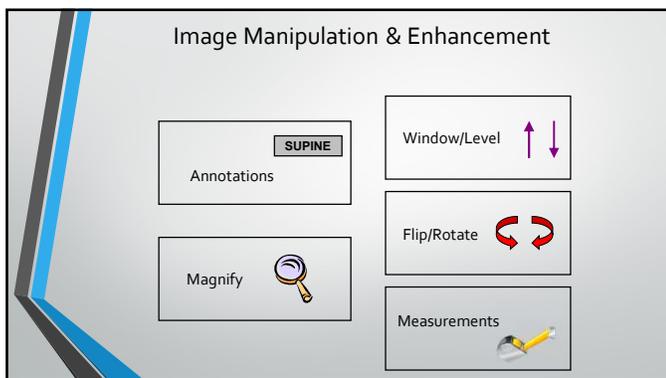
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91



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Image Management Functions

- Patient demographics
 - Edit patient information for proper correlation with previous studies, billing, etc.
- Query / Retrieve
 - Locate images based on patient demographics
- Hardcopy images
 - Either CD or plain film
 - Usually only image library has this function

93

3. Archive Servers

- File room of PACS
- Contains all historic and current data



94

PACS Archiving

- Consist of:
 - Image manager/controller
 - Image storage/server



95

Image Manager

- Contains master database of everything in the archive
- Controls the receipt, retrieval and distribution of the images it stores
- Controls all the DICOM processes running within the archive
- Communicates with RIS and HIS
- Can populate image information into the EMR

MANAGER

96

97

Image Storage/Archive Server

- Physical storage device for archive system
- Network of servers
- Setup in tiers
 - Short-term
 - Long-term

In the United States, storage requirement of a patient's images is from five to seven years.

98

Short Term Storage

- RAID
 - several magnetic disks or hard drives that are linked together in an array

RAID 5 is the most common level used for a PACS archive because it provides adequate redundancy and fault tolerance

99

Reading Hospital

- Short-term storage is done on servers located in IMS but maintained by Philips
 - Philips monitors the system through remote access
 - All backups and drive redundancy are handled by Philips

100

Long Term Storage

- RAID
- Optical disk
- Tape
- Magnetic disk

101

Cloud-Based Storage

- Offsite storage and servers supported by a secure network
- 3rd party vendor
- Shifts disaster recovery process to the vendor along with maintenance and storage equipment purchase
- You pay for the service and storage space

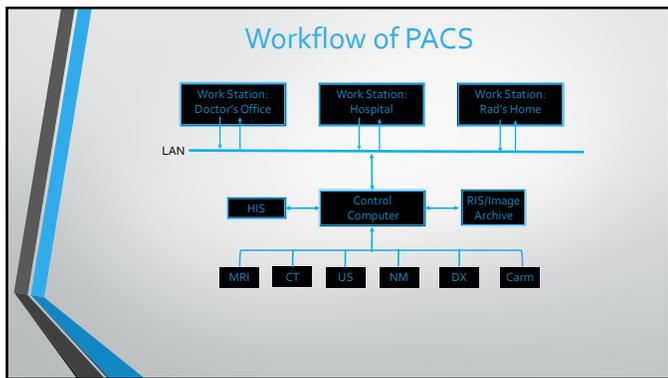
102

Reading Hospital:

- Prior to EPIC - \$1 million budget for record storage
- Legally obligated to retain films:
 - Pediatrics
 - Mammo
 - All other films



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Summary of PACS Functions

- Main function: Act as a *database*
 - Generate and sort according to status (i.e. pending, completed)
 - Various queries – users can search for specific information
- Manipulation – at any workstation
- Storage

105

Vendor Neutral Archives (VNA)

- Allows for images and data from different systems and in different formats to be stored using a singular system on a common infrastructure
- May be used as replacements to existing PACS to avoid very expensive transition costs
- Used to consolidate a number of systems that exist within a single facility or across a system of facilities

106

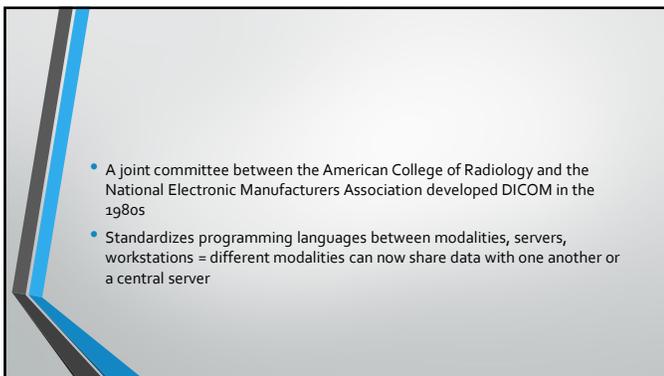
PACS Emergency Contingency Plan

- A backup copy of ALL archived records should be maintained either by the hospital or an Application Service Provider
- RH PACS Downtime Procedure Policy - <https://trh.elucid.com/documents/view/12114/33066/3>

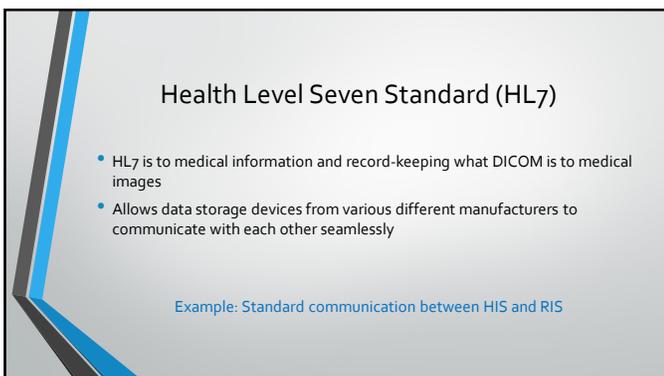
107



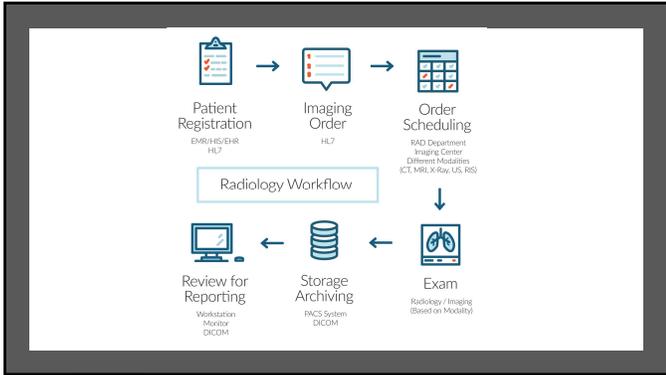
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113



114

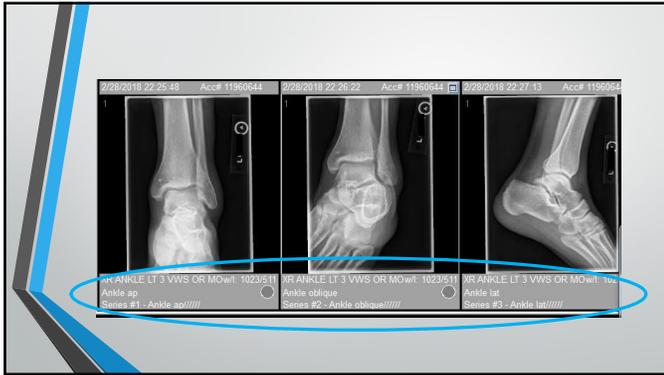
DICOM Header

- A summary of critical identification and study information such as:
 - Date and time of procedure
 - Number of images taken
 - Body part, position
 - Technique used
 - Image format and receptor size
 - Parameters used to digitally process the image
- All this information is stored as **metadata**
 - Should appear in a bar at the top of the screen for each image
 - Shows summary of essential metadata for the image

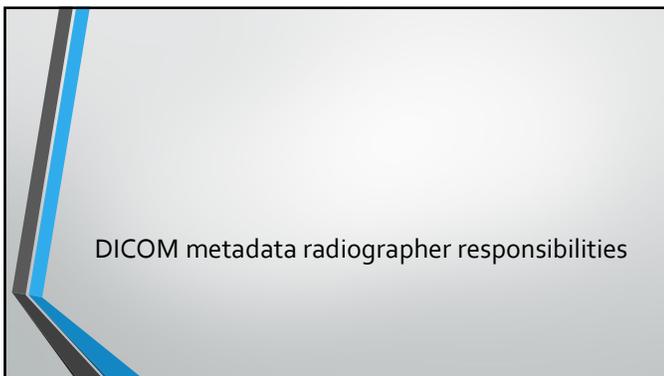
115

Group Tag	Element Tag	Tag Description	Value
0010	0011	Private Tag	MURKIN
0010	0020	Patient ID	12345
0010	0030	Patient's Birth Date	00000000
0010	0040	Patient's Sex	M
0010	1030	Patient's Weight	0
0010	2165	Private Tag	None
0010	2166	Private Tag	None
0010	4000	Patient Comments	
0018	0015	Body Part Examined	THORAX
0018	1000	Device Serial Number	00000000
0018	1020	Software Version(s)	1.0.1.120
0018	1164	Image Field Sequence	0.16
0018	1508	Positioner Type	COLLIMIN
0018	5100	Patient Position	ANTERIOR - POSTERIOR
0018	7004	Detector Type	DIRECT
0018	7006	Detector Description	
0018	7014	Detector Serial	1.1.1
0020	0020	Study Instance UID	1.2.826.0.1.3680043.2.1330.1000001.1.2211256762.2712337879
0020	000E	Series Instance UID	1.2.826.0.1.3680043.2.1330.1000001.4.2211256762.27123318877
0020	0010	Study ID	None
0020	0011	Series Number	1
0020	0019	Instance Number	29
0020	0020	Patient Orientation	N
0020	0060	Laterality	L
0020	0062	Private Tag	U
0020	4000	Image Comments	
0028	0002	Samples per Pixel	1

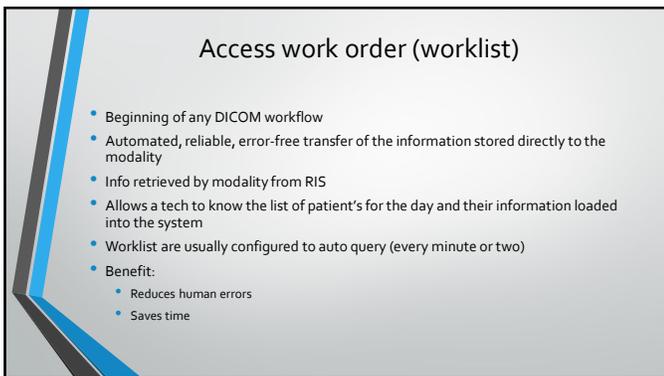
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119

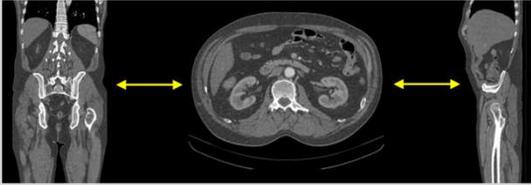
Post Processing – Image operation and manipulation

- Image operation activities
- Multiplanar Reconstruction
- Maximum and Minimum Intensity Projection
- Volume Rendering Technique (VRT)
- Shaded Surface Display (3D technology)
- CAD

120

Multiplanar Reconstruction

- Creates multiple planes of view from a single scan



<https://www.youtube.com/watch?v=H1nPMSVijag>

121

Maximum & Minimum Intensity Projections

- Enhancement of small vessels (MIP) and air-filled structures (MinIP)

MinIP – Minimum Intensity Projections

MIP – Maximum Intensity Projections



122

Volume Rendering Technique (VRT)

- Assists in differentiating between anatomical structures by adding color shades based on pixel intensity



123

Shaded Surface Display (SSD)

- Creates a 3D, moveable image based on the pixel intensity of choice



124

CAD (Computer Aided Diagnosis/Detection)

- used as a "second opinion" in assisting radiologists' image interpretations
 - complementary tools that draw the radiologists' attention to certain image areas that need further evaluation
- Uses algorithms
- Used in Mammography at RH



Source: Appl Radiol © 2004 Anderson Publishing, Ltd

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Annotation Issues: Annotations and Mark Ups

- *Image annotation* – describes the meaning in images
- *Image markup* – visual presentation of the annotation
- AIM Project (Annotation and Image Mark up project)
 - The model contains information about who created the annotation, the equipment with which the annotation was created, when the annotation was created, and the image(s) to which the annotation refers.
 - Once the annotation is defined in the AIM, sophisticated queries are now easily found
 - "Find all studies that contain enhancing right middle lobe lung masses that measure between 5 and 6 cm"

126

- Other concerns are
 - What is more accurate tool to use --- stylus or mouse for marking or measurements?
 - Human error
 - Legal issues

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Mouse Stylus

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Case number	Annotation time for mouse (s)	Annotation time for stylus (s)
1	109	86
2	121	71
3	108	70
4	78	74
5	109	91
6	55	57
7	78	77
8	90	54
9	113	60
10	89	85
11	101	98
12	81	41

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Image Transmission

- Concerns of medical data overload
 - CT may produce 300 to 500 images and a CT angiography runoff study may include 1,500 to 2,000 images
- In teleradiology, the header of the DICOM image is first transmitted followed by the compressed image data and then at the receiving end, images are reconstructed from low quality to high (or perfect) quality
- Facilities will compress images to send, this allow it to be sent more efficiently
 - Lossless compression have been defined as "visually acceptable" images by the medical imaging community

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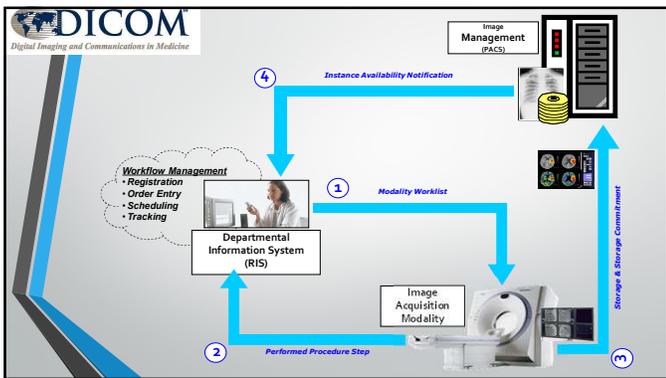
HIPAA

- Health Insurance Portability and Accountability Act of 1996 (HIPAA) Privacy Rule is to ensure you have rights over your own health information, no matter what form it is in.
- The government also created the HIPAA Security Rule to require specific protections to safeguard your electronic health information.
- Federal law requires doctors, hospitals, and other health care providers to notify you of a "breach."
- Facilities should implement high-grade security and encryption in their systems in order to protect records from hackers or theft
- Adhering to HIPAA guidelines often means subjecting software developments to a legal team who can determine whether or not the software falls within HIPAA regulations for security and confidentiality

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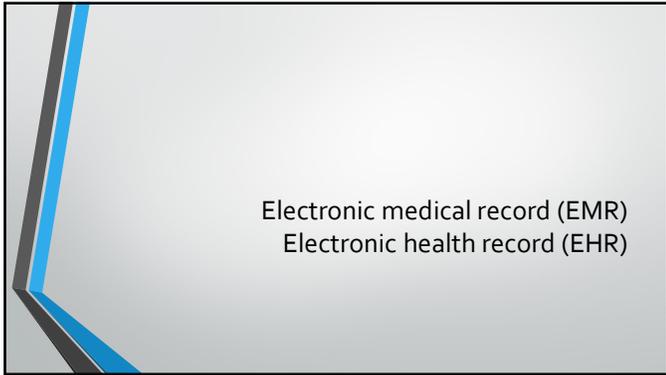
132



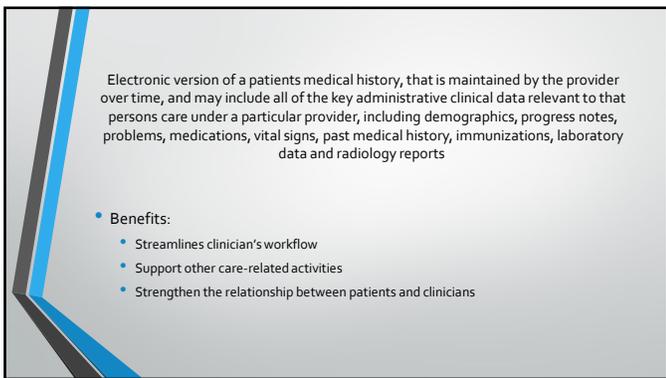
133

- DICOM Services for Acquisition Workflow Management
- Improve Interoperability of Imaging Equipment
 - Ensure Data Consistency
 - Facilitate Reliable Data Management
 - Improve Process Efficiency
 - Better Quality of Imaging Services
- 

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135



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137

- Any system which allows remote transmission and viewing of radiographic images via modems over phone or cable lines
- Makes it possible for images to be sent great distances for a specialist to collaborate with a radiologist, and for images stored at a hospital to be accessed almost instantly by doctors at their individual clinics
 - Example: transmit images to radiologist's home during off hours





1



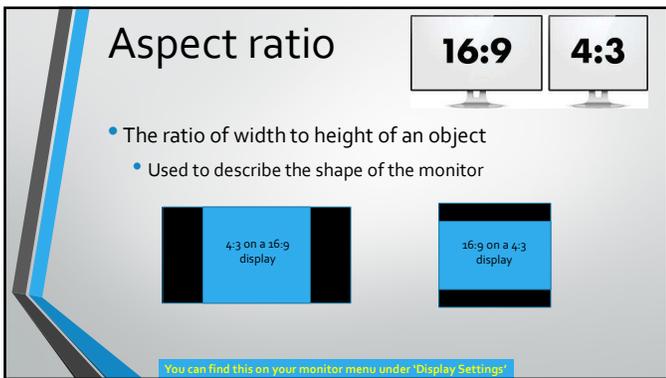
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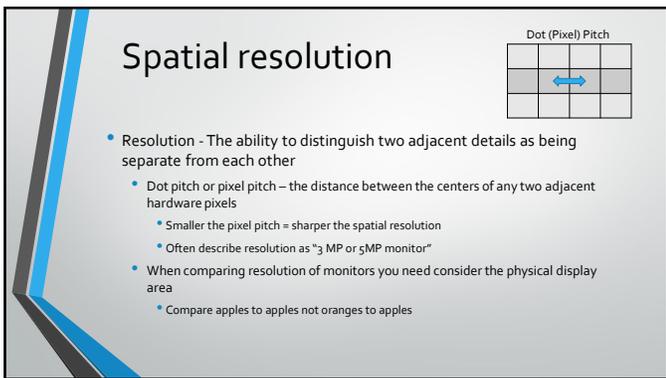
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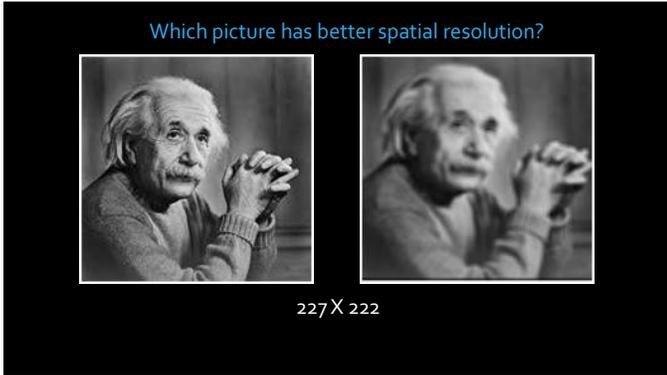
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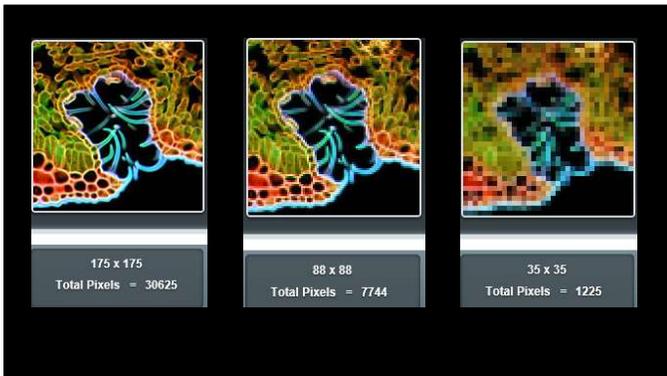
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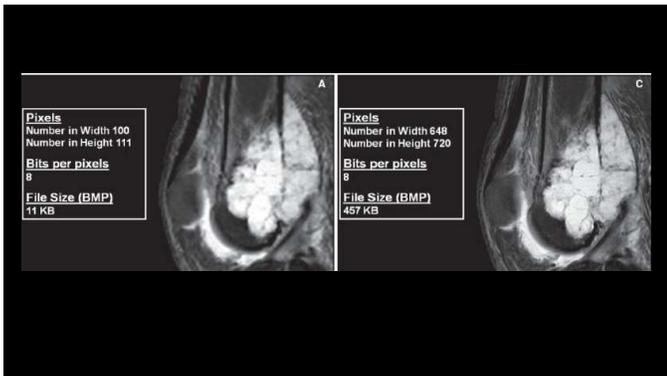
6



7



8



9

Brightness

- The black level of a display screen. Although it may sound peculiar, the brightness adjusts the "black level" of the display system (how black the black is) –*Computer Desktop Encyclopedia*
- Photometer is used to measure the brightness output of an LCD
- American College of Radiology (ACR) requires a minimum brightness capability for radiologic display systems of 250 lumens



Too dark Good brightness Too bright

10

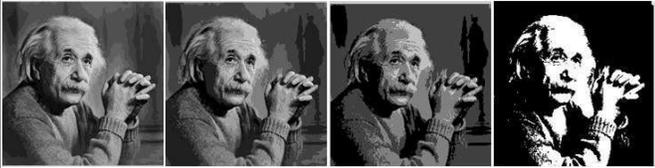
Contrast Ratio

- The difference between the darkest blacks and the brightest whites a given display can produce.
- Contrast ratio for LCD = 600:1, CRT = 3000:1
 - LCD - Inability to produce a "true black" due to backlight leakage



100% Contrast 75% Contrast 50% Contrast 25% Contrast 1% Contrast

12

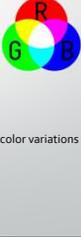


16 Gray Levels 8 Gray Levels 4 Gray Levels 2 Gray Levels

13

Color vs. Grayscale (monochrome)

- **Monochrome monitors**
 - Color images will appear as shades of gray
 - Has only one phosphor of color, but may have the ability to change the brightness causing the illusion of depth
 - Produces sharper text and image because 1 phosphor per pixel than color
- **Color monitors**
 - Monochrome images can be viewed on color monitors
 - Uses alternating intensities of red, green and blue to produce the different color variations
 - Uses 3 phosphors per pixel



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What color would be seen in a color monitor?

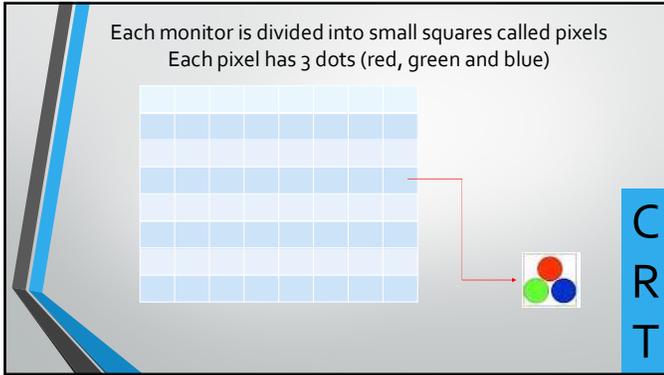
- If all 3 colors set at 0 = **BLACK**
- If all 3 colors set at 255 = **WHITE**
- If red was set at 255 and blue and green at 0 = **RED**

16

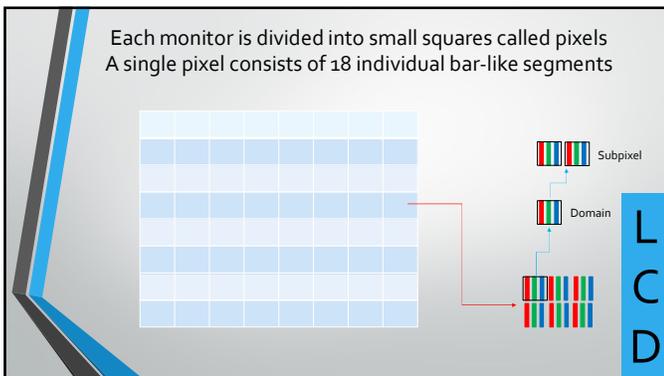
Pixels for Computers

- Pixel – multiple definitions
 - Carroll states it is “the smallest element of the matrix or device that can represent all pixel values within the system’s dynamic range”
- CRT – each triad of color (red, blue, and green) is considered one pixel
- LCD – a single pixel consists of 18 individual bar-like segments
- Hardware pixel in monitor – intersections of flat, transparent wires crossing over each other to form an overall square shape

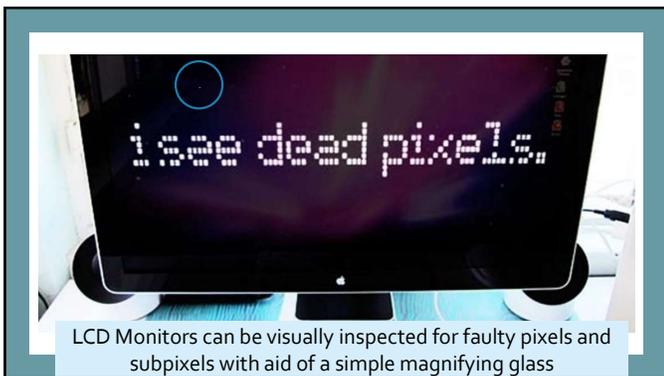
18



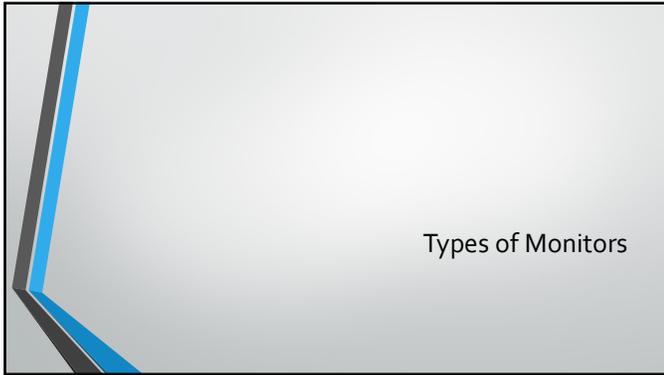
19



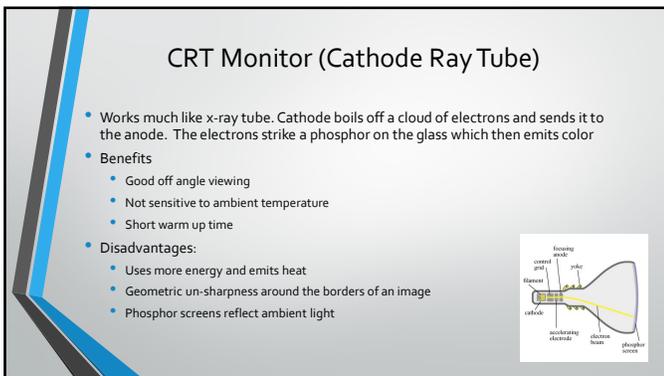
20



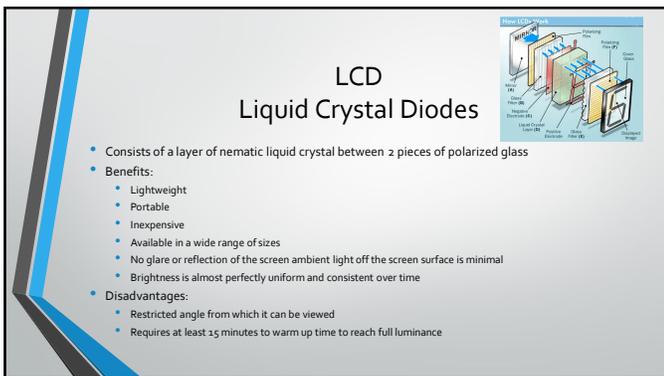
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23



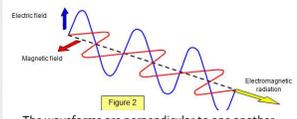
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25

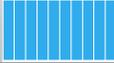
To understand the LCD monitor you must comprehend Light Polarization

- Like an x-ray, a ray of light is electromagnetic radiation that consists of a double wave

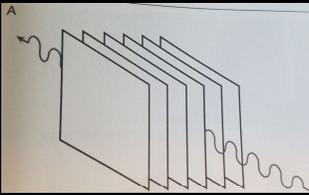


The waveforms are perpendicular to one another

- LCD Monitors use polarized glass
 - Polarized glass contains long chains of iodine molecules, all aligned parallel to each other
 - Just like a grid strips in a grid

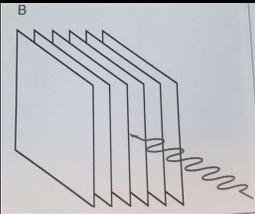


26



Electrical

The electrical component of the double wave can pass through a polarized glass with vertical string molecules because it vibrates parallel to it

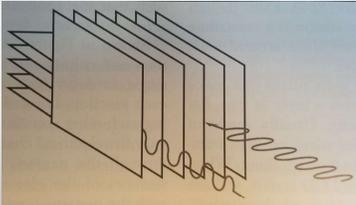


Magnetic

The magnetic component of the double wave cannot pass through a polarized glass with vertical string molecules because it vibrates perpendicular to it

27

What will happen if you layer 2 polarizing glass together so the string molecules are perpendicular to each other?



28

LCD – Light polarization

- LCD monitor consists of:
 - 2 thin sheets of glass
 - Each with a light polarizing layer that are perpendicular to the other sheet

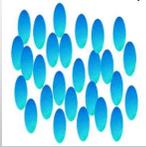
Perpendicular sheets = ALL light being blocked

Don't worry, the LCD process involves "tricking" these layers into allowing light to pass

29

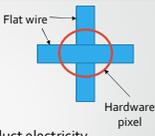
What are nematic liquid crystals?

- This is what is inserted between the polarizing glass sheets/lenses that plays the trick
- A crystalline arrangement of molecules that have a long linear shape and tend to align parallel to each other



30

Before we see the "trick", you need to know one more thing....



- In the polarizing glass there are a layer of thin, flat wires to conduct electricity
- These conductors are also aligned perpendicular to each other when the 2 polarized glass are together
- Each junction forms a single **hardware pixel**
 - Each electrode has a scratch on it
 - Scratches are perpendicular to one another
 - The crystals tend to line up with the "scratch" direction when no electric charge is present -- **known as "on" state**

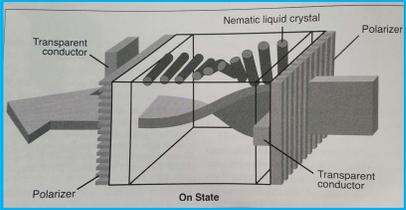
31

And **FINALLY**, Here is the Magic Trick.....



<https://www.youtube.com/watch?v=jiejNAUwcQ8>

32

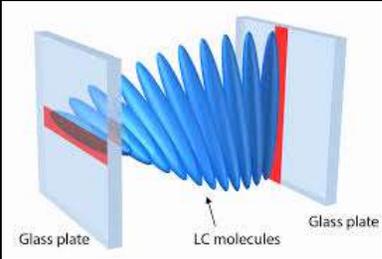


"ON" STATE

- Since the scratches are perpendicular, the liquid crystals line up in a spiral pattern that twists 90 degrees between the two glass plates
- This lets light waves pass through the nematic liquid crystal and follow the spiral
- Light is able to pass through the second glass plate to the viewer of the monitor

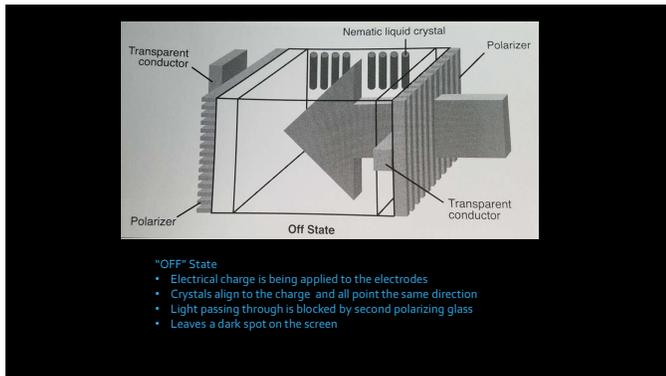
33

Just another way to look at it



Glass plate LC molecules Glass plate

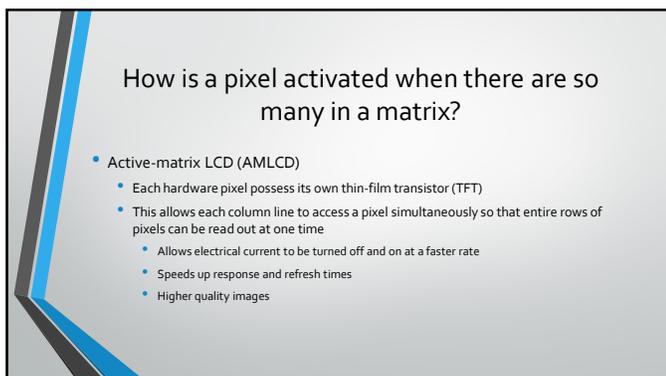
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35



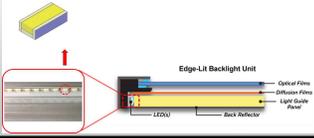
36



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More info on LCD Monitors

- As LCDs **do not** produce light by themselves—they need illumination to produce a visible image.
 - Without a **backlight**, an LCD display device will remain black, rendering it unviewable
- **Backlighting**
 - Types: Fluorescent bulbs or light-emitting diodes (LEDs)
 - LED - Most common



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Care and Maintenance

39

CARE

1. Apply cleaning solution to soft cloth
 - Do not spray solution directly on screen
 - Do not use paper towel can cause scratches
2. Wipe in one direction from top of screen to bottom

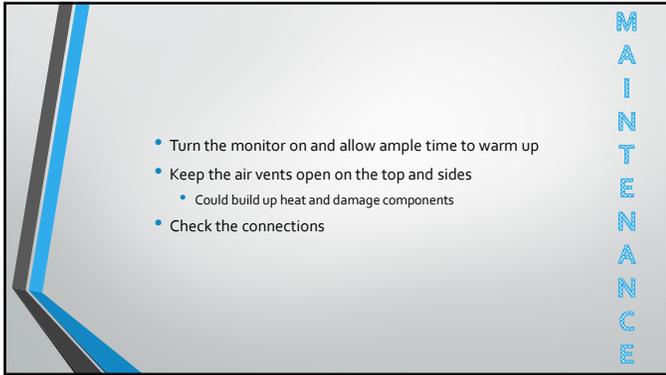
- The following cleaners should NOT be used: Acetone
 - Ethyl alcohol
 - Ethyl acid
 - Ammonia
 - Methyl chloride



- The following types of cleaners are acceptable: Water
 - Vinegar (mixed with water)
 - Isopropyl Alcohol
 - Petroleum Benzene



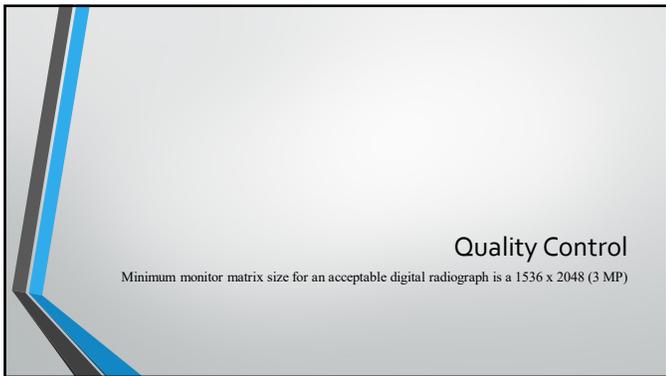
40



M-A-I-N-T-E-N-A-N-C-E

- Turn the monitor on and allow ample time to warm up
- Keep the air vents open on the top and sides
 - Could build up heat and damage components
- Check the connections

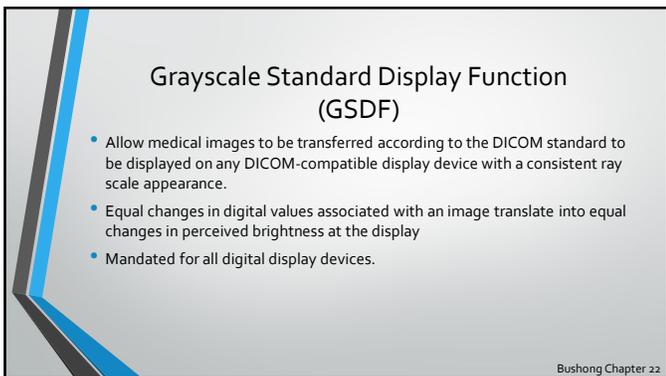
41



Quality Control

Minimum monitor matrix size for an acceptable digital radiograph is a 1536 x 2048 (3 MP)

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Grayscale Standard Display Function (GSDf)

- Allow medical images to be transferred according to the DICOM standard to be displayed on any DICOM-compatible display device with a consistent ray scale appearance.
- Equal changes in digital values associated with an image translate into equal changes in perceived brightness at the display
- Mandated for all digital display devices.

Bushong Chapter 22

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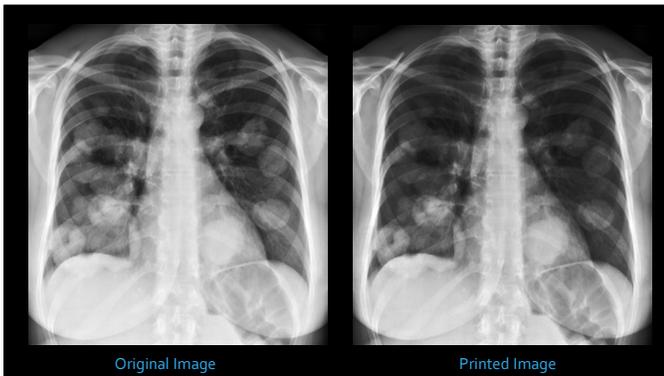
DICOM Grayscale Standard Display Function (GSDF) generates a display function matching the perceptual characteristics of a human observer.

Standard developed having human observer view monitor while luminance output of monitor changed in small steps from black to white and noting when they observed a **Just Noticeable Difference** (JND) in light output as the drive signal is changed.

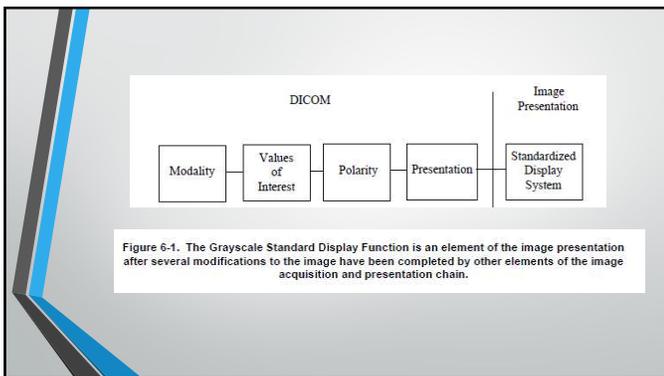
Most digital radiologic images are windowed to attempt to display 256 different shades of gray at any one time, (256 is approximate JND that humans can perceive)

The perceptual linearization implemented with the DICOM Grayscale Standard Display Function (GSDF) ensures that pixel values that are supposed to increase brightness in a linear fashion, say 6, 7, and 8, for example, actually appear that way to the human eye, despite the nonlinearity of our perception.

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45



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Luminance

The rate of light (brightness) emitted from a source such as an LCD monitor

- **Maximum luminance** (*maximum brightness*)- checked at same monitor setting over a period of time with a photometer
- **Luminance response** – monitors ability to accurately display different shades of brightness from a test pattern
- **Luminance ratio** – compares maximum luminance to the minimum luminance
- **Luminance uniformity** – consistency of a single brightness level displayed across the area of the screen

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Luminance Ratio

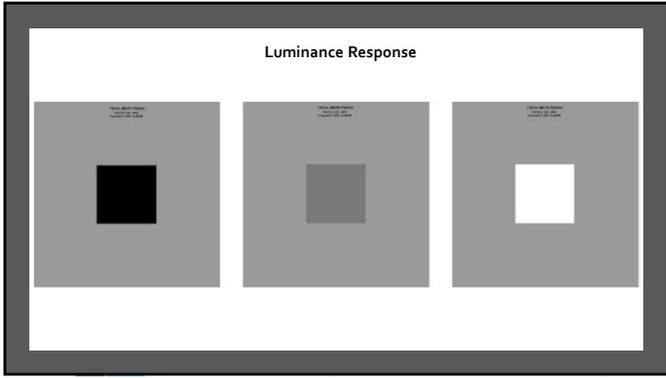
48

Luminance Response

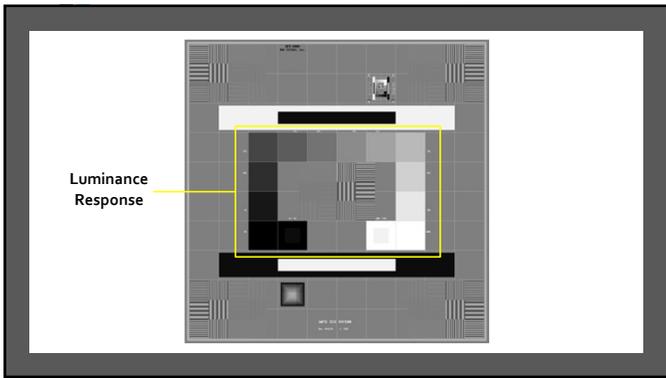
TG55-CT Patterns
Version 5.0, 10/11
Copyright © 2011 by Apple

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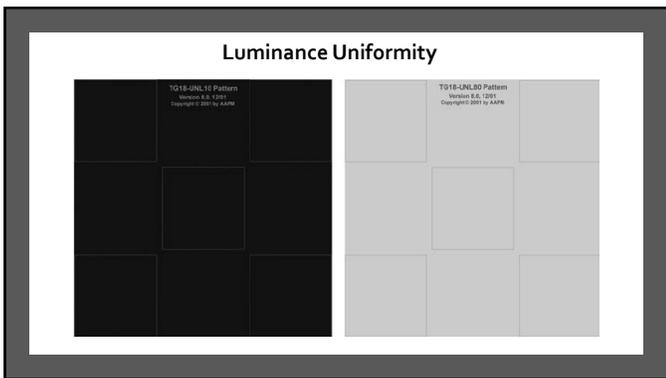
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51



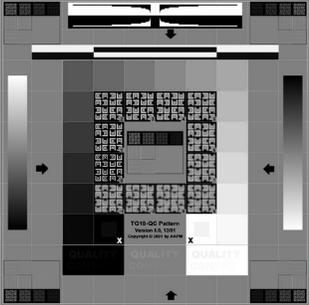
52

Resolution

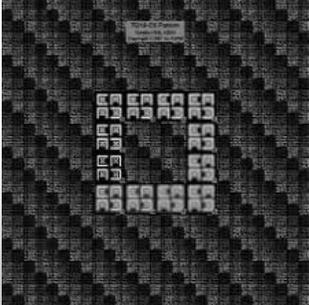
- ACR and AAPM minimum resolution for electronically displayed images of 2.5LP/mm
 - Generic SMPTE test pattern can be used
 - Check for blurring
- AAPM TG18 – QC and TG 18 CX provides an excellent check for resolution across the area of the display screen
 - Evaluate the CX pattern in the middle and in the corners
- Test can be done daily, weekly or monthly

53

TG18 - QC

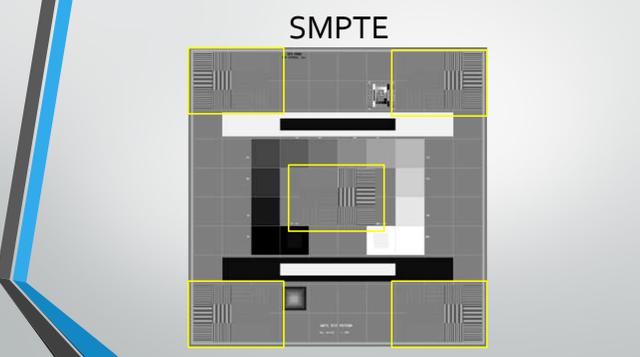


TG18 - CX

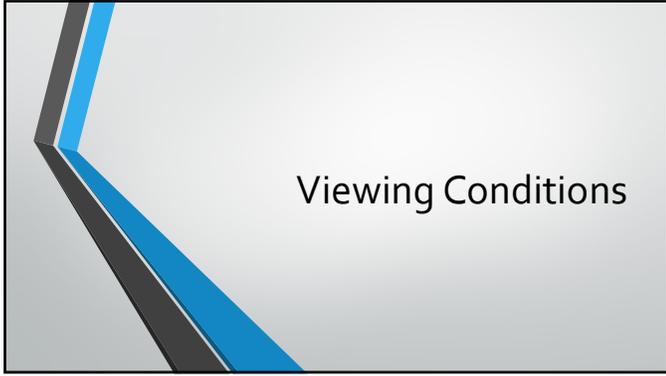


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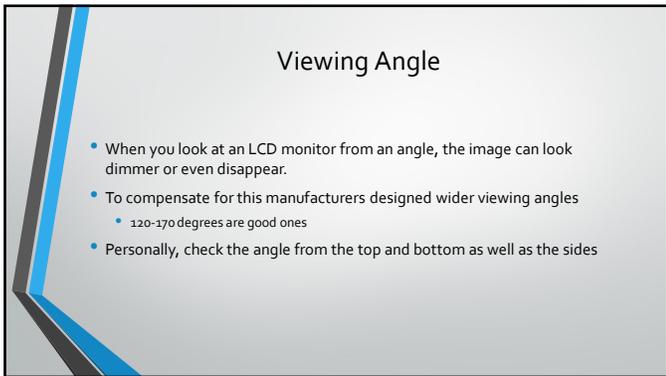
SMPTE



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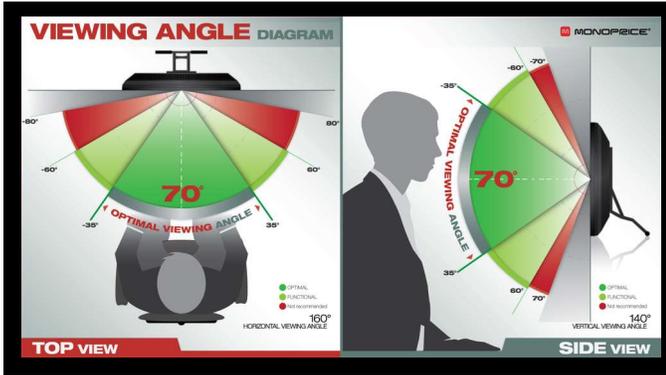
57



58



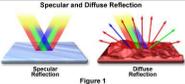
59



60

Ambient Lighting

Illuminance – the rate of light striking a surface



The diagram shows two types of reflection: 'Specular Reflection' where light rays reflect off a smooth surface at an equal angle, and 'Diffuse Reflection' where light rays scatter in multiple directions off a rough surface. The caption is 'Figure 1'.

- The effect of ambient room lighting on the surface of and LCD monitor screen, including **reflectance** off the screen, and the resulting reduction in visible contrast of the image, is a result of **illuminance**
- Diffuse reflectance
 - The cumulative effect of room lighting across the area of the monitor screen
- Specular reflectance
 - The reflection of actual light sources such as a light bulb or window

The ambient lighting within the room must be dimmed to a point where both types of reflectance are below any noticeable level, that would impede full visibility of the image and image contrast

62

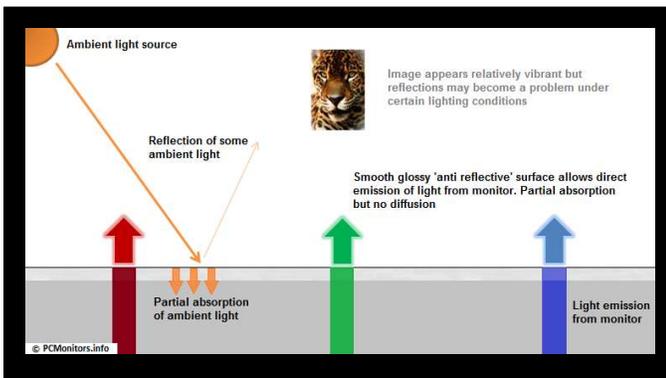
QC Aspect or Ambient Light

- While diagnosis is taking place, the maximum ambient lighting in a reading room should never be more than 25 lux
 - Approximately 1/4 the typical brightness of normal office lighting (75-100 lux)

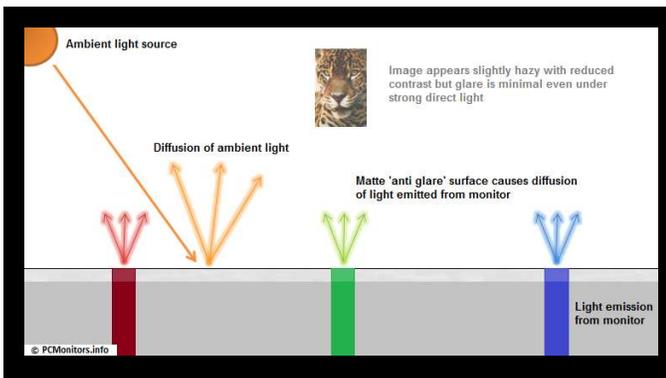
63



64



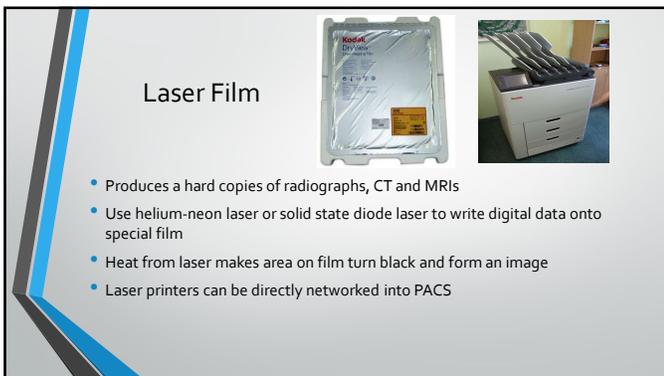
65



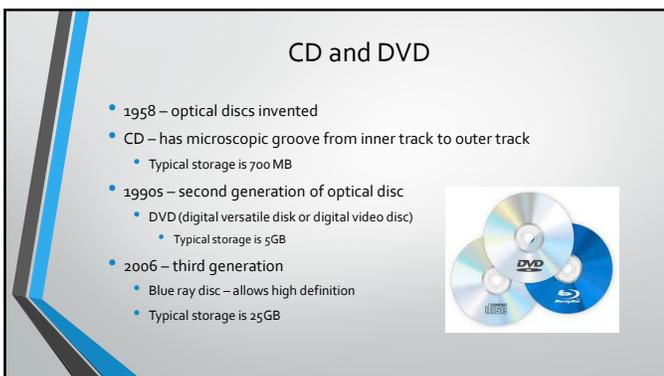
66



67



68



69

Data Management

75

Network Connectivity

- LAN – Local Area Network
 - Computerized communications network generally contained within a single building or business
 - Devices share one server
- WAN – Wide Area Network
 - Extends to other businesses or locations that may be at great distances
 - Publically or commercially owned
 - Uses transmission services provided by common carriers (phone or cable companies)



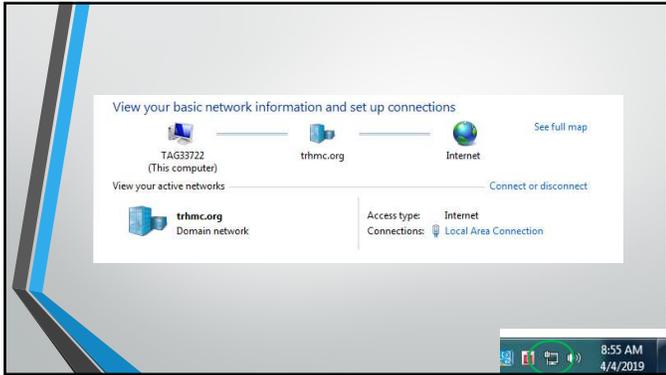
76

Computer Network

- Every computer within a network has a unique internet protocol or IP address
 - Ex. 172.811.3.1
- Every computer must have a network interface card
- Router
 - Connects 2 or more networks
 - Wireless routers – allow "point-of-care" access to a network for physicians and other caregivers via tablet or laptop



77



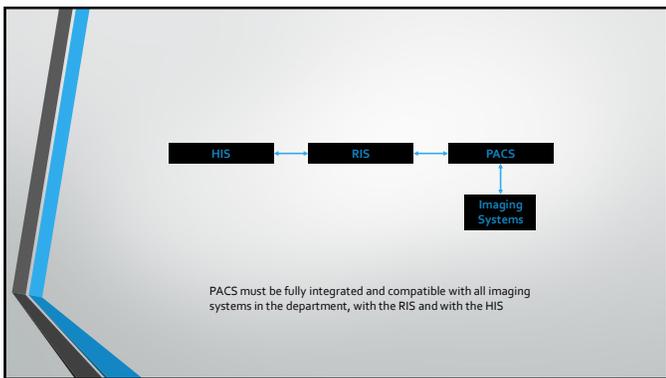
78

Type of LAN

RIS and HIS

- Radiology Information System
 - Data system for patient-related functions in the department, such as scheduling of x-ray appointments, tracking of patients, storage and distribution of reports
 - Makes info accessible from different locations within the radiology department
 - Assigns the **accession number**
- Hospital/Health Information System
 - Performs same functions for the entire institution (patient's general medical file)
 - Assigns a unique identifying number for each patient (**MRN**)

79



80

Picture Archiving and Communications System (PACS)

- Comprehensive computer network that is responsible for the electronic storage and distribution of medical images.
- Makes radiographs, CT and MRI scans, US and Nuclear Med images for a particular patient available within the network
- Allows Radiologists and Technologist to access these images from various locations, improving the efficiency of communication

Soon to be Called....
Medical image management and processing system (MIMPS)

81

PACS

- Digital acquisition (Picture)
- Display workstations
- Storage devices (Archiving)
- Components are interconnected by a network (Communication)

82

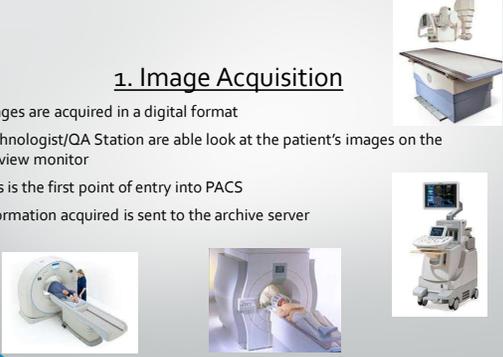
Components of PACS

- Image acquisition
- Display workstations
- Archive servers

83

1. Image Acquisition

- Images are acquired in a digital format
- Technologist/OA Station are able look at the patient's images on the preview monitor
- This is the first point of entry into PACS
- Information acquired is sent to the archive server



84

2. Display Workstations

Any computer used to view digital images

- Radiologists
- Physicians, surgeons, nurses & patients
- Technologists

- Most interactive part of PACS
- Used inside and out of Radiology
- Has PACS application software that allows minor image-manipulation

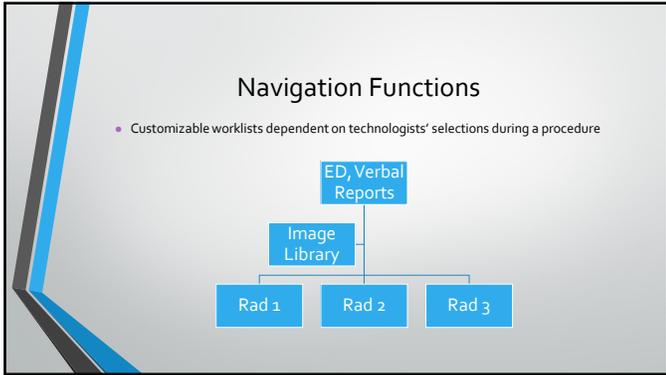


85

Common Workstation Functions

- Navigation Functions
- Hanging Protocol
- Study Navigation
- Image Manipulation & Enhancement
- Image Management

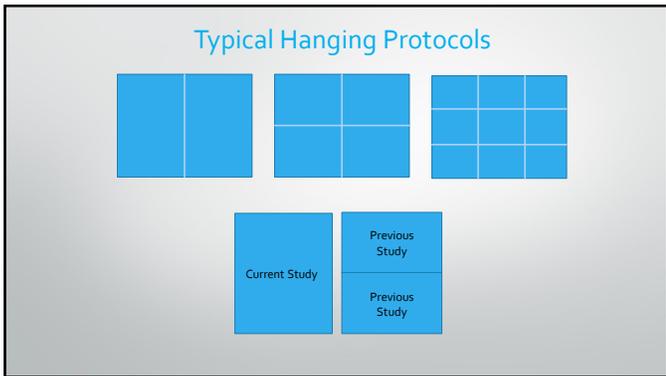
86



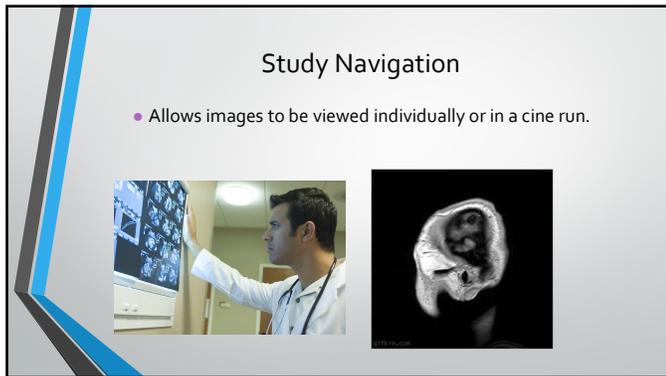
87



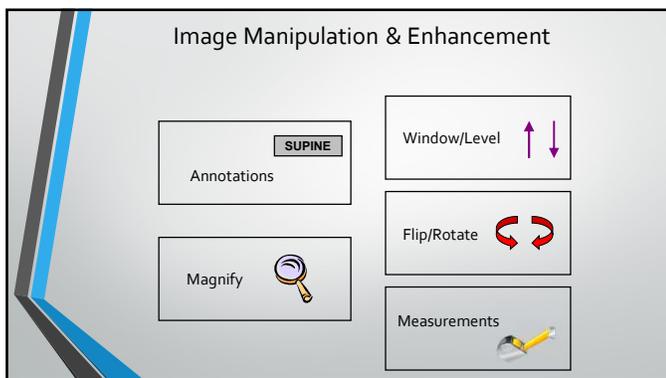
88



89



90



91



92

Image Management Functions

- Patient demographics
 - Edit patient information for proper correlation with previous studies, billing, etc.
- Query / Retrieve
 - Locate images based on patient demographics
- Hardcopy images
 - Either CD or plain film
 - Usually only image library has this function

93

3. Archive Servers

- File room of PACS
- Contains all historic and current data



94

PACS Archiving

- Consist of:
 - Image manager/controller
 - Image storage/server



95

Image Manager

- Contains master database of everything in the archive
- Controls the receipt, retrieval and distribution of the images it stores
- Controls all the DICOM processes running within the archive
- Communicates with RIS and HIS
- Can populate image information into the EMR

MANAGER

96

97

Image Storage/Archive Server

- Physical storage device for archive system
- Network of servers
- Setup in tiers
 - Short-term
 - Long-term

In the United States, storage requirement of a patient's images is from five to seven years.

98

Short Term Storage

- RAID
 - several magnetic disks or hard drives that are linked together in an array

RAID 5 is the most common level used for a PACS archive because it provides adequate redundancy and fault tolerance

99

Reading Hospital

- Short-term storage is done on servers located in IMS but maintained by Philips
 - Philips monitors the system through remote access
 - All backups and drive redundancy are handled by Philips

100

Long Term Storage

- RAID
- Optical disk
- Tape
- Magnetic disk

101

Cloud-Based Storage

- Offsite storage and servers supported by a secure network
- 3rd party vendor
- Shifts disaster recovery process to the vendor along with maintenance and storage equipment purchase
- You pay for the service and storage space

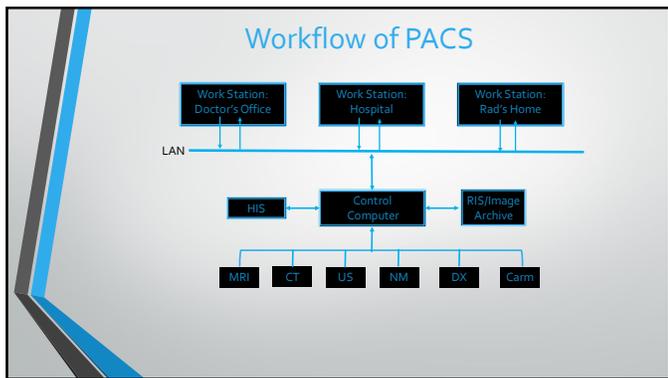
102

Reading Hospital:

- Prior to EPIC - \$1 million budget for record storage
- Legally obligated to retain films:
 - Pediatrics
 - Mammo
 - All other films



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Summary of PACS Functions

- Main function: Act as a *database*
 - Generate and sort according to status (i.e. pending, completed)
 - Various queries – users can search for specific information
- Manipulation – at any workstation
- Storage

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Vendor Neutral Archives (VNA)

- Allows for images and data from different systems and in different formats to be stored using a singular system on a common infrastructure
- May be used as replacements to existing PACS to avoid very expensive transition costs
- Used to consolidate a number of systems that exist within a single facility or across a system of facilities

106

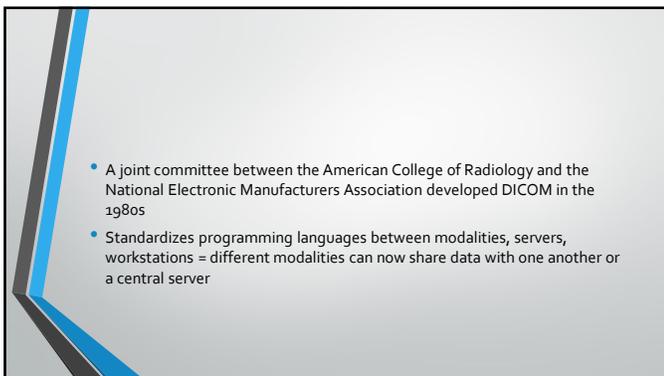
PACS Emergency Contingency Plan

- A backup copy of ALL archived records should be maintained either by the hospital or an Application Service Provider
- RH PACS Downtime Procedure Policy - <https://trh.elucid.com/documents/view/12114/33066/3>

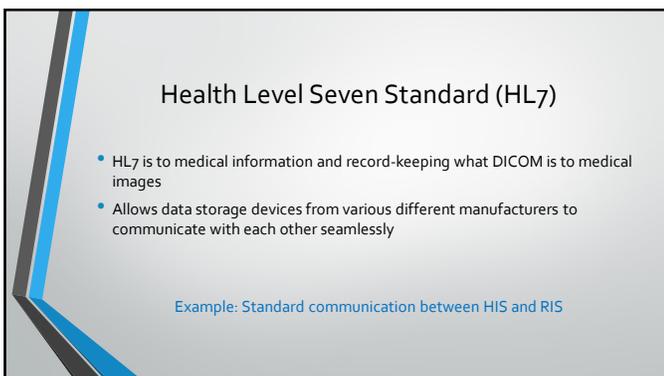
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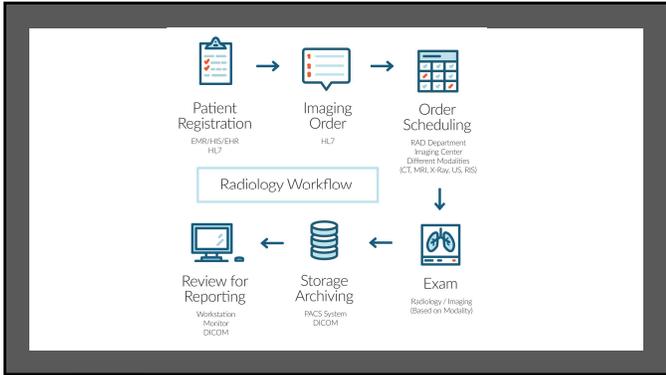
111



112



113



114

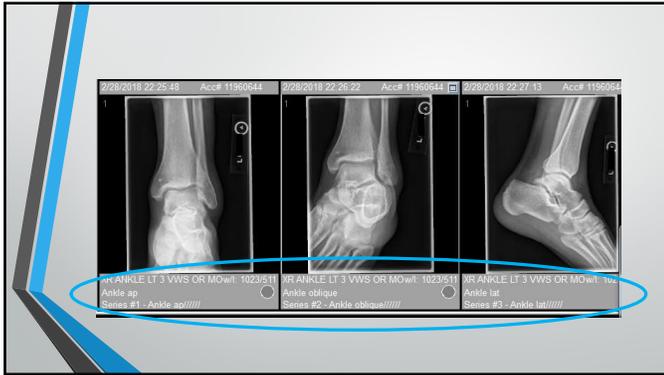
DICOM Header

- A summary of critical identification and study information such as:
 - Date and time of procedure
 - Number of images taken
 - Body part, position
 - Technique used
 - Image format and receptor size
 - Parameters used to digitally process the image
- All this information is stored as **metadata**
 - Should appear in a bar at the top of the screen for each image
 - Shows summary of essential metadata for the image

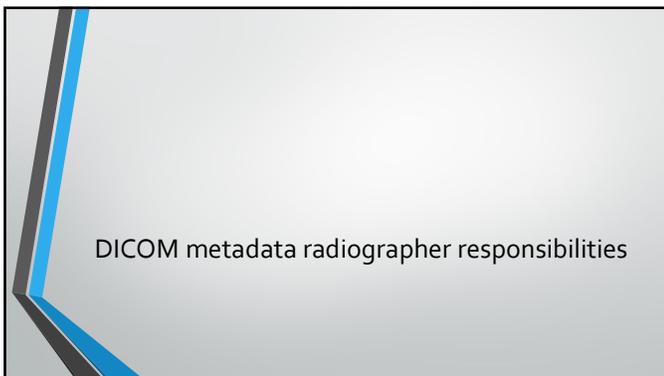
115

Group Tag	Element Tag	Tag Description	Value
0010	0011	Private Tag	MURKIN
0010	0020	Patient ID	12345
0010	0030	Patient's Birth Date	00000000
0010	0040	Patient's Sex	M
0010	1030	Patient's Weight	0
0010	2165	Private Tag	None
0010	2166	Private Tag	None
0010	4000	Patient Comments	
0018	0015	Body Part Examined	THORAX
0018	1000	Device Serial Number	00000000
0018	1020	Software Version(s)	1.0.1.120
0018	1164	Image Field Source	0.0.0
0018	1508	Positioner Type	COLLIMIN
0018	5100	Patient Position	ANTERIOR - POSTERIOR
0018	7004	Detector Type	DIRECT
0018	7006	Detector Description	
0018	7014	Detector Serial	1.1.1
0020	0020	Study Instance UID	1.2.825.0.1.3680043.2.1330.1000001.1.2213256752.2712337879
0020	000E	Series Instance UID	1.2.825.0.1.3680043.2.1330.1000001.4.2213256752.27123318877
0020	0010	Study ID	None
0020	0011	Series Number	1
0020	0019	Instance Number	29
0020	0020	Patient Orientation	N
0020	0060	Laterality	L
0020	0062	Private Tag	U
0020	4000	Image Comments	
0028	0002	Samples per Pixel	1

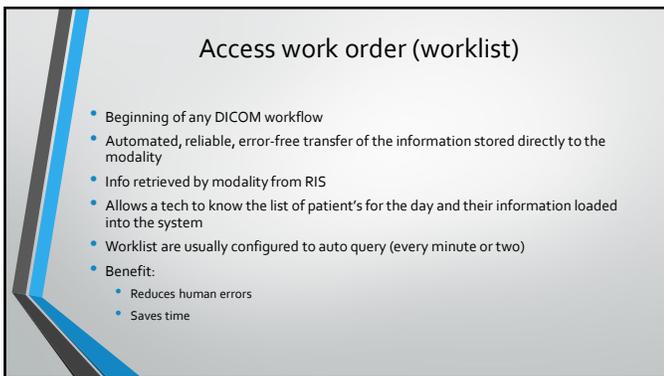
116



117



118



119

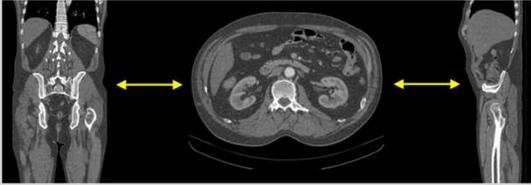
Post Processing – Image operation and manipulation

- Image operation activities
- Multiplanar Reconstruction
- Maximum and Minimum Intensity Projection
- Volume Rendering Technique (VRT)
- Shaded Surface Display (3D technology)
- CAD

120

Multiplanar Reconstruction

- Creates multiple planes of view from a single scan



<https://www.youtube.com/watch?v=H1nPMSVijag>

121

Maximum & Minimum Intensity Projections

- Enhancement of small vessels (MIP) and air-filled structures (MinIP)

MinIP – Minimum Intensity Projections

MIP – Maximum Intensity Projections



MinIP AIP MIP

122

Volume Rendering Technique (VRT)

- Assists in differentiating between anatomical structures by adding color shades based on pixel intensity



123

Shaded Surface Display (SSD)

- Creates a 3D, moveable image based on the pixel intensity of choice



124

CAD (Computer Aided Diagnosis/Detection)

- used as a "second opinion" in assisting radiologists' image interpretations
 - complementary tools that draw the radiologists' attention to certain image areas that need further evaluation
- Uses algorithms
- Used in Mammography at RH



Source: Appl Radiol © 2004 Anderson Publishing, Ltd

125

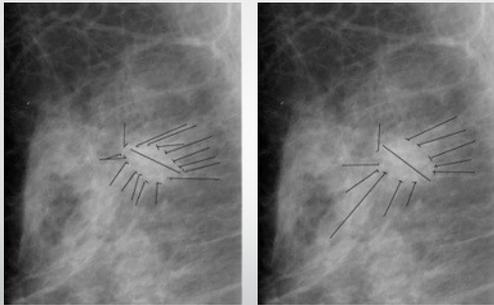
Annotation Issues: Annotations and Mark Ups

- *Image annotation* – describes the meaning in images
- *Image markup* – visual presentation of the annotation
- AIM Project (Annotation and Image Mark up project)
 - The model contains information about who created the annotation, the equipment with which the annotation was created, when the annotation was created, and the image(s) to which the annotation refers.
 - Once the annotation is defined in the AIM, sophisticated queries are now easily found
 - "Find all studies that contain enhancing right middle lobe lung masses that measure between 5 and 6 cm"

126

- Other concerns are
 - What is more accurate tool to use --- stylus or mouse for marking or measurements?
 - Human error
 - Legal issues

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Mouse Stylus

128

Case number	Annotation time for mouse (s)	Annotation time for stylus (s)
1	109	86
2	121	71
3	108	70
4	78	74
5	109	91
6	55	57
7	78	77
8	90	54
9	113	60
10	89	85
11	101	98
12	81	41

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Image Transmission

- Concerns of medical data overload
 - CT may produce 300 to 500 images and a CT angiography runoff study may include 1,500 to 2,000 images
- In teleradiology, the header of the DICOM image is first transmitted followed by the compressed image data and then at the receiving end, images are reconstructed from low quality to high (or perfect) quality
- Facilities will compress images to send, this allow it to be sent more efficiently
 - Lossless compression have been defined as "visually acceptable" images by the medical imaging community

130

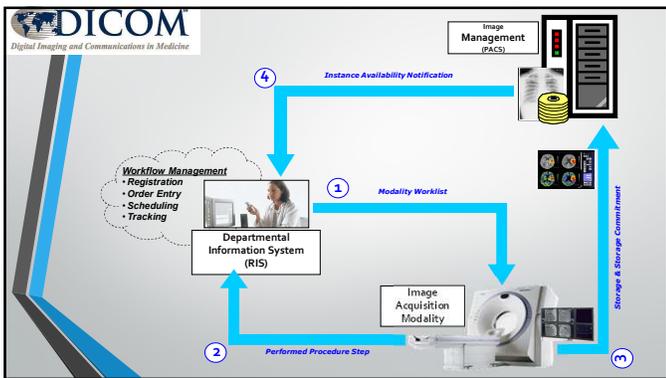
HIPAA

- Health Insurance Portability and Accountability Act of 1996 (HIPAA) Privacy Rule is to ensure you have rights over your own health information, no matter what form it is in.
- The government also created the HIPAA Security Rule to require specific protections to safeguard your electronic health information.
- Federal law requires doctors, hospitals, and other health care providers to notify you of a "breach."
- Facilities should implement high-grade security and encryption in their systems in order to protect records from hackers or theft
- Adhering to HIPAA guidelines often means subjecting software developments to a legal team who can determine whether or not the software falls within HIPAA regulations for security and confidentiality

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132



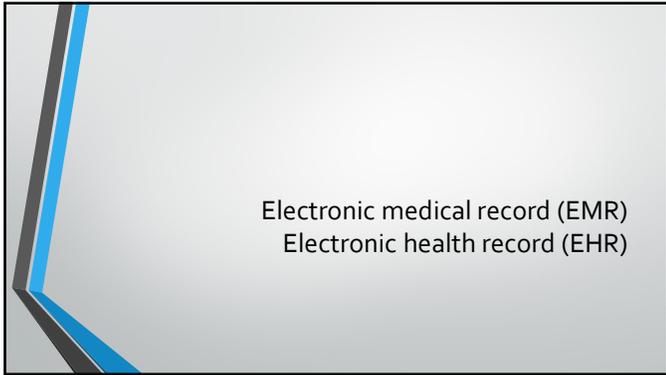
133

DICOM Services for Acquisition Workflow Management

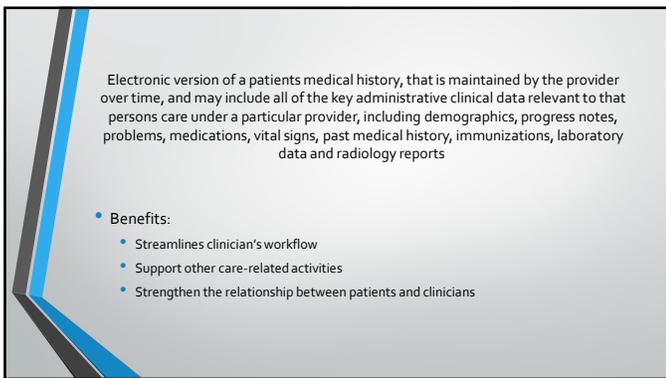
- Improve Interoperability of Imaging Equipment
- Ensure Data Consistency
- Facilitate Reliable Data Management
- Improve Process Efficiency
- Better Quality of Imaging Services



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135



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137

- Any system which allows remote transmission and viewing of radiographic images via modems over phone or cable lines
- Makes it possible for images to be sent great distances for a specialist to collaborate with a radiologist, and for images stored at a hospital to be accessed almost instantly by doctors at their individual clinics
 - Example: transmit images to radiologist's home during off hours



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1



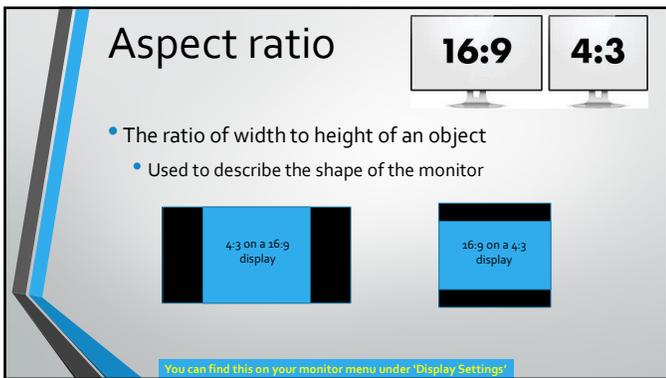
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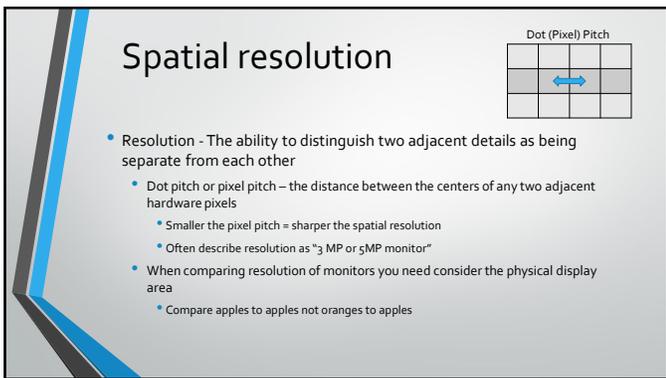
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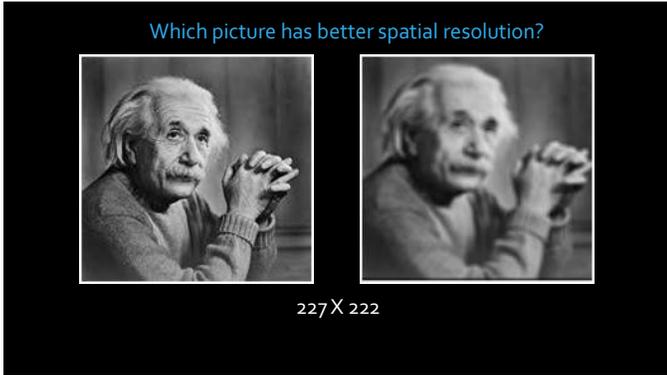
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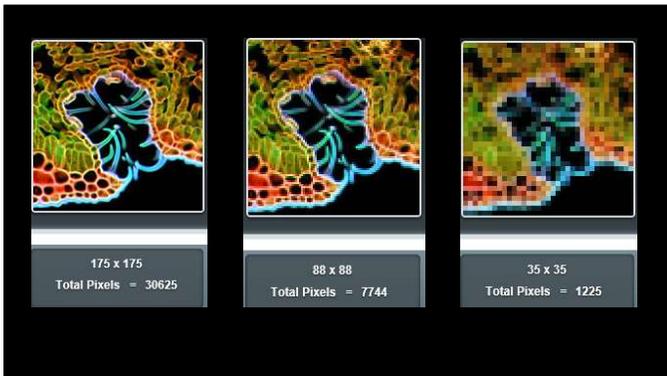
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6



7



8



9

Brightness

- The black level of a display screen. Although it may sound peculiar, the brightness adjusts the "black level" of the display system (how black the black is) –*Computer Desktop Encyclopedia*
- Photometer is used to measure the brightness output of an LCD
- American College of Radiology (ACR) requires a minimum brightness capability for radiologic display systems of 250 lumens

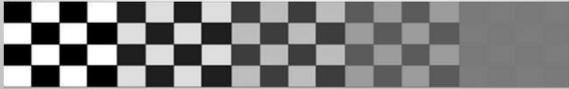


Too dark Good brightness Too bright

10

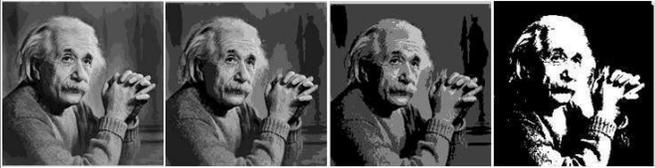
Contrast Ratio

- The difference between the darkest blacks and the brightest whites a given display can produce.
- Contrast ratio for LCD = 600:1, CRT = 3000:1
 - LCD - Inability to produce a "true black" due to backlight leakage



100% Contrast 75% Contrast 50% Contrast 25% Contrast 1% Contrast

12

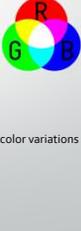


16 Gray Levels 8 Gray Levels 4 Gray Levels 2 Gray Levels

13

Color vs. Grayscale (monochrome)

- **Monochrome monitors**
 - Color images will appear as shades of gray
 - Has only one phosphor of color, but may have the ability to change the brightness causing the illusion of depth
 - Produces sharper text and image because 1 phosphor per pixel than color
- **Color monitors**
 - Monochrome images can be viewed on color monitors
 - Uses alternating intensities of red, green and blue to produce the different color variations
 - Uses 3 phosphors per pixel



15

What color would be seen in a color monitor?

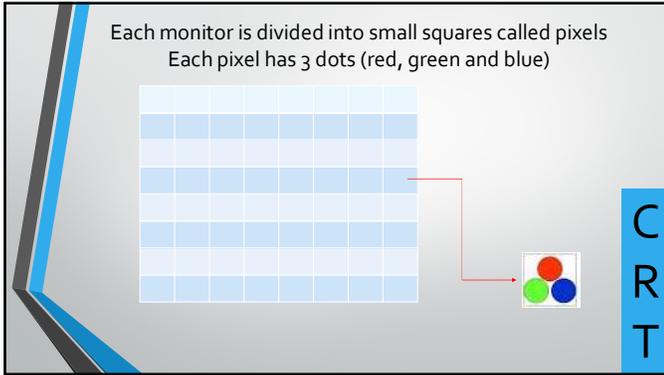
- If all 3 colors set at 0 = **BLACK**
- If all 3 colors set at 255 = **WHITE**
- If red was set at 255 and blue and green at 0 = **RED**

16

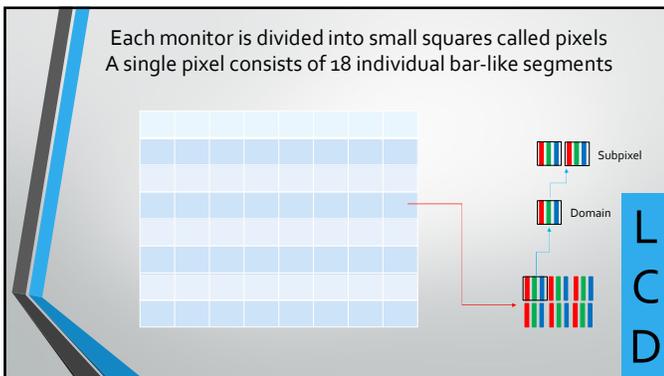
Pixels for Computers

- Pixel – multiple definitions
 - Carroll states it is “the smallest element of the matrix or device that can represent all pixel values within the system’s dynamic range”
- CRT – each triad of color (red, blue, and green) is considered one pixel
- LCD – a single pixel consists of 18 individual bar-like segments
- Hardware pixel in monitor – intersections of flat, transparent wires crossing over each other to form an overall square shape

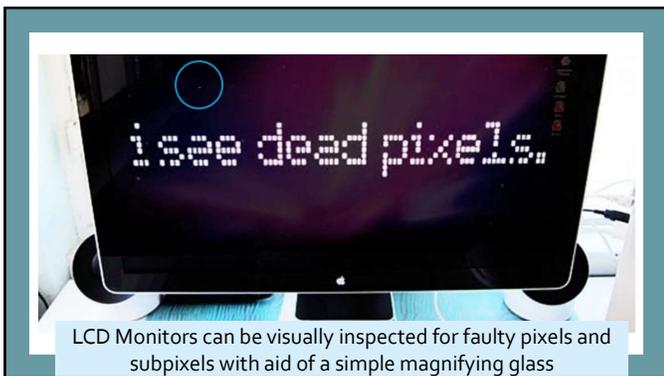
18



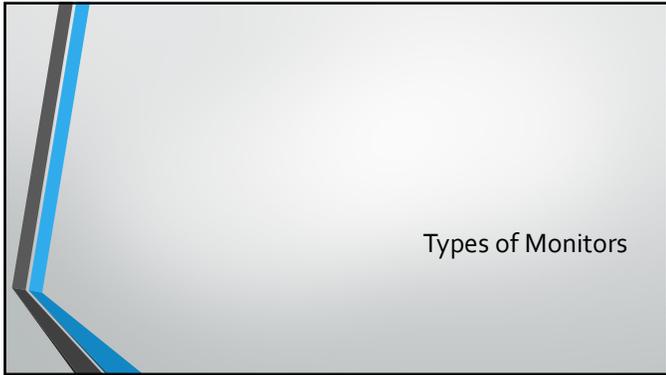
19



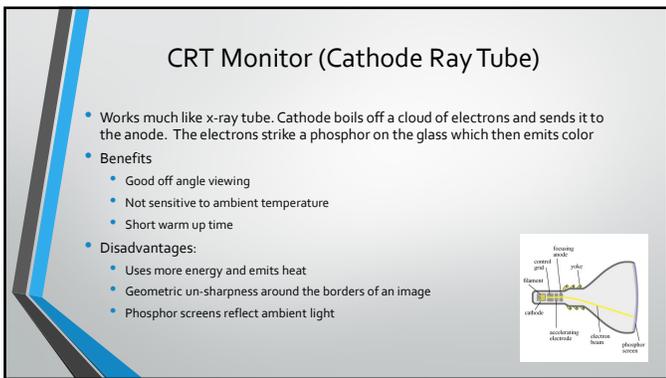
20



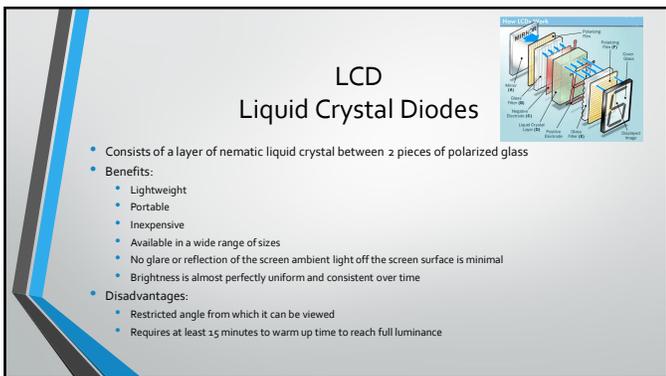
21



23



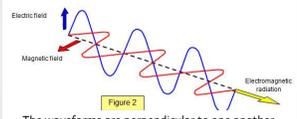
24



25

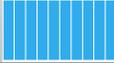
To understand the LCD monitor you must comprehend Light Polarization

- Like an x-ray, a ray of light is electromagnetic radiation that consists of a double wave

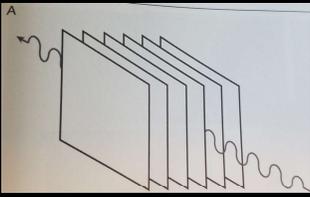


The waveforms are perpendicular to one another

- LCD Monitors use polarized glass
 - Polarized glass contains long chains of iodine molecules, all aligned parallel to each other
 - Just like a grid strips in a grid

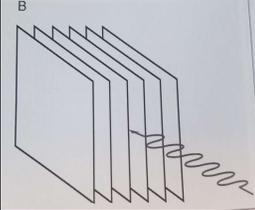


26



Electrical

The electrical component of the double wave can pass through a polarized glass with vertical string molecules because it vibrates parallel to it

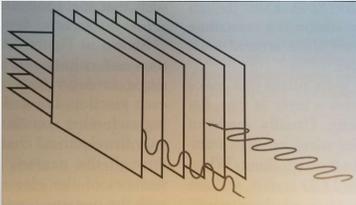


Magnetic

The magnetic component of the double wave cannot pass through a polarized glass with vertical string molecules because it vibrates perpendicular to it

27

What will happen if you layer 2 polarizing glass together so the string molecules are perpendicular to each other?



28

LCD – Light polarization

- LCD monitor consists of:
 - 2 thin sheets of glass
 - Each with a light polarizing layer that are perpendicular to the other sheet

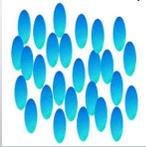
Perpendicular sheets = ALL light being blocked

Don't worry, the LCD process involves "tricking" these layers into allowing light to pass

29

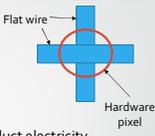
What are nematic liquid crystals?

- This is what is inserted between the polarizing glass sheets/lenses that plays the trick
- A crystalline arrangement of molecules that have a long linear shape and tend to align parallel to each other



30

Before we see the "trick", you need to know one more thing....



- In the polarizing glass there are a layer of thin, flat wires to conduct electricity
- These conductors are also aligned perpendicular to each other when the 2 polarized glass are together
- Each junction forms a single **hardware pixel**
 - Each electrode has a scratch on it
 - Scratches are perpendicular to one another
 - The crystals tend to line up with the "scratch" direction when no electric charge is present -- **known as "on" state**

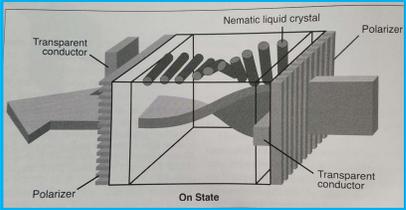
31

And **FINALLY**, Here is the Magic Trick.....



<https://www.youtube.com/watch?v=jiejNAUwcQ8>

32

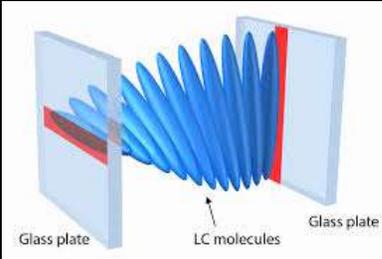


"ON" STATE

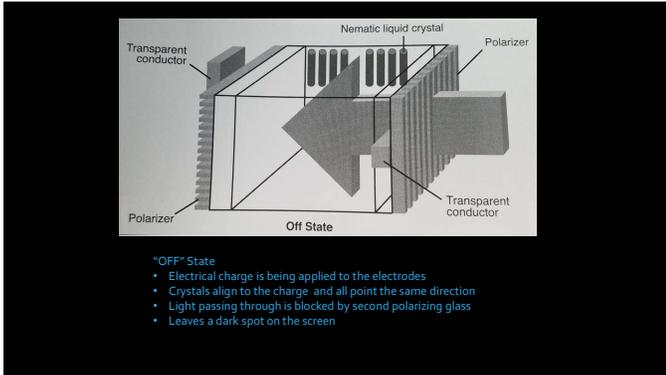
- Since the scratches are perpendicular, the liquid crystals line up in a spiral pattern that twists 90 degrees between the two glass plates
- This lets light waves pass through the nematic liquid crystal and follow the spiral
- Light is able to pass through the second glass plate to the viewer of the monitor

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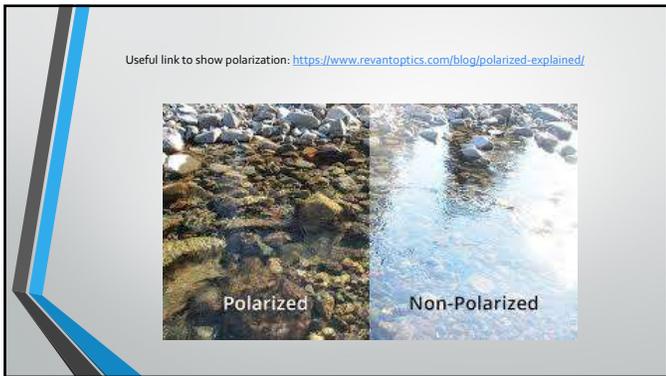
Just another way to look at it



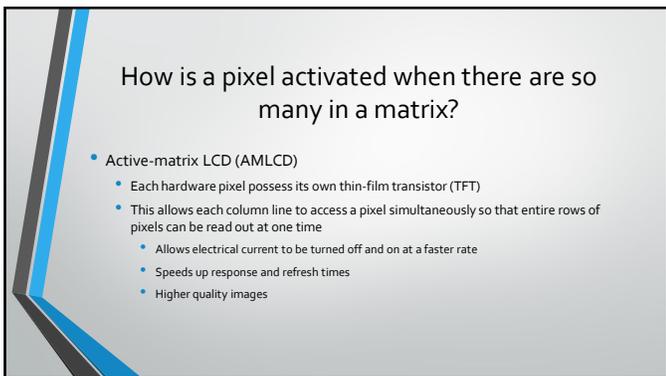
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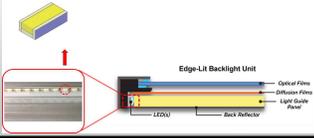
36



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More info on LCD Monitors

- As LCDs **do not** produce light by themselves—they need illumination to produce a visible image.
 - Without a **backlight**, an LCD display device will remain black, rendering it unviewable
- **Backlighting**
 - Types: Fluorescent bulbs or light-emitting diodes (LEDs)
 - LED - Most common



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Care and Maintenance

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CARE

1. Apply cleaning solution to soft cloth
 - Do not spray solution directly on screen
 - Do not use paper towel can cause scratches
2. Wipe in one direction from top of screen to bottom

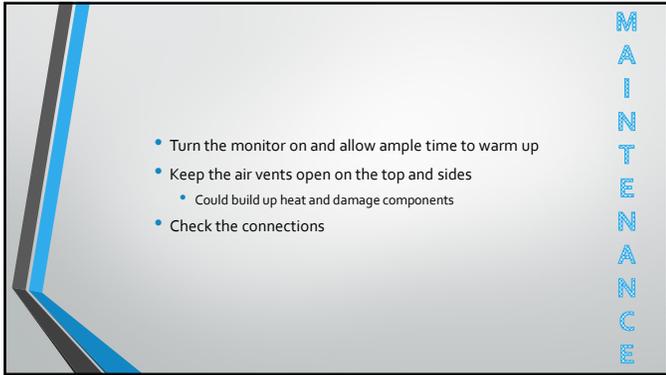
- The following cleaners should NOT be used: Acetone
 - Ethyl alcohol
 - Ethyl acid
 - Ammonia
 - Methyl chloride



- The following types of cleaners are acceptable: Water
 - Vinegar (mixed with water)
 - Isopropyl Alcohol
 - Petroleum Benzene



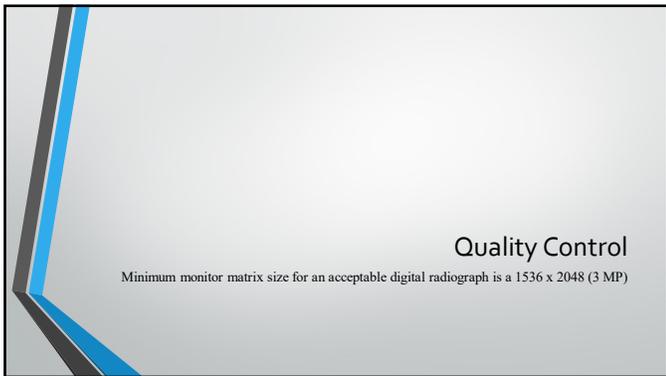
40



M-A-I-N-T-E-N-A-N-C-E

- Turn the monitor on and allow ample time to warm up
- Keep the air vents open on the top and sides
 - Could build up heat and damage components
- Check the connections

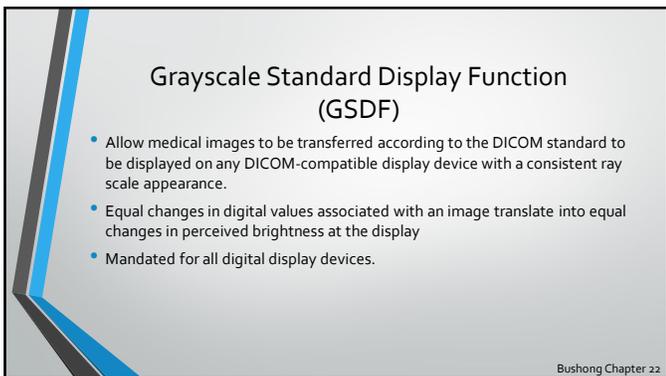
41



Quality Control

Minimum monitor matrix size for an acceptable digital radiograph is a 1536 x 2048 (3 MP)

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Grayscale Standard Display Function (GSDf)

- Allow medical images to be transferred according to the DICOM standard to be displayed on any DICOM-compatible display device with a consistent ray scale appearance.
- Equal changes in digital values associated with an image translate into equal changes in perceived brightness at the display
- Mandated for all digital display devices.

Bushong Chapter 22

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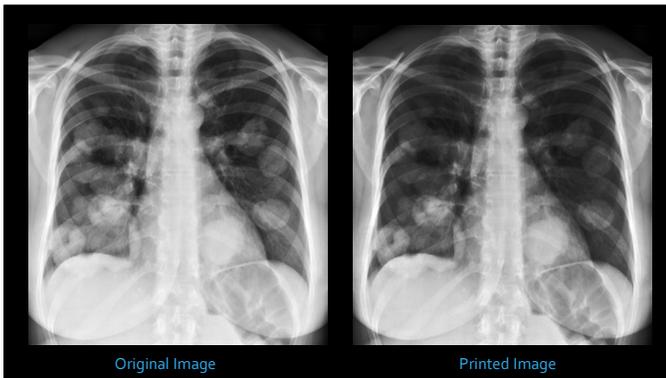
DICOM Grayscale Standard Display Function (GSDF) generates a display function matching the perceptual characteristics of a human observer.

Standard developed having human observer view monitor while luminance output of monitor changed in small steps from black to white and noting when they observed a **Just Noticeable Difference** (JND) in light output as the drive signal is changed.

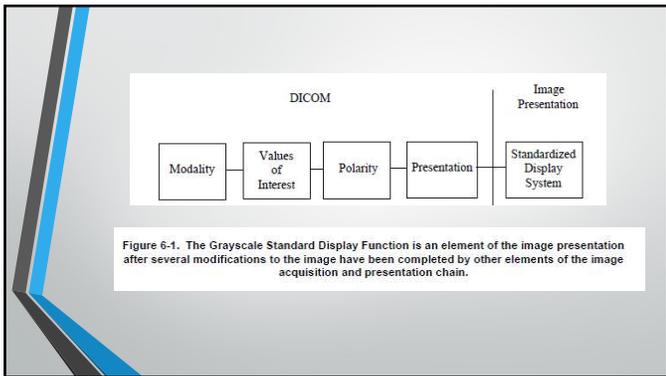
Most digital radiologic images are windowed to attempt to display 256 different shades of gray at any one time, (256 is approximate JND that humans can perceive)

The perceptual linearization implemented with the DICOM Grayscale Standard Display Function (GSDF) ensures that pixel values that are supposed to increase brightness in a linear fashion, say 6, 7, and 8, for example, actually appear that way to the human eye, despite the nonlinearity of our perception.

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45



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Luminance

The rate of light (brightness) emitted from a source such as an LCD monitor

- **Maximum luminance** (*maximum brightness*)- checked at same monitor setting over a period of time with a photometer
- **Luminance response** – monitors ability to accurately display different shades of brightness from a test pattern
- **Luminance ratio** – compares maximum luminance to the minimum luminance
- **Luminance uniformity** – consistency of a single brightness level displayed across the area of the screen

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Luminance Ratio

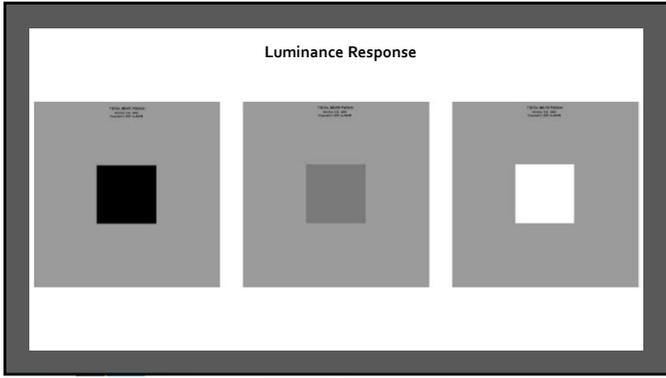
48

Luminance Response

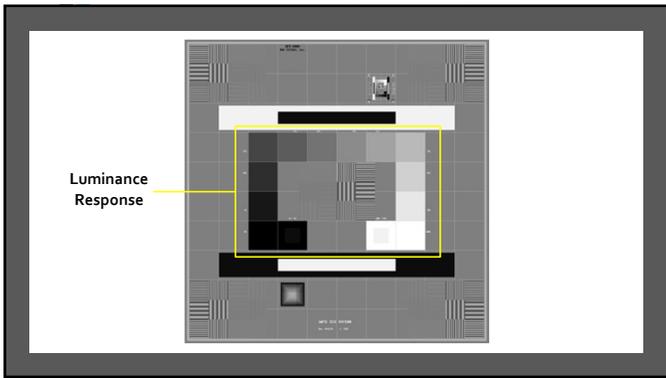
TDS-CT Pattern
Version 2.0, 10/11
Copyright © 2011 by Avance

A

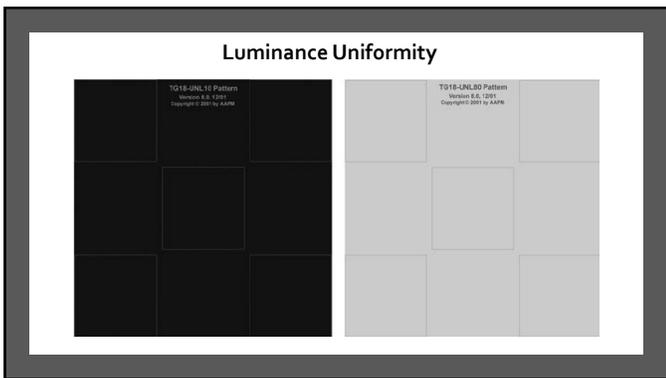
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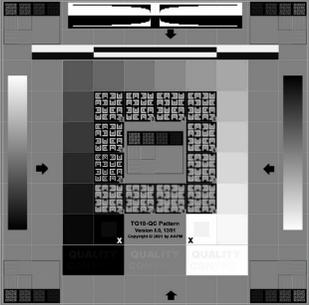
52

Resolution

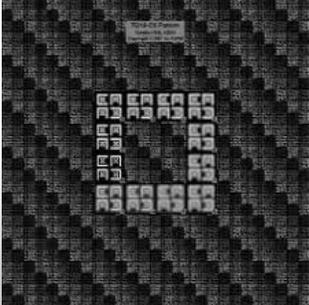
- ACR and AAPM minimum resolution for electronically displayed images of 2.5LP/mm
 - Generic SMPTE test pattern can be used
 - Check for blurring
- AAPM TG18 – QC and TG 18 CX provides an excellent check for resolution across the area of the display screen
 - Evaluate the CX pattern in the middle and in the corners
- Test can be done daily, weekly or monthly

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TG18 - QC

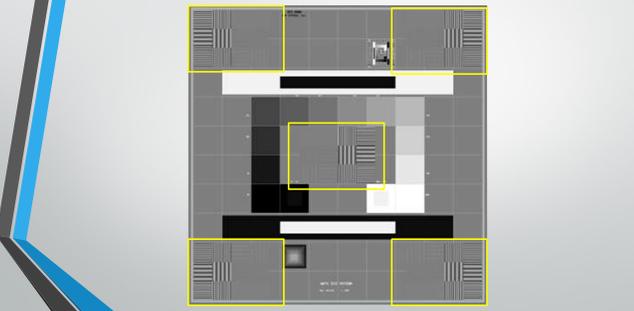


TG18 - CX

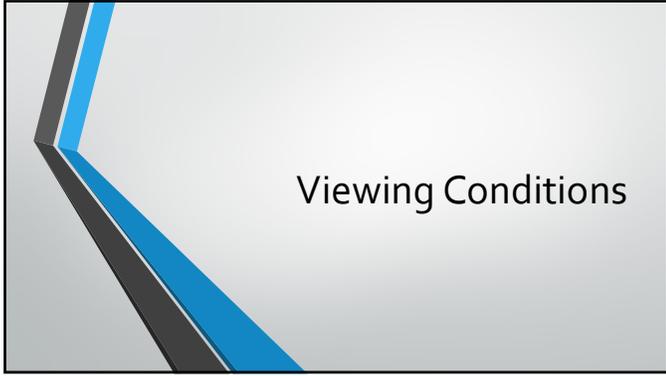


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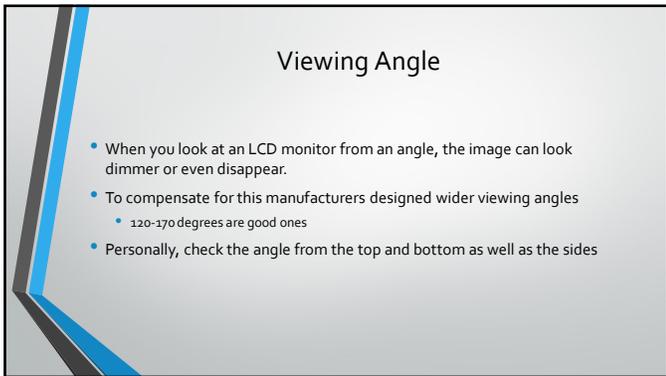
SMPTE



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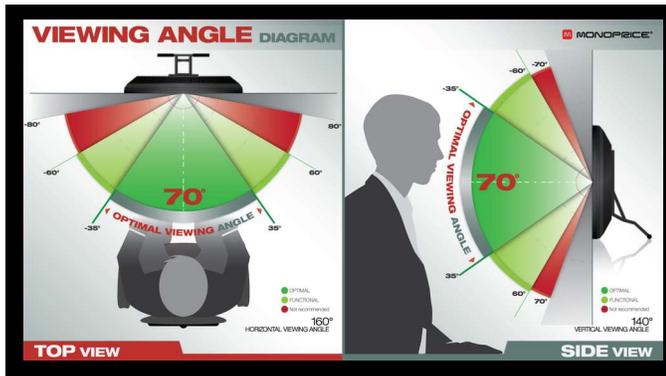
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60

Ambient Lighting

Illuminance – the rate of light striking a surface

- The effect of ambient room lighting on the surface of and LCD monitor screen, including **reflectance** off the screen, and the resulting reduction in visible contrast of the image, is a result of **illuminance**
- Diffuse reflectance
 - The cumulative effect of room lighting across the area of the monitor screen
- Specular reflectance
 - The reflection of actual light sources such as a light bulb or window

The ambient lighting within the room must be dimmed to a point where both types of reflectance are below any noticeable level, that would impede full visibility of the image and image contrast

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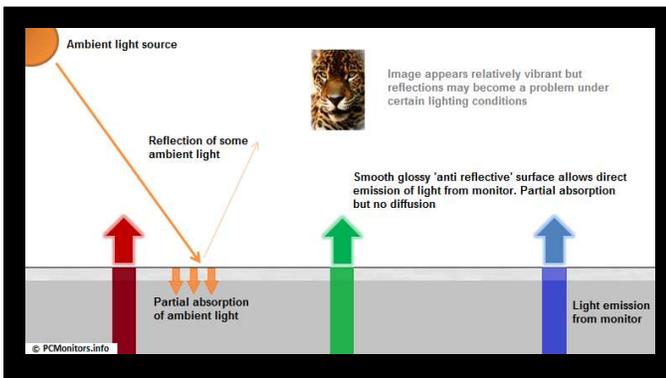
QC Aspect or Ambient Light

- While diagnosis is taking place, the maximum ambient lighting in a reading room should never be more than 25 lux
 - Approximately 1/4 the typical brightness of normal office lighting (75-100 lux)

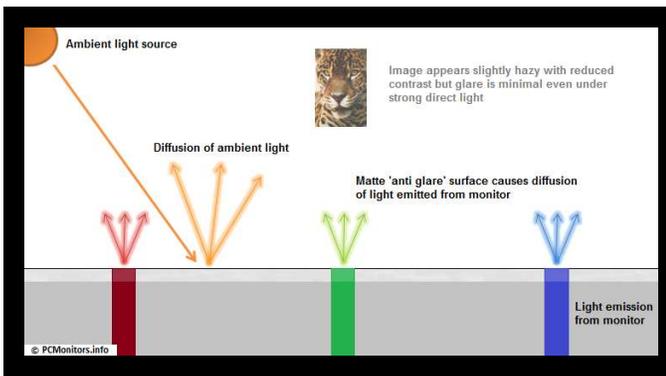
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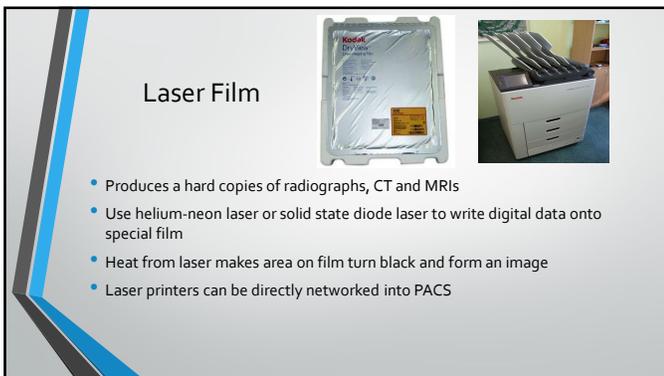
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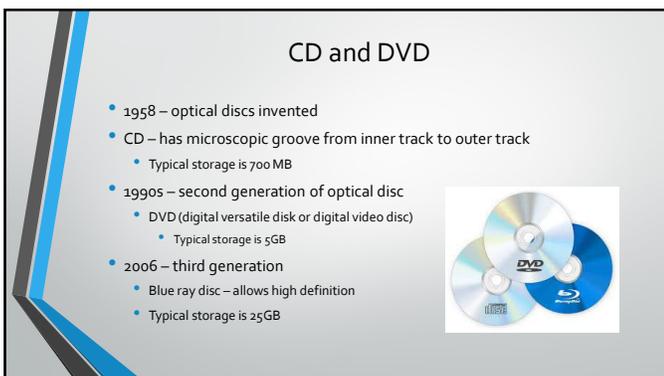
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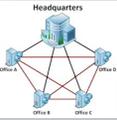
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Data Management

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Network Connectivity

- LAN – Local Area Network
 - Computerized communications network generally contained within a single building or business
 - Devices share one server
- WAN – Wide Area Network
 - Extends to other businesses or locations that may be at great distances
 - Publically or commercially owned
 - Uses transmission services provided by common carriers (phone or cable companies)



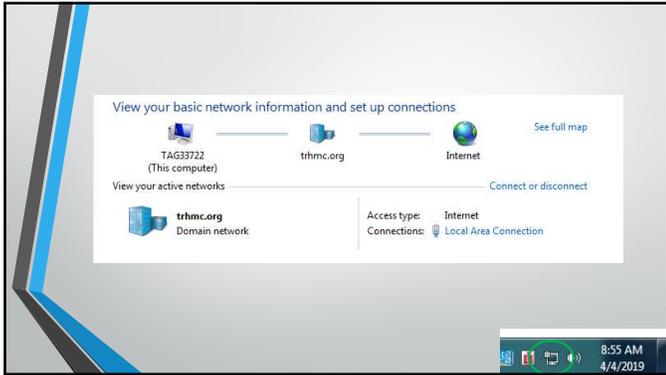
76

Computer Network

- Every computer within a network has a unique internet protocol or IP address
 - Ex. 172.811.3.1
- Every computer must have a network interface card
- Router
 - Connects 2 or more networks
 - Wireless routers – allow "point-of-care" access to a network for physicians and other caregivers via tablet or laptop



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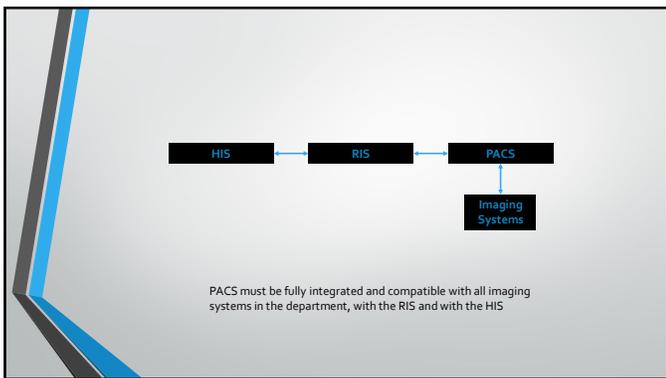
78

Type of LAN

RIS and HIS

- Radiology Information System
 - Data system for patient-related functions in the department, such as scheduling of x-ray appointments, tracking of patients, storage and distribution of reports
 - Makes info accessible from different locations within the radiology department
 - Assigns the **accession number**
- Hospital/Health Information System
 - Performs same functions for the entire institution (patient's general medical file)
 - Assigns a unique identifying number for each patient (**MRN**)

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Picture Archiving and Communications System (PACS)

- Comprehensive computer network that is responsible for the electronic storage and distribution of medical images.
- Makes radiographs, CT and MRI scans, US and Nuclear Med images for a particular patient available within the network
- Allows Radiologists and Technologist to access these images from various locations, improving the efficiency of communication

Soon to be Called....
Medical image management and processing system (MIMPS)

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PACS

- Digital acquisition (Picture)
- Display workstations
- Storage devices (Archiving)
- Components are interconnected by a network (Communication)

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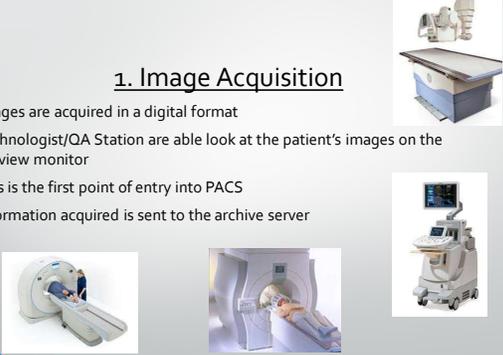
Components of PACS

- Image acquisition
- Display workstations
- Archive servers

83

1. Image Acquisition

- Images are acquired in a digital format
- Technologist/OA Station are able look at the patient's images on the preview monitor
- This is the first point of entry into PACS
- Information acquired is sent to the archive server



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2. Display Workstations

Any computer used to view digital images

- Radiologists
- Physicians, surgeons, nurses & patients
- Technologists

- Most interactive part of PACS
- Used inside and out of Radiology
- Has PACS application software that allows minor image-manipulation

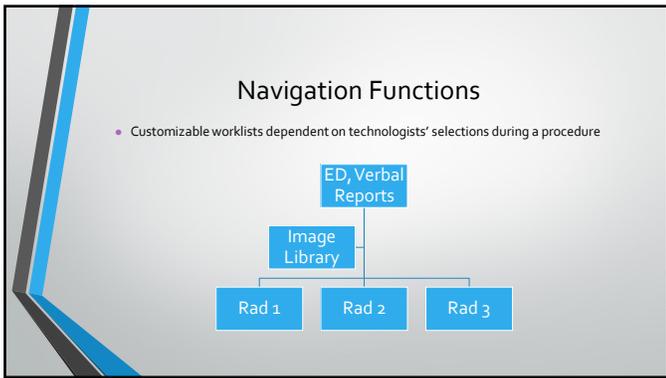


85

Common Workstation Functions

- Navigation Functions
- Hanging Protocol
- Study Navigation
- Image Manipulation & Enhancement
- Image Management

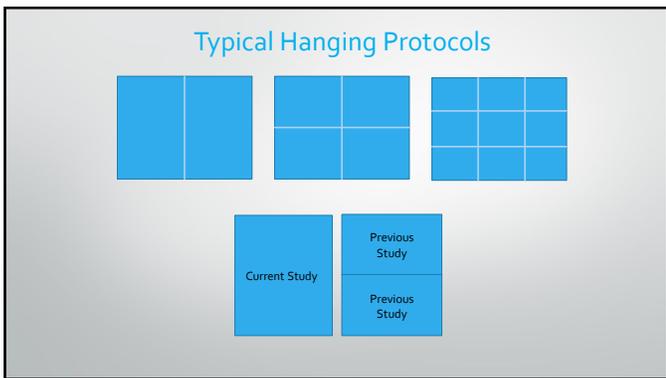
86



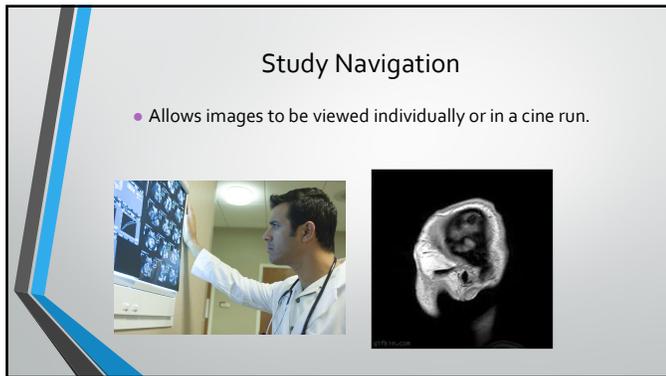
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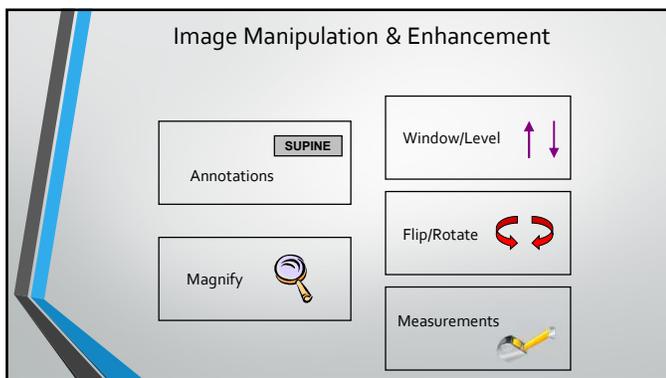
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89



90



91



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Image Management Functions

- Patient demographics
 - Edit patient information for proper correlation with previous studies, billing, etc.
- Query / Retrieve
 - Locate images based on patient demographics
- Hardcopy images
 - Either CD or plain film
 - Usually only image library has this function

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3. Archive Servers

- File room of PACS
- Contains all historic and current data



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PACS Archiving

- Consist of:
 - Image manager/controller
 - Image storage/server



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Image Manager

- Contains master database of everything in the archive
- Controls the receipt, retrieval and distribution of the images it stores
- Controls all the DICOM processes running within the archive
- Communicates with RIS and HIS
- Can populate image information into the EMR

MANAGER

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Image Storage/Archive Server

- Physical storage device for archive system
- Network of servers
- Setup in tiers
 - Short-term
 - Long-term

In the United States, storage requirement of a patient's images is from five to seven years.

98

Short Term Storage

- RAID
 - several magnetic disks or hard drives that are linked together in an array

RAID 5 is the most common level used for a PACS archive because it provides adequate redundancy and fault tolerance

99

Reading Hospital

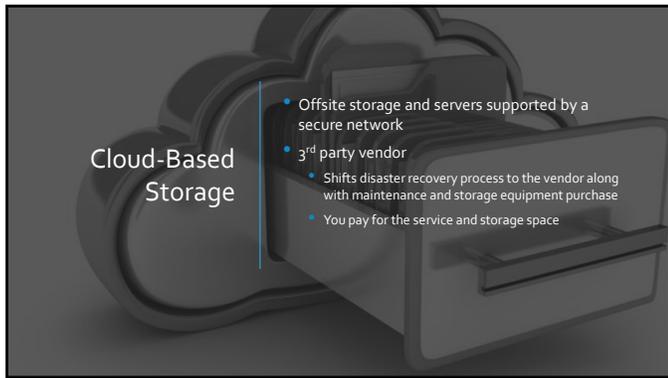
- Short-term storage is done on servers located in IMS but maintained by Philips
 - Philips monitors the system through remote access
 - All backups and drive redundancy are handled by Philips

100

Long Term Storage

- RAID
- Optical disk
- Tape
- Magnetic disk

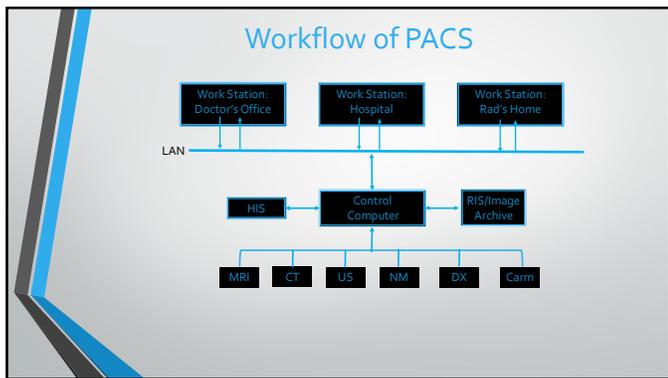
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103



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Summary of PACS Functions

- Main function: Act as a *database*
 - Generate and sort according to status (i.e. pending, completed)
 - Various queries – users can search for specific information
- Manipulation – at any workstation
- Storage

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Vendor Neutral Archives (VNA)

- Allows for images and data from different systems and in different formats to be stored using a singular system on a common infrastructure
- May be used as replacements to existing PACS to avoid very expensive transition costs
- Used to consolidate a number of systems that exist within a single facility or across a system of facilities

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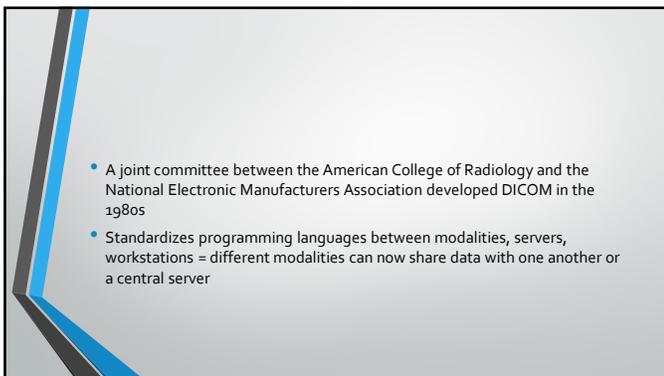
PACS Emergency Contingency Plan

- A backup copy of ALL archived records should be maintained either by the hospital or an Application Service Provider
- RH PACS Downtime Procedure Policy - <https://trh.elucid.com/documents/view/12114/33066/3>

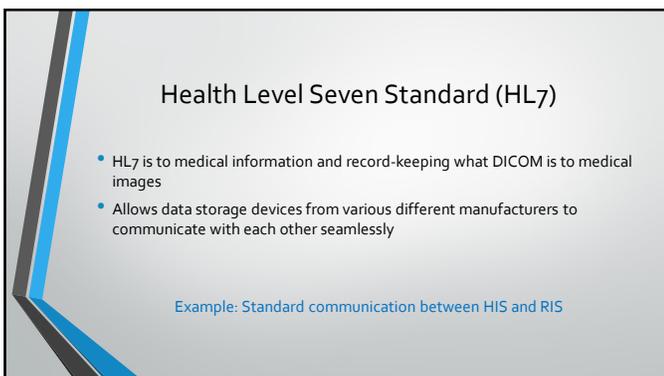
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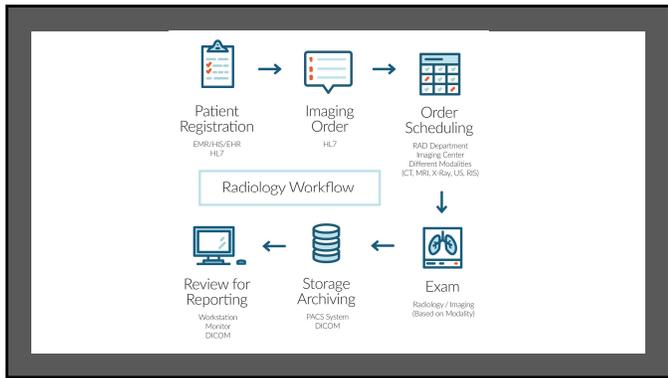
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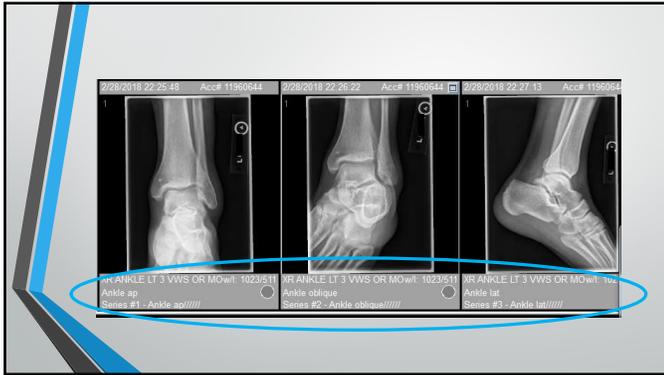
DICOM Header

- A summary of critical identification and study information such as:
 - Date and time of procedure
 - Number of images taken
 - Body part, position
 - Technique used
 - Image format and receptor size
 - Parameters used to digitally process the image
- All this information is stored as **metadata**
 - Should appear in a bar at the top of the screen for each image
 - Shows summary of essential metadata for the image

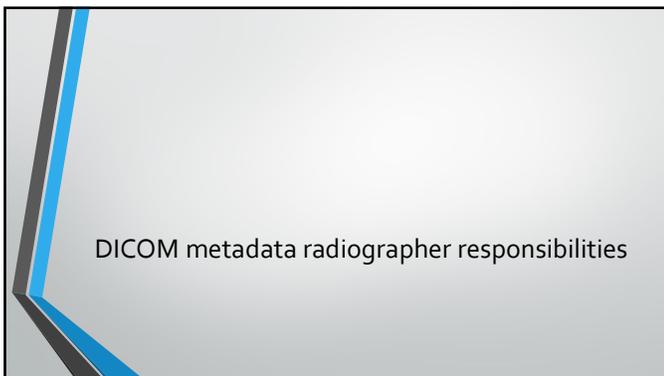
115

Group Tag	Element Tag	Tag Description	Value
0010	0011	Private Tag	MURKIN
0010	0020	Patient ID	12345
0010	0030	Patient's Birth Date	00000000
0010	0040	Patient's Sex	M
0010	1030	Patient's Weight	0
0010	2165	Private Tag	None
0010	2166	Private Tag	None
0010	4000	Patient Comments	
0018	0015	Body Part Examined	THORAX
0018	1000	Device Serial Number	00000000
0018	1020	Software Version(s)	1.0.1.120
0018	1164	Image Field Source	0.16
0018	1508	Positioner Type	COLLIMIN
0018	5100	Patient Position	ANTERIOR - POSTERIOR
0018	7004	Detector Type	DIRECT
0018	7006	Detector Description	
0018	7014	Detector Serial	1.1.1
0020	0020	Study Instance UID	1.2.825.0.1.3680043.2.1330.1000001.1.2213256752.2712337879
0020	000E	Series Instance UID	1.2.825.0.1.3680043.2.1330.1000001.4.2213256752.27123318877
0020	0010	Study ID	None
0020	0011	Series Number	1
0020	0019	Instance Number	29
0020	0020	Patient Orientation	N
0020	0060	Laterality	L
0020	0062	Private Tag	U
0020	4000	Image Comments	
0028	0002	Samples per Pixel	1

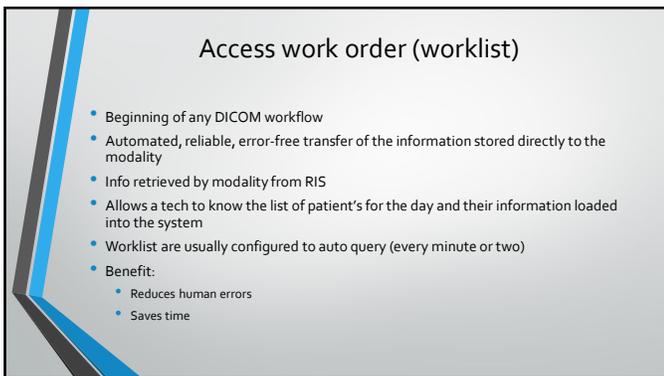
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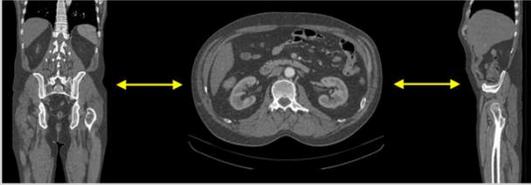
Post Processing – Image operation and manipulation

- Image operation activities
- Multiplanar Reconstruction
- Maximum and Minimum Intensity Projection
- Volume Rendering Technique (VRT)
- Shaded Surface Display (3D technology)
- CAD

120

Multiplanar Reconstruction

- Creates multiple planes of view from a single scan



<https://www.youtube.com/watch?v=H1nPMSVijag>

121

Maximum & Minimum Intensity Projections

- Enhancement of small vessels (MIP) and air-filled structures (MinIP)

MinIP – Minimum Intensity Projections

MIP – Maximum Intensity Projections



MinIP AIP MIP

122

Volume Rendering Technique (VRT)

- Assists in differentiating between anatomical structures by adding color shades based on pixel intensity



123

Shaded Surface Display (SSD)

- Creates a 3D, moveable image based on the pixel intensity of choice



124

CAD (Computer Aided Diagnosis/Detection)

- used as a "second opinion" in assisting radiologists' image interpretations
 - complementary tools that draw the radiologists' attention to certain image areas that need further evaluation
- Uses algorithms
- Used in Mammography at RH



Source: Appl Radiol © 2004 Anderson Publishing, Ltd

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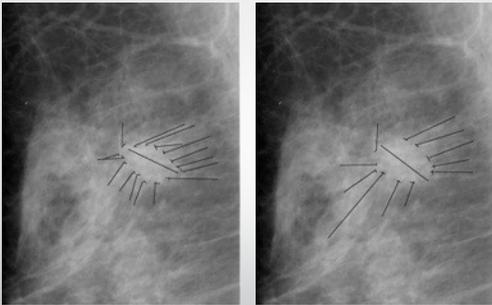
Annotation Issues: Annotations and Mark Ups

- *Image annotation* – describes the meaning in images
- *Image markup* – visual presentation of the annotation
- AIM Project (Annotation and Image Mark up project)
 - The model contains information about who created the annotation, the equipment with which the annotation was created, when the annotation was created, and the image(s) to which the annotation refers.
 - Once the annotation is defined in the AIM, sophisticated queries are now easily found
 - "Find all studies that contain enhancing right middle lobe lung masses that measure between 5 and 6 cm"

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- Other concerns are
 - What is more accurate tool to use --- stylus or mouse for marking or measurements?
 - Human error
 - Legal issues

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Mouse Stylus

128

Case number	Annotation time for mouse (s)	Annotation time for stylus (s)
1	109	86
2	121	71
3	108	70
4	78	74
5	109	91
6	55	57
7	78	77
8	90	54
9	113	60
10	89	85
11	101	98
12	81	41

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Image Transmission

- Concerns of medical data overload
 - CT may produce 300 to 500 images and a CT angiography runoff study may include 1,500 to 2,000 images
- In teleradiology, the header of the DICOM image is first transmitted followed by the compressed image data and then at the receiving end, images are reconstructed from low quality to high (or perfect) quality
- Facilities will compress images to send, this allow it to be sent more efficiently
 - Lossless compression have been defined as "visually acceptable" images by the medical imaging community

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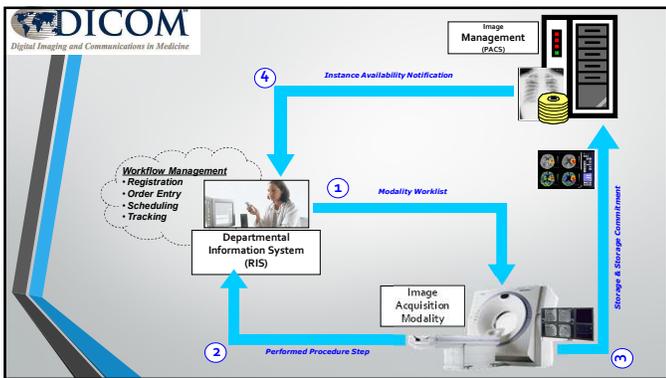
HIPAA

- Health Insurance Portability and Accountability Act of 1996 (HIPAA) Privacy Rule is to ensure you have rights over your own health information, no matter what form it is in.
- The government also created the HIPAA Security Rule to require specific protections to safeguard your electronic health information.
- Federal law requires doctors, hospitals, and other health care providers to notify you of a "breach."
- Facilities should implement high-grade security and encryption in their systems in order to protect records from hackers or theft
- Adhering to HIPAA guidelines often means subjecting software developments to a legal team who can determine whether or not the software falls within HIPAA regulations for security and confidentiality

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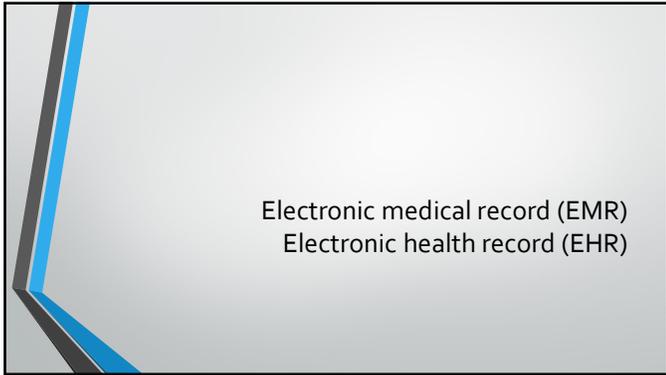
133

DICOM Services for Acquisition Workflow Management

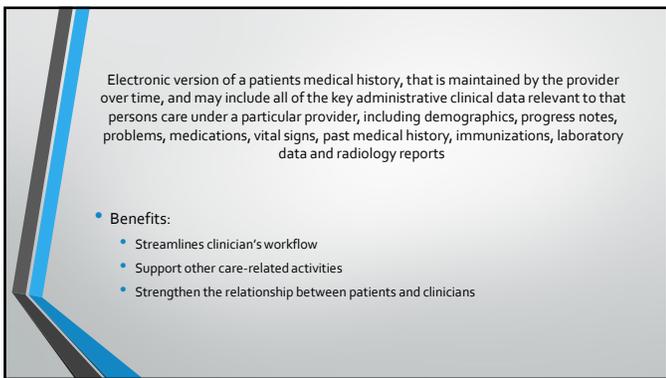
- Improve Interoperability of Imaging Equipment
- Ensure Data Consistency
- Facilitate Reliable Data Management
- Improve Process Efficiency
- Better Quality of Imaging Services

DICOM
Digital Imaging and Communications in Medicine

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135



136



137

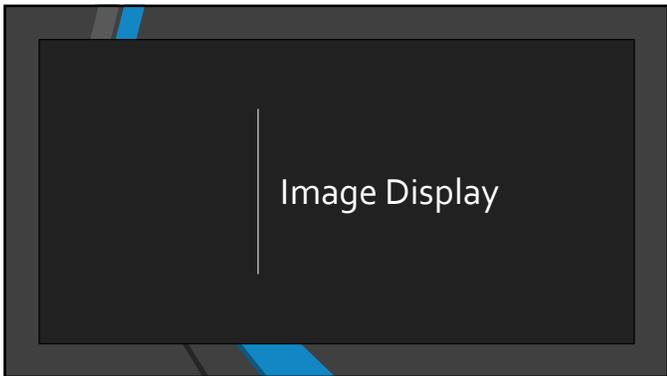
- Any system which allows remote transmission and viewing of radiographic images via modems over phone or cable lines
- Makes it possible for images to be sent great distances for a specialist to collaborate with a radiologist, and for images stored at a hospital to be accessed almost instantly by doctors at their individual clinics
 - Example: transmit images to radiologist's home during off hours



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1



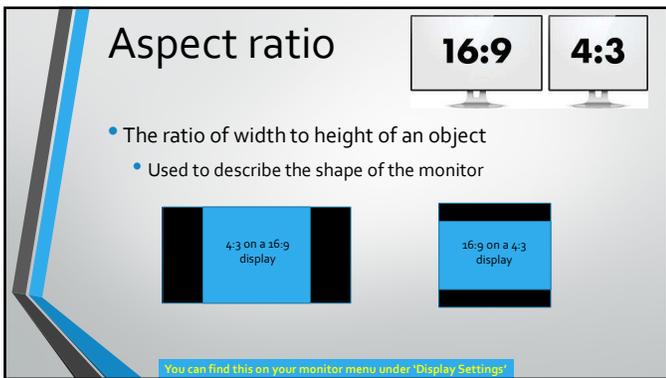
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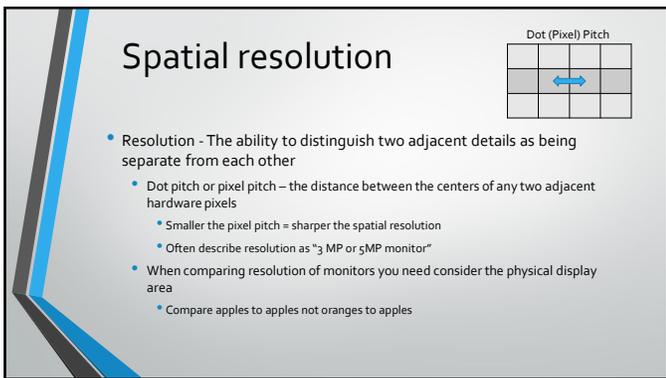
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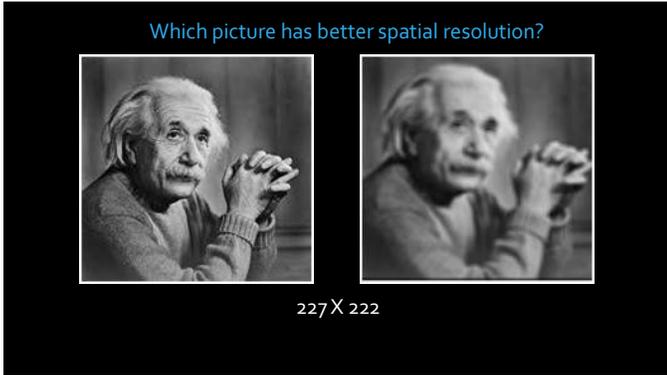
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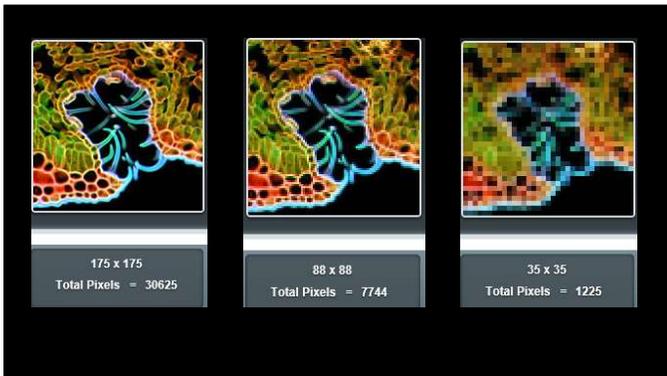
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7



8



9

Brightness

- The black level of a display screen. Although it may sound peculiar, the brightness adjusts the "black level" of the display system (how black the black is) –*Computer Desktop Encyclopedia*
- Photometer is used to measure the brightness output of an LCD
- American College of Radiology (ACR) requires a minimum brightness capability for radiologic display systems of 250 lumens



Too dark Good brightness Too bright

10

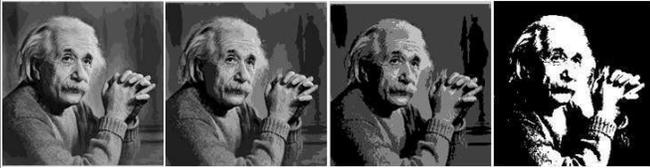
Contrast Ratio

- The difference between the darkest blacks and the brightest whites a given display can produce.
- Contrast ratio for LCD = 600:1, CRT = 3000:1
 - LCD - Inability to produce a "true black" due to backlight leakage



100% Contrast 75% Contrast 50% Contrast 25% Contrast 1% Contrast

12

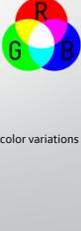


16 Gray Levels 8 Gray Levels 4 Gray Levels 2 Gray Levels

13

Color vs. Grayscale (monochrome)

- **Monochrome monitors**
 - Color images will appear as shades of gray
 - Has only one phosphor of color, but may have the ability to change the brightness causing the illusion of depth
 - Produces sharper text and image because 1 phosphor per pixel than color
- **Color monitors**
 - Monochrome images can be viewed on color monitors
 - Uses alternating intensities of red, green and blue to produce the different color variations
 - Uses 3 phosphors per pixel



15

What color would be seen in a color monitor?

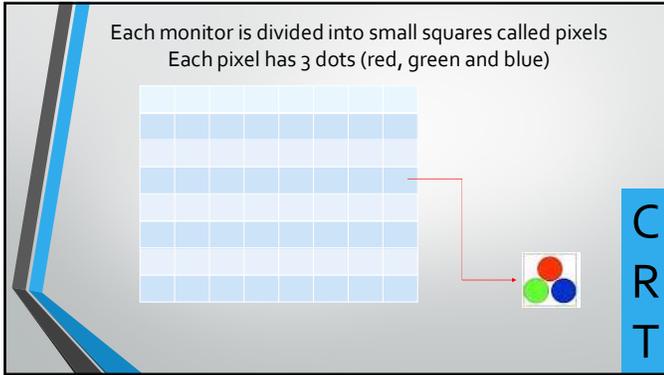
- If all 3 colors set at 0 = **BLACK**
- If all 3 colors set at 255 = **WHITE**
- If red was set at 255 and blue and green at 0 = **RED**

16

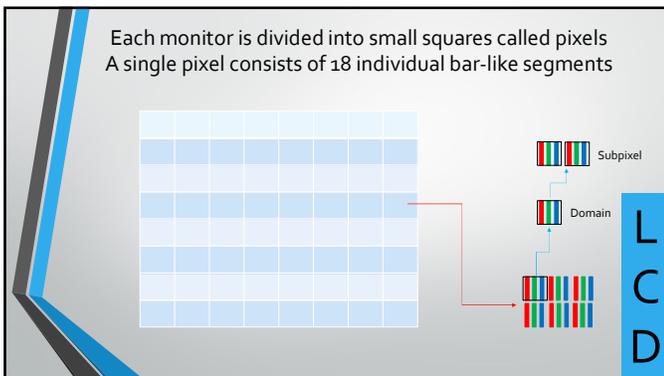
Pixels for Computers

- Pixel – multiple definitions
 - Carroll states it is “the smallest element of the matrix or device that can represent all pixel values within the system’s dynamic range”
- CRT – each triad of color (red, blue, and green) is considered one pixel
- LCD – a single pixel consists of 18 individual bar-like segments
- Hardware pixel in monitor – intersections of flat, transparent wires crossing over each other to form an overall square shape

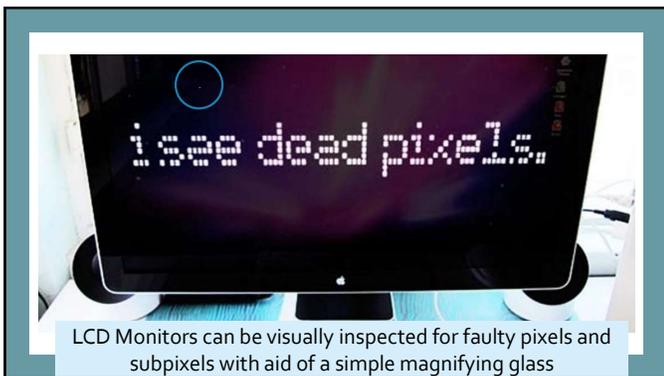
18



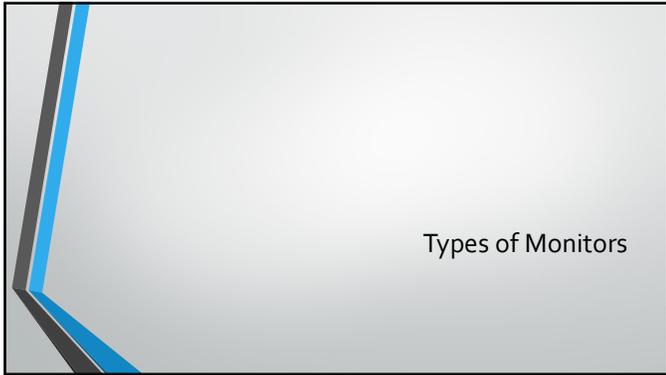
19



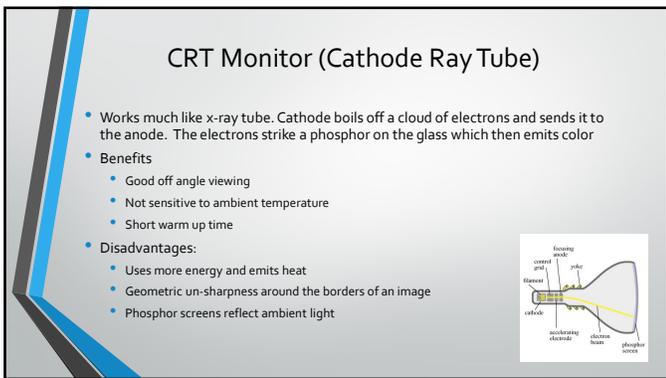
20



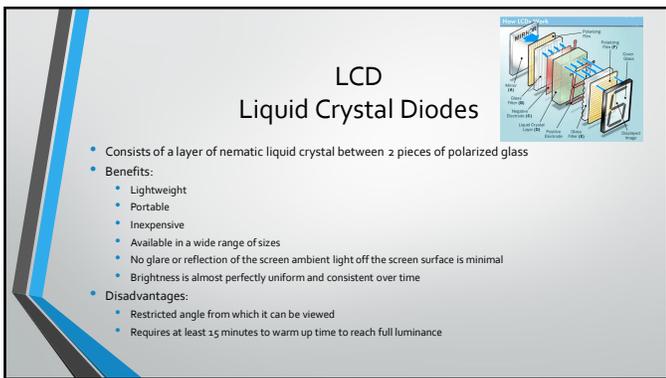
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23



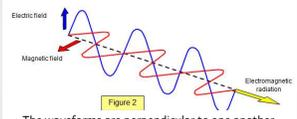
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25

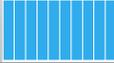
To understand the LCD monitor you must comprehend Light Polarization

- Like an x-ray, a ray of light is electromagnetic radiation that consists of a double wave

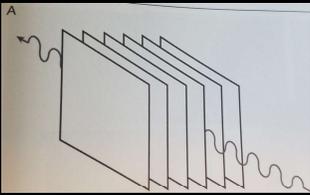


The waveforms are perpendicular to one another

- LCD Monitors use polarized glass
 - Polarized glass contains long chains of iodine molecules, all aligned parallel to each other
 - Just like a grid strips in a grid

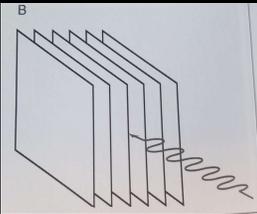


26



Electrical

The electrical component of the double wave can pass through a polarized glass with vertical string molecules because it vibrates parallel to it

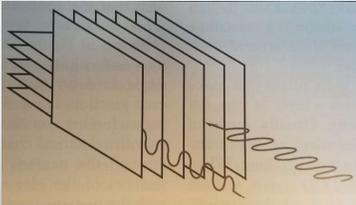


Magnetic

The magnetic component of the double wave cannot pass through a polarized glass with vertical string molecules because it vibrates perpendicular to it

27

What will happen if you layer 2 polarizing glass together so the string molecules are perpendicular to each other?



28

LCD – Light polarization

- LCD monitor consists of:
 - 2 thin sheets of glass
 - Each with a light polarizing layer that are perpendicular to the other sheet

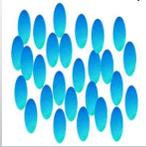
Perpendicular sheets = ALL light being blocked

Don't worry, the LCD process involves "tricking" these layers into allowing light to pass

29

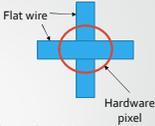
What are nematic liquid crystals?

- This is what is inserted between the polarizing glass sheets/lenses that plays the trick
- A crystalline arrangement of molecules that have a long linear shape and tend to align parallel to each other



30

Before we see the "trick", you need to know one more thing....



- In the polarizing glass there are a layer of thin, flat wires to conduct electricity
- These conductors are also aligned perpendicular to each other when the 2 polarized glass are together
- Each junction forms a single **hardware pixel**
 - Each electrode has a scratch on it
 - Scratches are perpendicular to one another
 - The crystals tend to line up with the "scratch" direction when no electric charge is present -- **known as "on" state**

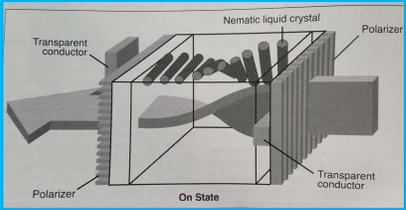
31

And **FINALLY**, Here is the Magic Trick.....



<https://www.youtube.com/watch?v=jiejNAUwcQ8>

32

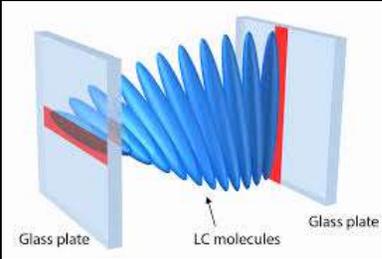


"ON" STATE

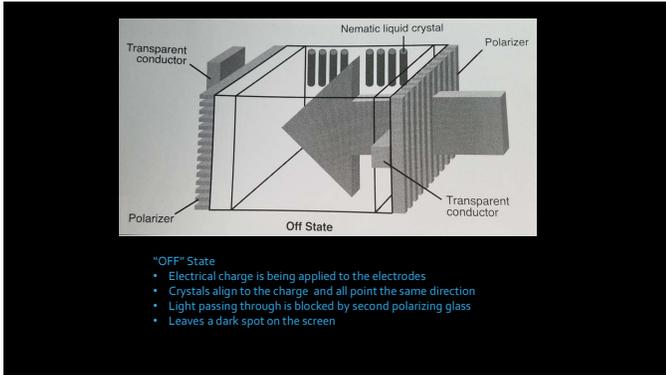
- Since the scratches are perpendicular, the liquid crystals line up in a spiral pattern that twists 90 degrees between the two glass plates
- This lets light waves pass through the nematic liquid crystal and follow the spiral
- Light is able to pass through the second glass plate to the viewer of the monitor

33

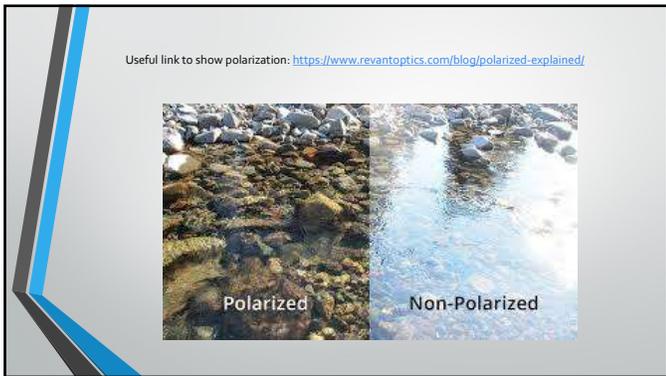
Just another way to look at it



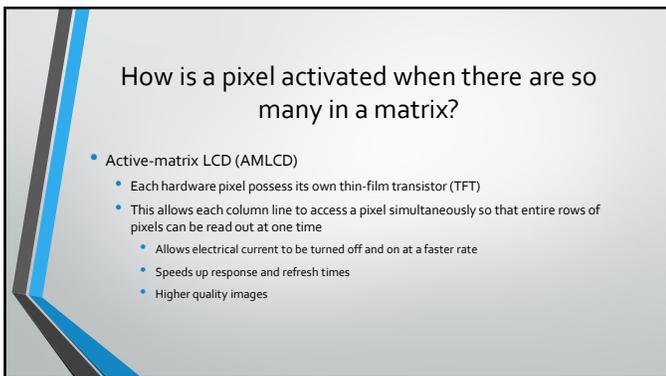
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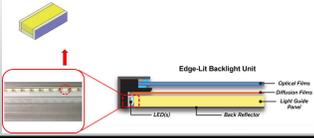
36



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More info on LCD Monitors

- As LCDs **do not** produce light by themselves—they need illumination to produce a visible image.
 - Without a **backlight**, an LCD display device will remain black, rendering it unviewable
- **Backlighting**
 - Types: Fluorescent bulbs or light-emitting diodes (LEDs)
 - LED - Most common



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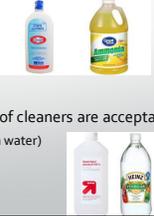
Care and Maintenance

39

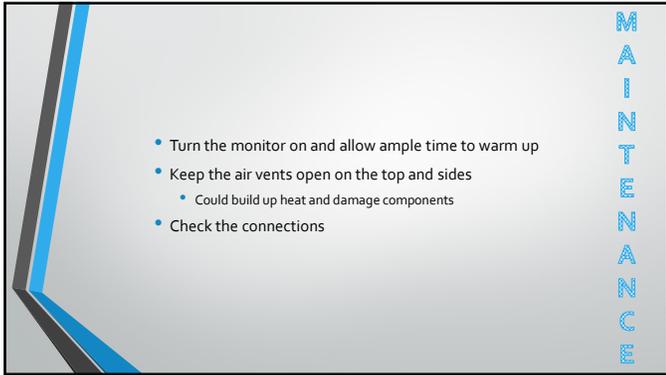
CARE

1. Apply cleaning solution to soft cloth
 - Do not spray solution directly on screen
 - Do not use paper towel can cause scratches
2. Wipe in one direction from top of screen to bottom

- The following cleaners should NOT be used: Acetone
 - Ethyl alcohol
 - Ethyl acid
 - Ammonia
 - Methyl chloride
- The following types of cleaners are acceptable: Water
 - Vinegar (mixed with water)
 - Isopropyl Alcohol
 - Petroleum Benzene



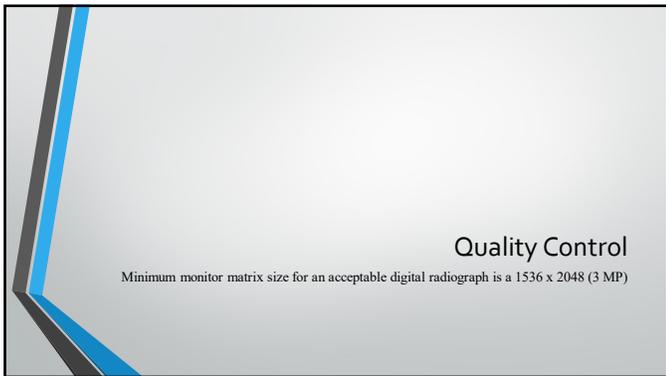
40



M-A-I-N-T-E-N-A-N-C-E

- Turn the monitor on and allow ample time to warm up
- Keep the air vents open on the top and sides
 - Could build up heat and damage components
- Check the connections

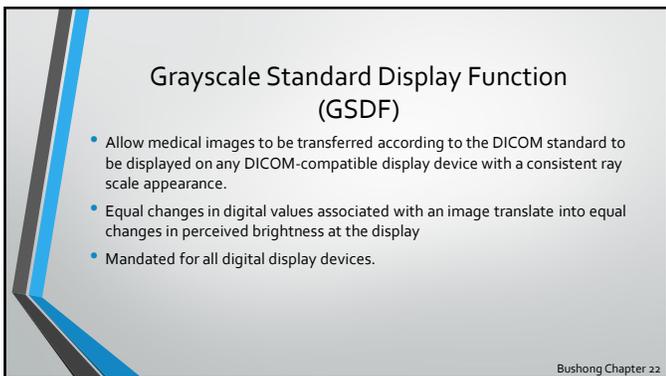
41



Quality Control

Minimum monitor matrix size for an acceptable digital radiograph is a 1536 x 2048 (3 MP)

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Grayscale Standard Display Function (GSDf)

- Allow medical images to be transferred according to the DICOM standard to be displayed on any DICOM-compatible display device with a consistent ray scale appearance.
- Equal changes in digital values associated with an image translate into equal changes in perceived brightness at the display
- Mandated for all digital display devices.

Bushong Chapter 22

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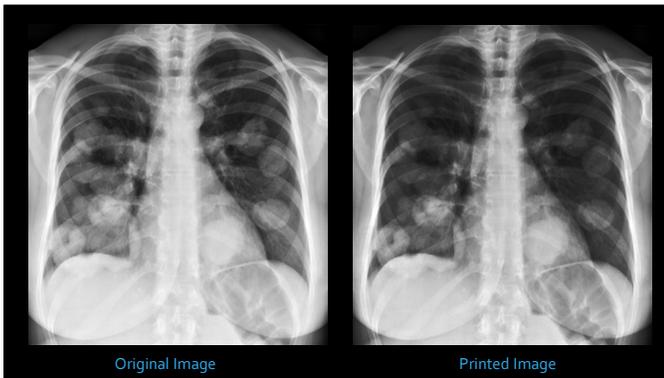
DICOM Grayscale Standard Display Function (GSDF) generates a display function matching the perceptual characteristics of a human observer.

Standard developed having human observer view monitor while luminance output of monitor changed in small steps from black to white and noting when they observed a **Just Noticeable Difference** (JND) in light output as the drive signal is changed.

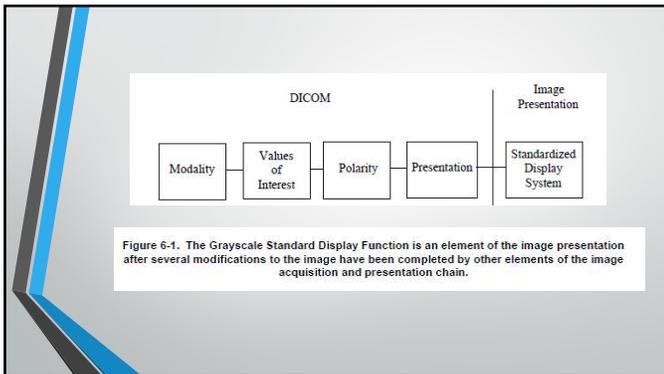
Most digital radiologic images are windowed to attempt to display 256 different shades of gray at any one time, (256 is approximate JND that humans can perceive)

The perceptual linearization implemented with the DICOM Grayscale Standard Display Function (GSDF) ensures that pixel values that are supposed to increase brightness in a linear fashion, say 6, 7, and 8, for example, actually appear that way to the human eye, despite the nonlinearity of our perception.

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Luminance

The rate of light (brightness) emitted from a source such as an LCD monitor

- **Maximum luminance** (*maximum brightness*)- checked at same monitor setting over a period of time with a photometer
- **Luminance response** – monitors ability to accurately display different shades of brightness from a test pattern
- **Luminance ratio** – compares maximum luminance to the minimum luminance
- **Luminance uniformity** – consistency of a single brightness level displayed across the area of the screen

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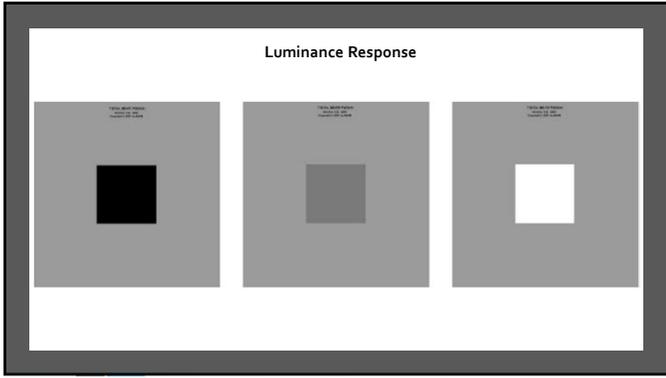
Luminance Ratio

48

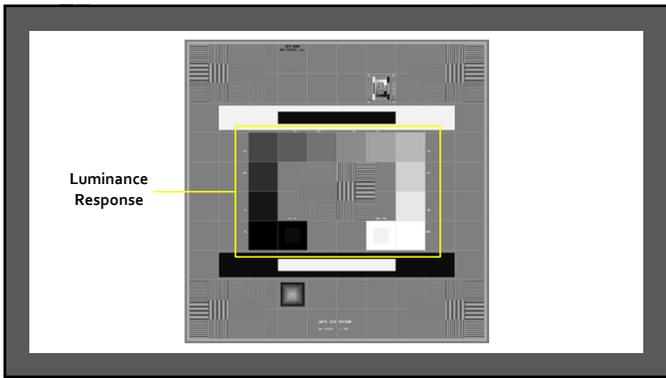
Luminance Response

A

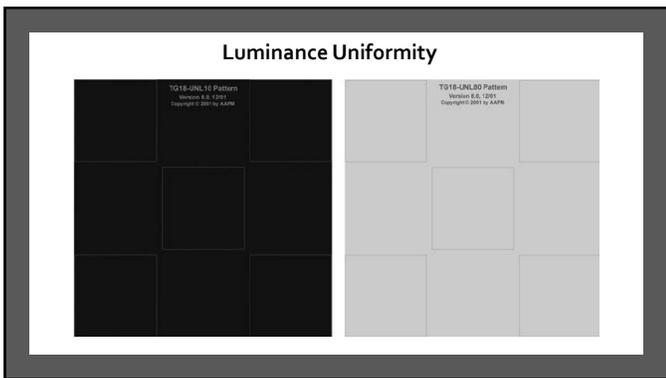
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51



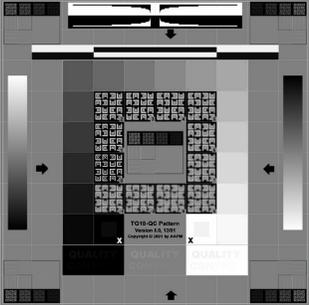
52

Resolution

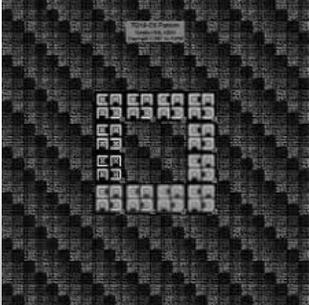
- ACR and AAPM minimum resolution for electronically displayed images of 2.5LP/mm
 - Generic SMPTE test pattern can be used
 - Check for blurring
- AAPM TG18 – QC and TG 18 CX provides an excellent check for resolution across the area of the display screen
 - Evaluate the CX pattern in the middle and in the corners
- Test can be done daily, weekly or monthly

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TG18 - QC

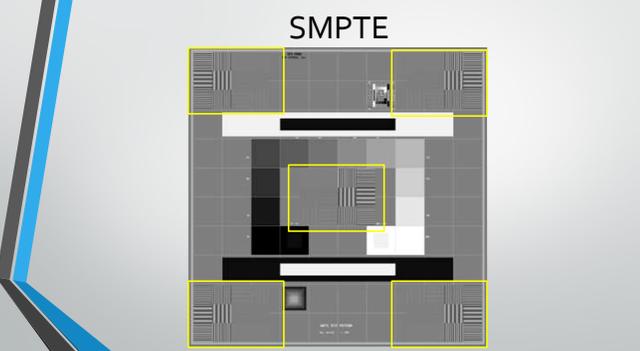


TG18 - CX

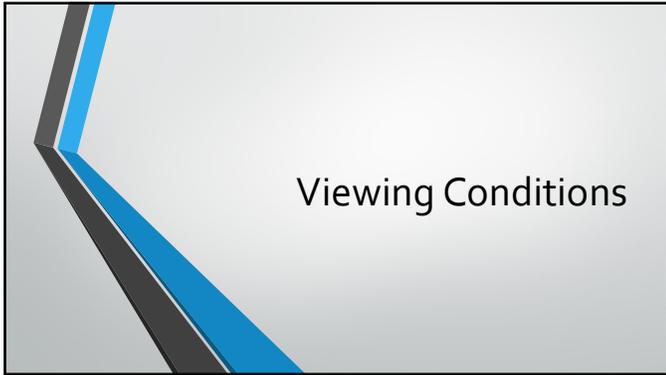


54

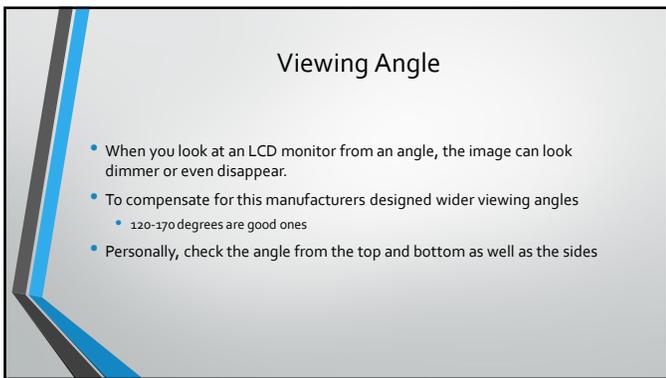
SMPTE



55



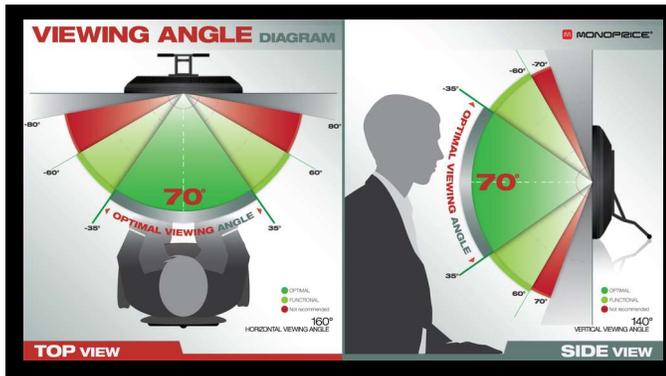
57



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Ambient Lighting

Illuminance – the rate of light striking a surface

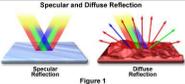


Figure 1 shows two types of reflection: Specular Reflection, where light rays reflect off a smooth surface at an equal angle, and Diffuse Reflection, where light rays scatter in multiple directions off a rough surface.

- The effect of ambient room lighting on the surface of and LCD monitor screen, including **reflectance** off the screen, and the resulting reduction in visible contrast of the image, is a result of **illuminance**
- Diffuse reflectance
 - The cumulative effect of room lighting across the area of the monitor screen
- Specular reflectance
 - The reflection of actual light sources such as a light bulb or window

The ambient lighting within the room must be dimmed to a point where both types of reflectance are below any noticeable level, that would impede full visibility of the image and image contrast

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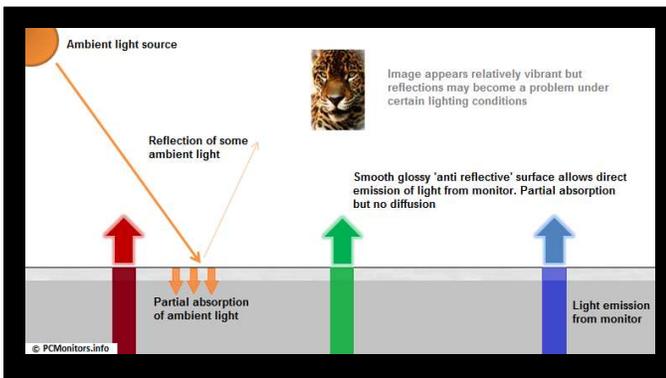
QC Aspect or Ambient Light

- While diagnosis is taking place, the maximum ambient lighting in a reading room should never be more than 25 lux
 - Approximately 1/4 the typical brightness of normal office lighting (75-100 lux)

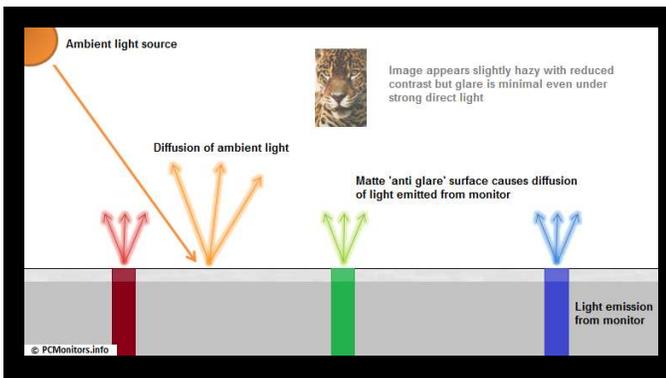
63



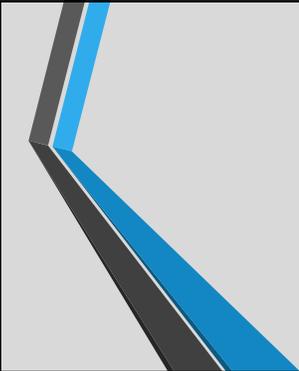
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65

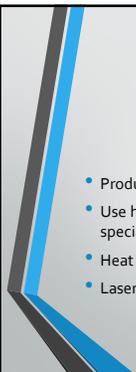


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Hard Copy

67



Laser Film



- Produces a hard copies of radiographs, CT and MRIs
- Use helium-neon laser or solid state diode laser to write digital data onto special film
- Heat from laser makes area on film turn black and form an image
- Laser printers can be directly networked into PACS

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CD and DVD

- 1958 – optical discs invented
- CD – has microscopic groove from inner track to outer track
 - Typical storage is 700 MB
- 1990s – second generation of optical disc
 - DVD (digital versatile disk or digital video disc)
 - Typical storage is 5GB
- 2006 – third generation
 - Blue ray disc – allows high definition
 - Typical storage is 25GB



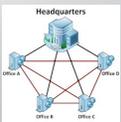
69

Data Management

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Network Connectivity

- LAN – Local Area Network
 - Computerized communications network generally contained within a single building or business
 - Devices share one server
- WAN – Wide Area Network
 - Extends to other businesses or locations that may be at great distances
 - Publically or commercially owned
 - Uses transmission services provided by common carriers (phone or cable companies)



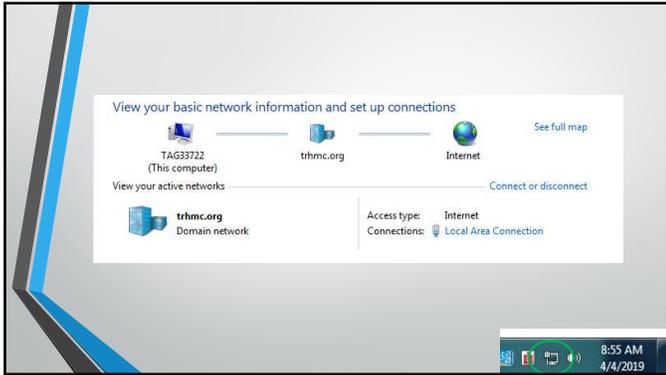
76

Computer Network

- Every computer within a network has a unique internet protocol or IP address
 - Ex. 172.811.3.1
- Every computer must have a network interface card
- Router
 - Connects 2 or more networks
 - Wireless routers – allow "point-of-care" access to a network for physicians and other caregivers via tablet or laptop



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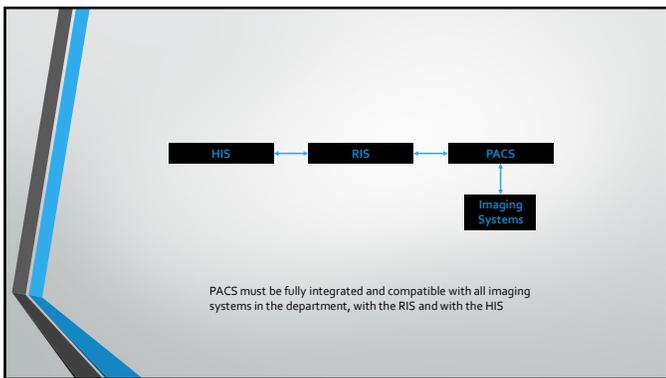
78

Type of LAN

RIS and HIS

- Radiology Information System
 - Data system for patient-related functions in the department, such as scheduling of x-ray appointments, tracking of patients, storage and distribution of reports
 - Makes info accessible from different locations within the radiology department
 - Assigns the **accession number**
- Hospital/Health Information System
 - Performs same functions for the entire institution (patient's general medical file)
 - Assigns a unique identifying number for each patient (**MRN**)

79



80

Picture Archiving and Communications System (PACS)

- Comprehensive computer network that is responsible for the electronic storage and distribution of medical images.
- Makes radiographs, CT and MRI scans, US and Nuclear Med images for a particular patient available within the network
- Allows Radiologists and Technologist to access these images from various locations, improving the efficiency of communication

Soon to be Called....
Medical image management and processing system (MIMPS)

81

PACS

- Digital acquisition (Picture)
- Display workstations
- Storage devices (Archiving)
- Components are interconnected by a network (Communication)

82

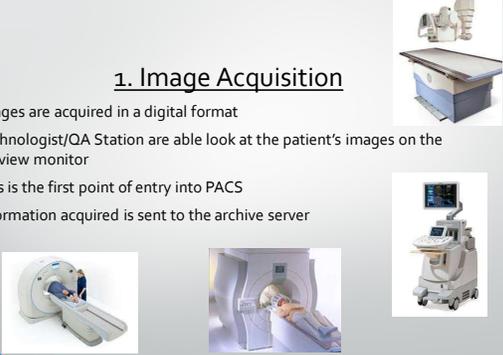
Components of PACS

- Image acquisition
- Display workstations
- Archive servers

83

1. Image Acquisition

- Images are acquired in a digital format
- Technologist/OA Station are able look at the patient's images on the preview monitor
- This is the first point of entry into PACS
- Information acquired is sent to the archive server



84

2. Display Workstations

Any computer used to view digital images

- Radiologists
- Physicians, surgeons, nurses & patients
- Technologists

- Most interactive part of PACS
- Used inside and out of Radiology
- Has PACS application software that allows minor image-manipulation

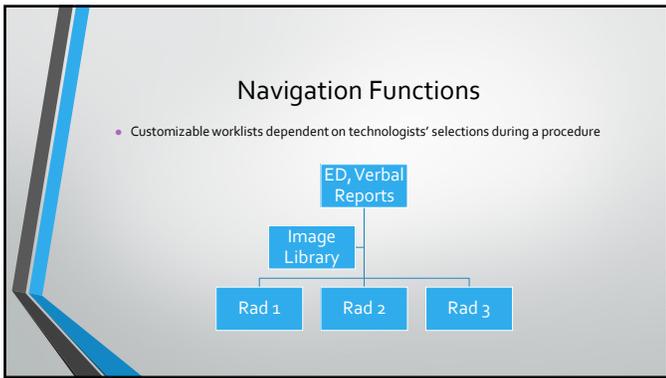


85

Common Workstation Functions

- Navigation Functions
- Hanging Protocol
- Study Navigation
- Image Manipulation & Enhancement
- Image Management

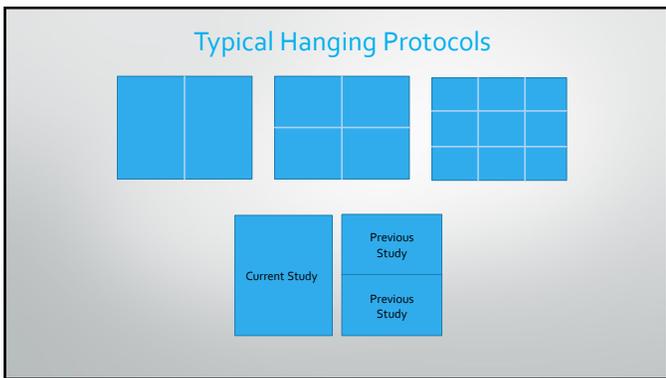
86



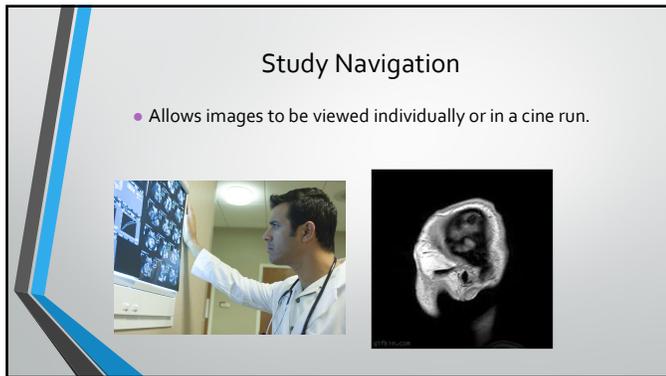
87



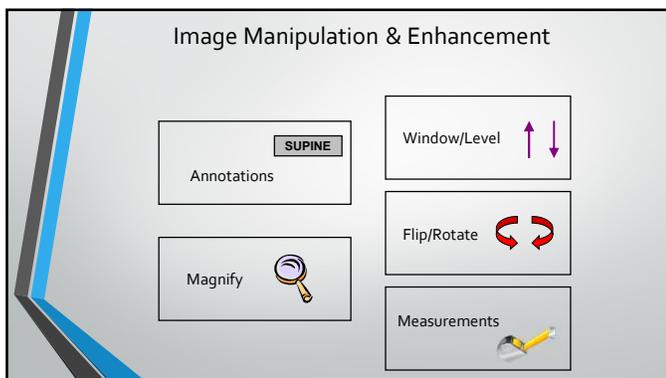
88



89



90



91



92

Image Management Functions

- Patient demographics
 - Edit patient information for proper correlation with previous studies, billing, etc.
- Query / Retrieve
 - Locate images based on patient demographics
- Hardcopy images
 - Either CD or plain film
 - Usually only image library has this function

93

3. Archive Servers

- File room of PACS
- Contains all historic and current data



94

PACS Archiving

- Consist of:
 - Image manager/controller
 - Image storage/server



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Image Manager

- Contains master database of everything in the archive
- Controls the receipt, retrieval and distribution of the images it stores
- Controls all the DICOM processes running within the archive
- Communicates with RIS and HIS
- Can populate image information into the EMR

MANAGER

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97

Image Storage/Archive Server

- Physical storage device for archive system
- Network of servers
- Setup in tiers
 - Short-term
 - Long-term

In the United States, storage requirement of a patient's images is from five to seven years.

98

Short Term Storage

- RAID
 - several magnetic disks or hard drives that are linked together in an array

RAID 5 is the most common level used for a PACS archive because it provides adequate redundancy and fault tolerance

99

Reading Hospital

- Short-term storage is done on servers located in IMS but maintained by Philips
 - Philips monitors the system through remote access
 - All backups and drive redundancy are handled by Philips

100

Long Term Storage

- RAID
- Optical disk
- Tape
- Magnetic disk

101

Cloud-Based Storage

- Offsite storage and servers supported by a secure network
- 3rd party vendor
- Shifts disaster recovery process to the vendor along with maintenance and storage equipment purchase
- You pay for the service and storage space

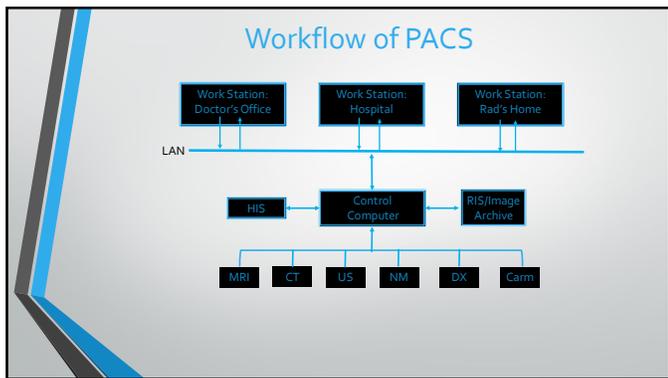
102

Reading Hospital:

- Prior to EPIC - \$1 million budget for record storage
- Legally obligated to retain films:
 - Pediatrics
 - Mammo
 - All other films



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Summary of PACS Functions

- Main function: Act as a *database*
 - Generate and sort according to status (i.e. pending, completed)
 - Various queries – users can search for specific information
- Manipulation – at any workstation
- Storage

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Vendor Neutral Archives (VNA)

- Allows for images and data from different systems and in different formats to be stored using a singular system on a common infrastructure
- May be used as replacements to existing PACS to avoid very expensive transition costs
- Used to consolidate a number of systems that exist within a single facility or across a system of facilities

106

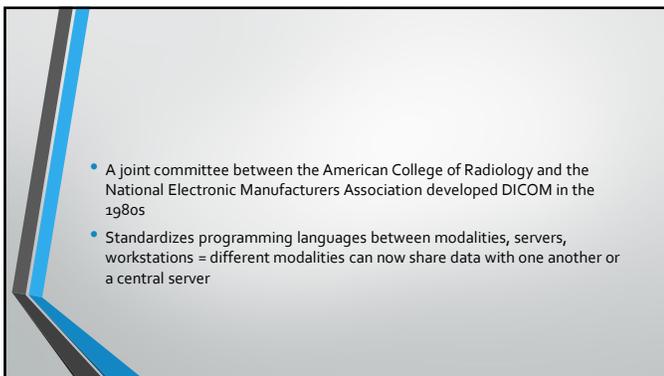
PACS Emergency Contingency Plan

- A backup copy of ALL archived records should be maintained either by the hospital or an Application Service Provider
- RH PACS Downtime Procedure Policy - <https://trh.elucid.com/documents/view/12114/33066/3>

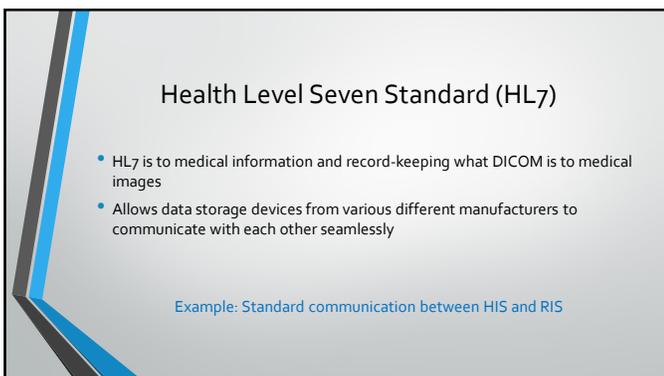
107



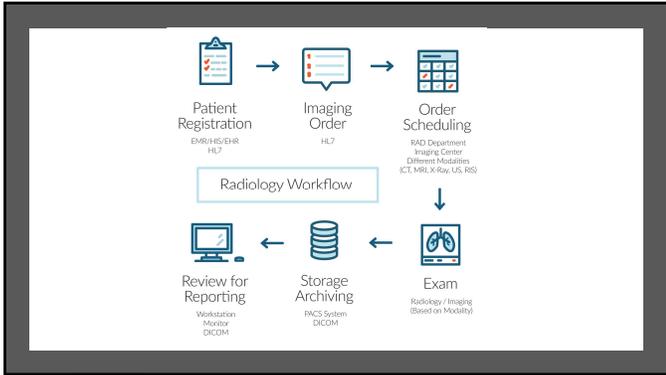
111



112



113



114

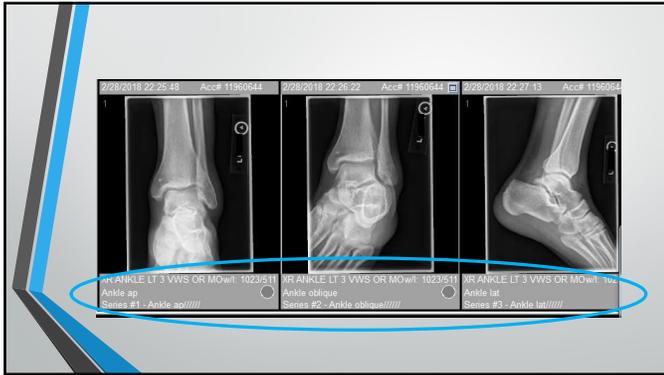
DICOM Header

- A summary of critical identification and study information such as:
 - Date and time of procedure
 - Number of images taken
 - Body part, position
 - Technique used
 - Image format and receptor size
 - Parameters used to digitally process the image
- All this information is stored as **metadata**
 - Should appear in a bar at the top of the screen for each image
 - Shows summary of essential metadata for the image

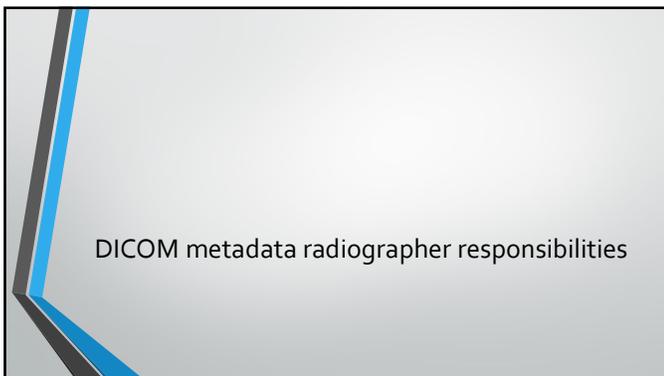
115

Group Tag	Element Tag	Tag Description	Value
0010	0011	Private Tag	MURKIN
0010	0020	Patient ID	12345
0010	0030	Patient's Birth Date	00000000
0010	0040	Patient's Sex	M
0010	1030	Patient's Weight	0
0010	2165	Private Tag	None
0010	2166	Private Tag	None
0010	4000	Patient Comments	
0018	0015	Body Part Examined	THORAX
0018	1000	Device Serial Number	00000000
0018	1020	Software Version(s)	1.0.1.120
0018	1164	Image Field Source	0.16
0018	1508	Positioner Type	COLLIMIN
0018	5100	Patient Position	ANTERIOR - POSTERIOR
0018	7004	Detector Type	DIRECT
0018	7006	Detector Description	
0018	7014	Detector Serial	1.1.1
0020	0020	Study Instance UID	1.2.826.0.1.3680043.2.1330.1000001.1.2213256762.2712337879
0020	000E	Series Instance UID	1.2.826.0.1.3680043.2.1330.1000001.4.2213256762.27123318877
0020	0010	Study ID	None
0020	0011	Series Number	1
0020	0019	Instance Number	29
0020	0020	Patient Orientation	N
0020	0060	Laterality	L
0020	0062	Private Tag	U
0020	4000	Image Comments	
0028	0002	Samples per Pixel	1

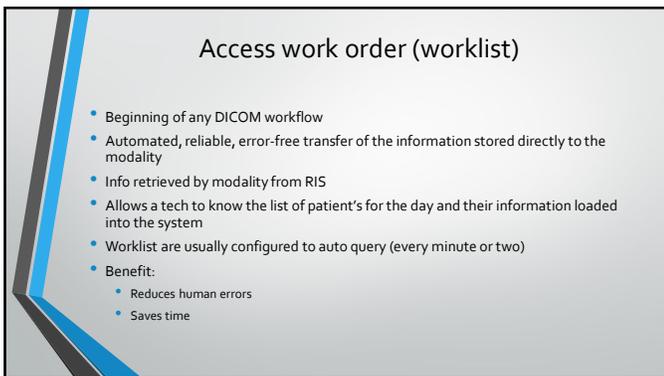
116



117



118



119

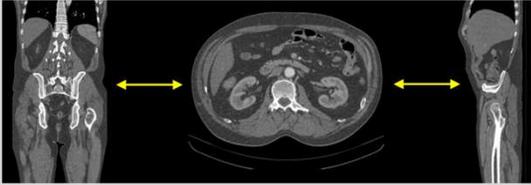
Post Processing – Image operation and manipulation

- Image operation activities
- Multiplanar Reconstruction
- Maximum and Minimum Intensity Projection
- Volume Rendering Technique (VRT)
- Shaded Surface Display (3D technology)
- CAD

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Multiplanar Reconstruction

- Creates multiple planes of view from a single scan



<https://www.youtube.com/watch?v=H1nPmSVijag>

121

Maximum & Minimum Intensity Projections

- Enhancement of small vessels (MIP) and air-filled structures (MinIP)

MinIP – Minimum Intensity Projections

MIP – Maximum Intensity Projections



MinIP AIP MIP

122

Volume Rendering Technique (VRT)

- Assists in differentiating between anatomical structures by adding color shades based on pixel intensity



123

Shaded Surface Display (SSD)

- Creates a 3D, moveable image based on the pixel intensity of choice



124

CAD (Computer Aided Diagnosis/Detection)

- used as a "second opinion" in assisting radiologists' image interpretations
 - complementary tools that draw the radiologists' attention to certain image areas that need further evaluation
- Uses algorithms
- Used in Mammography at RH



Source: Appl Radiol © 2004 Anderson Publishing, Ltd

125

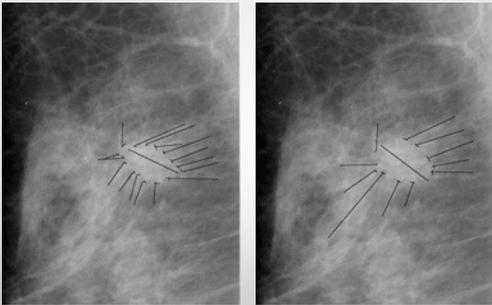
Annotation Issues: Annotations and Mark Ups

- *Image annotation* – describes the meaning in images
- *Image markup* – visual presentation of the annotation
- AIM Project (Annotation and Image Mark up project)
 - The model contains information about who created the annotation, the equipment with which the annotation was created, when the annotation was created, and the image(s) to which the annotation refers.
 - Once the annotation is defined in the AIM, sophisticated queries are now easily found
 - "Find all studies that contain enhancing right middle lobe lung masses that measure between 5 and 6 cm"

126

- Other concerns are
 - What is more accurate tool to use --- stylus or mouse for marking or measurements?
 - Human error
 - Legal issues

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Mouse Stylus

128

Case number	Annotation time for mouse (s)	Annotation time for stylus (s)
1	109	86
2	121	71
3	108	70
4	78	74
5	109	91
6	55	57
7	78	77
8	90	54
9	113	60
10	89	85
11	101	98
12	81	41

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Image Transmission

- Concerns of medical data overload
 - CT may produce 300 to 500 images and a CT angiography runoff study may include 1,500 to 2,000 images
- In teleradiology, the header of the DICOM image is first transmitted followed by the compressed image data and then at the receiving end, images are reconstructed from low quality to high (or perfect) quality
- Facilities will compress images to send, this allow it to be sent more efficiently
 - Lossless compression have been defined as "visually acceptable" images by the medical imaging community

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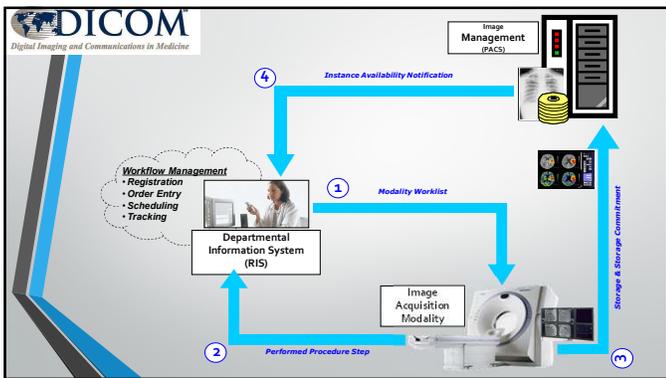
HIPAA

- Health Insurance Portability and Accountability Act of 1996 (HIPAA) Privacy Rule is to ensure you have rights over your own health information, no matter what form it is in.
- The government also created the HIPAA Security Rule to require specific protections to safeguard your electronic health information.
- Federal law requires doctors, hospitals, and other health care providers to notify you of a "breach."
- Facilities should implement high-grade security and encryption in their systems in order to protect records from hackers or theft
- Adhering to HIPAA guidelines often means subjecting software developments to a legal team who can determine whether or not the software falls within HIPAA regulations for security and confidentiality

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132



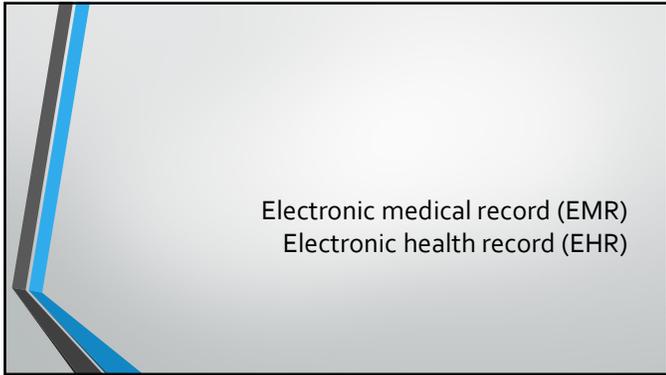
133

DICOM Services for Acquisition Workflow Management

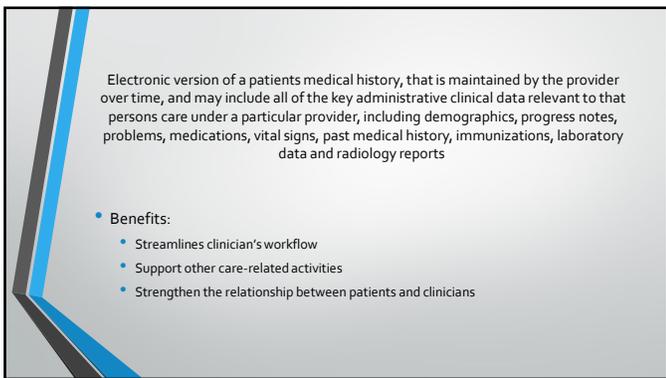
- Improve Interoperability of Imaging Equipment
- Ensure Data Consistency
- Facilitate Reliable Data Management
- Improve Process Efficiency
- Better Quality of Imaging Services

DICOM
Digital Imaging and Communications in Medicine

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137

- Any system which allows remote transmission and viewing of radiographic images via modems over phone or cable lines
- Makes it possible for images to be sent great distances for a specialist to collaborate with a radiologist, and for images stored at a hospital to be accessed almost instantly by doctors at their individual clinics
 - Example: transmit images to radiologist's home during off hours





1



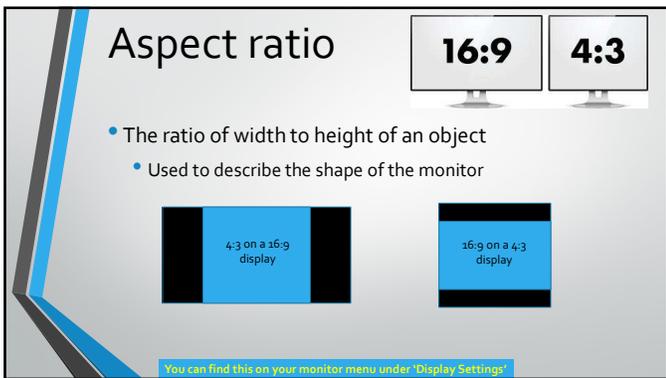
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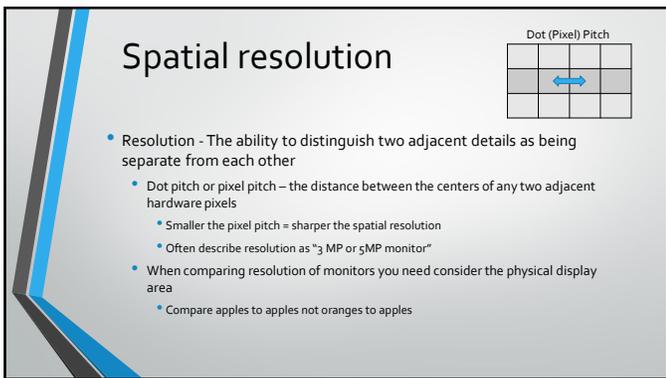
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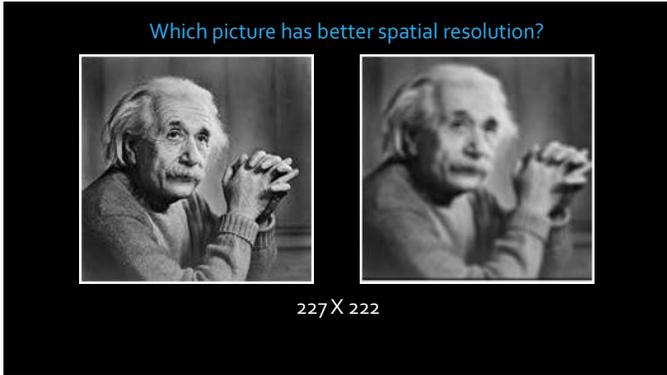
4



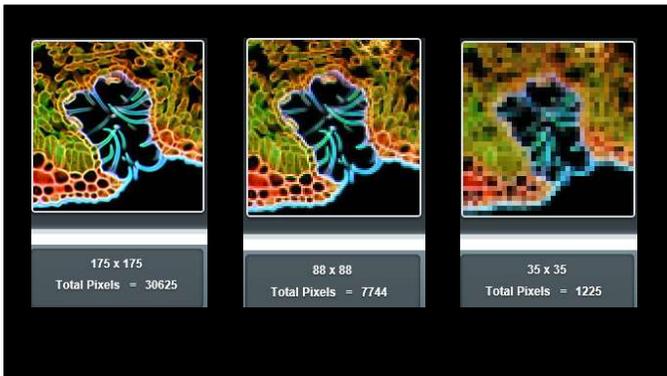
5



6



7



8



9

Brightness

- The black level of a display screen. Although it may sound peculiar, the brightness adjusts the "black level" of the display system (how black the black is) –*Computer Desktop Encyclopedia*
- Photometer is used to measure the brightness output of an LCD
- American College of Radiology (ACR) requires a minimum brightness capability for radiologic display systems of 250 lumens



Too dark Good brightness Too bright

10

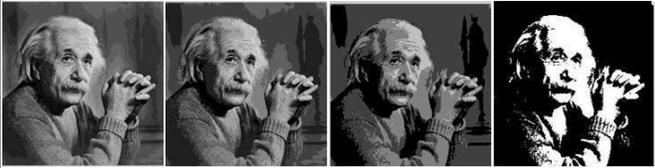
Contrast Ratio

- The difference between the darkest blacks and the brightest whites a given display can produce.
- Contrast ratio for LCD = 600:1, CRT = 3000:1
 - LCD - Inability to produce a "true black" due to backlight leakage



100% Contrast 75% Contrast 50% Contrast 25% Contrast 1% Contrast

12

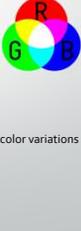


16 Gray Levels 8 Gray Levels 4 Gray Levels 2 Gray Levels

13

Color vs. Grayscale (monochrome)

- **Monochrome monitors**
 - Color images will appear as shades of gray
 - Has only one phosphor of color, but may have the ability to change the brightness causing the illusion of depth
 - Produces sharper text and image because 1 phosphor per pixel than color
- **Color monitors**
 - Monochrome images can be viewed on color monitors
 - Uses alternating intensities of red, green and blue to produce the different color variations
 - Uses 3 phosphors per pixel



15

What color would be seen in a color monitor?

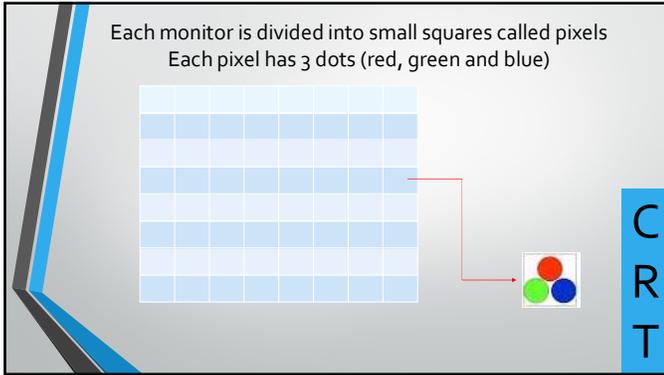
- If all 3 colors set at 0 = **BLACK**
- If all 3 colors set at 255 = **WHITE**
- If red was set at 255 and blue and green at 0 = **RED**

16

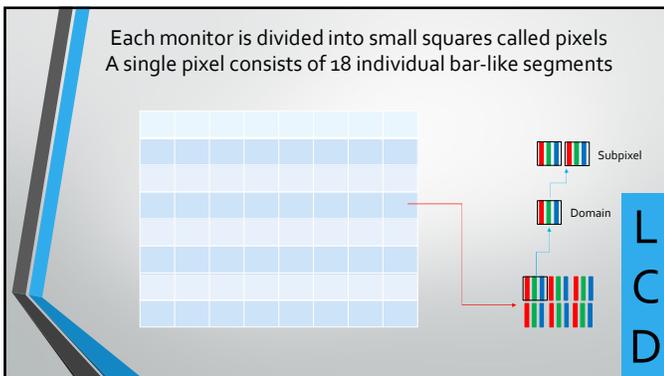
Pixels for Computers

- Pixel – multiple definitions
 - Carroll states it is “the smallest element of the matrix or device that can represent all pixel values within the system’s dynamic range”
- CRT – each triad of color (red, blue, and green) is considered one pixel
- LCD – a single pixel consists of 18 individual bar-like segments
- Hardware pixel in monitor – intersections of flat, transparent wires crossing over each other to form an overall square shape

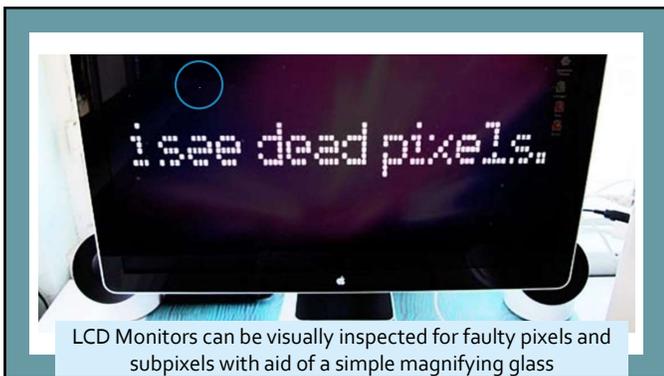
18



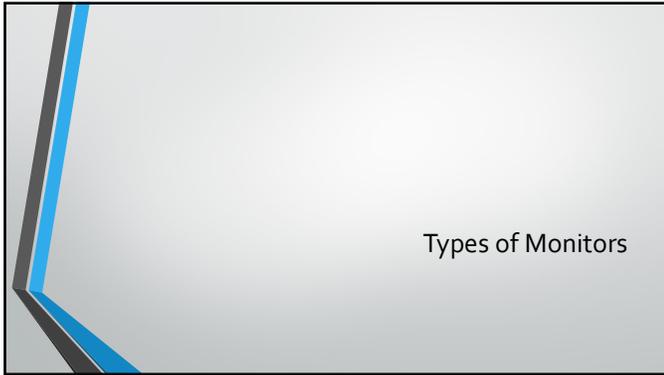
19



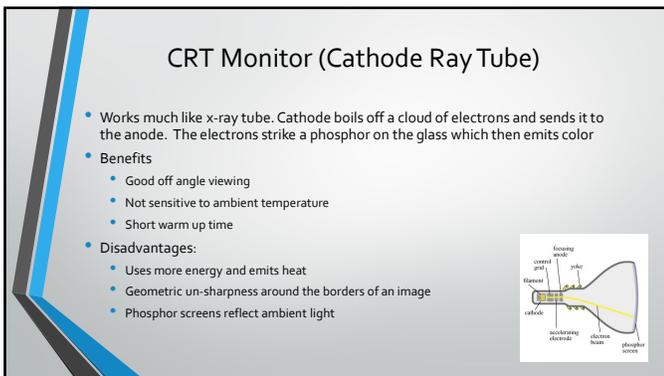
20



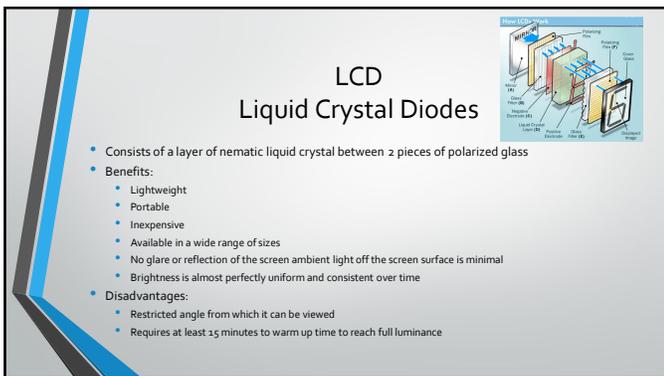
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23



24



25

To understand the LCD monitor you must comprehend Light Polarization

- Like an x-ray, a ray of light is electromagnetic radiation that consists of a double wave

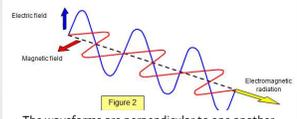
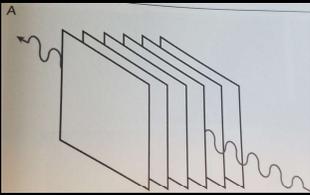


Figure 2
The waveforms are perpendicular to one another

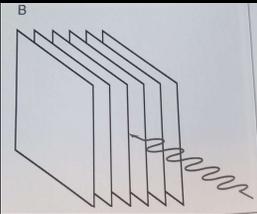
- LCD Monitors use polarized glass
 - Polarized glass contains long chains of iodine molecules, all aligned parallel to each other
 - Just like a grid strips in a grid

26



Electrical

The electrical component of the double wave can pass through a polarized glass with vertical string molecules because it vibrates parallel to it

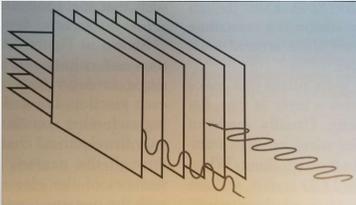


Magnetic

The magnetic component of the double wave cannot pass through a polarized glass with vertical string molecules because it vibrates perpendicular to it

27

What will happen if you layer 2 polarizing glass together so the string molecules are perpendicular to each other?



28

LCD – Light polarization

- LCD monitor consists of:
 - 2 thin sheets of glass
 - Each with a light polarizing layer that are perpendicular to the other sheet

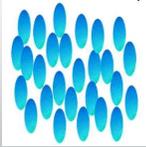
Perpendicular sheets = ALL light being blocked

Don't worry, the LCD process involves "tricking" these layers into allowing light to pass

29

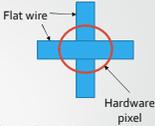
What are nematic liquid crystals?

- This is what is inserted between the polarizing glass sheets/lenses that plays the trick
- A crystalline arrangement of molecules that have a long linear shape and tend to align parallel to each other



30

Before we see the "trick", you need to know one more thing....



- In the polarizing glass there are a layer of thin, flat wires to conduct electricity
- These conductors are also aligned perpendicular to each other when the 2 polarized glass are together
- Each junction forms a single **hardware pixel**
 - Each electrode has a scratch on it
 - Scratches are perpendicular to one another
 - The crystals tend to line up with the "scratch" direction when no electric charge is present -- **known as "on" state**

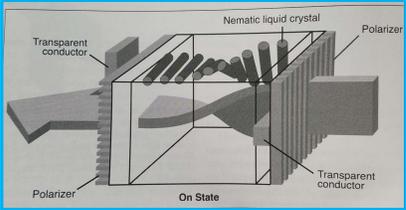
31

And **FINALLY**, Here is the Magic Trick.....



<https://www.youtube.com/watch?v=jiejNAUwcQ8>

32

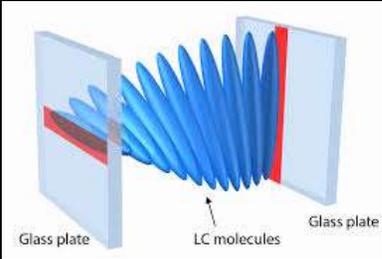


"ON" STATE

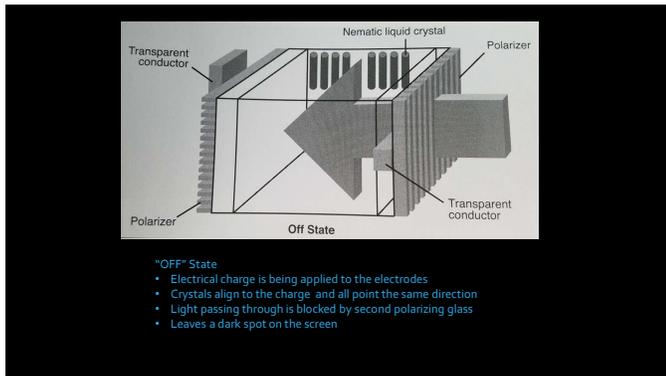
- Since the scratches are perpendicular, the liquid crystals line up in a spiral pattern that twists 90 degrees between the two glass plates
- This lets light waves pass through the nematic liquid crystal and follow the spiral
- Light is able to pass through the second glass plate to the viewer of the monitor

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Just another way to look at it



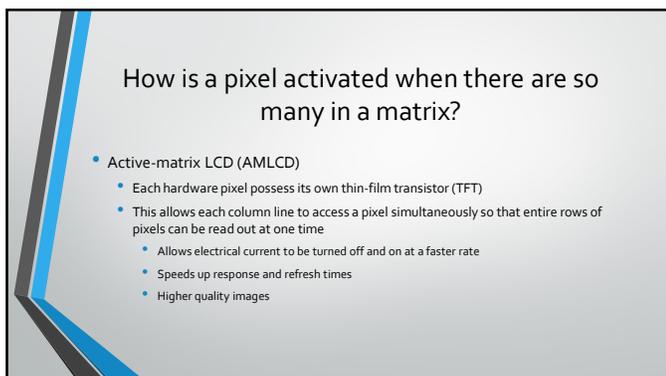
34



35



36



37

More info on LCD Monitors

- As LCDs **do not** produce light by themselves—they need illumination to produce a visible image.
 - Without a **backlight**, an LCD display device will remain black, rendering it unviewable
- Backlighting**
 - Types: Fluorescent bulbs or light-emitting diodes (LEDs)
 - LED - Most common

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Care and Maintenance

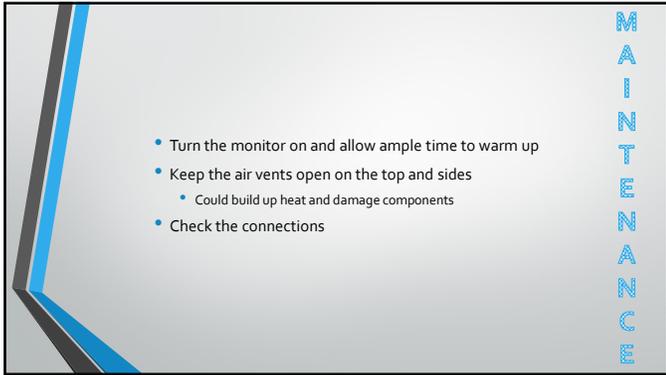
39

CARE

- Apply cleaning solution to soft cloth
 - Do not spray solution directly on screen
 - Do not use paper towel can cause scratches
- Wipe in one direction from top of screen to bottom

- The following cleaners should NOT be used: Acetone
 - Ethyl alcohol
 - Ethyl acid
 - Ammonia
 - Methyl chloride
- The following types of cleaners are acceptable: Water
 - Vinegar (mixed with water)
 - Isopropyl Alcohol
 - Petroleum Benzene

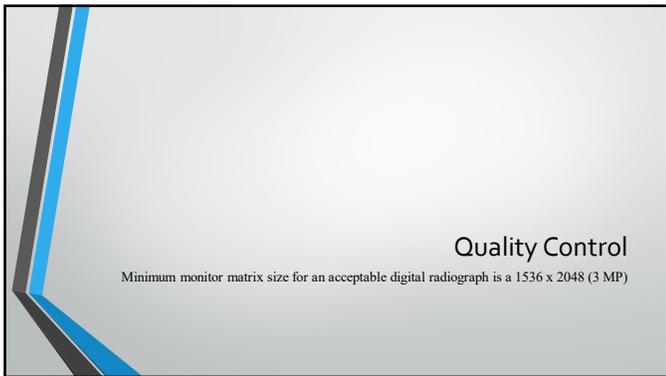
40



M-A-I-N-T-E-N-A-N-C-E

- Turn the monitor on and allow ample time to warm up
- Keep the air vents open on the top and sides
 - Could build up heat and damage components
- Check the connections

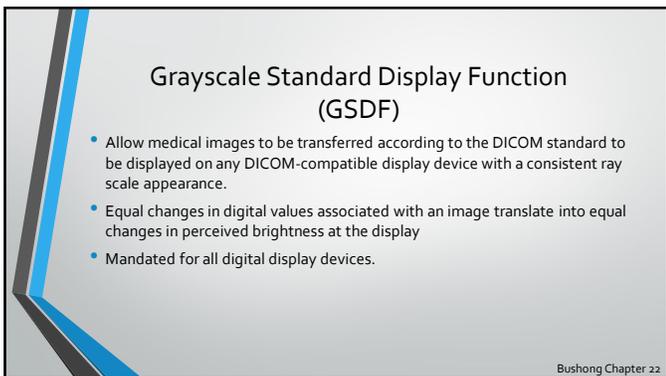
41



Quality Control

Minimum monitor matrix size for an acceptable digital radiograph is a 1536 x 2048 (3 MP)

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Grayscale Standard Display Function (GSDf)

- Allow medical images to be transferred according to the DICOM standard to be displayed on any DICOM-compatible display device with a consistent ray scale appearance.
- Equal changes in digital values associated with an image translate into equal changes in perceived brightness at the display
- Mandated for all digital display devices.

Bushong Chapter 22

43

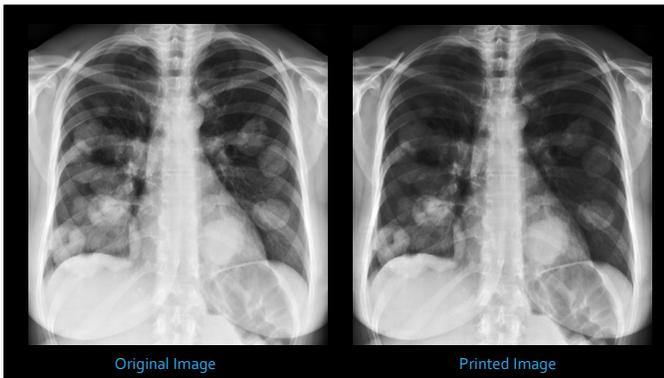
DICOM Grayscale Standard Display Function (GSDF) generates a display function matching the perceptual characteristics of a human observer.

Standard developed having human observer view monitor while luminance output of monitor changed in small steps from black to white and noting when they observed a **Just Noticeable Difference** (JND) in light output as the drive signal is changed.

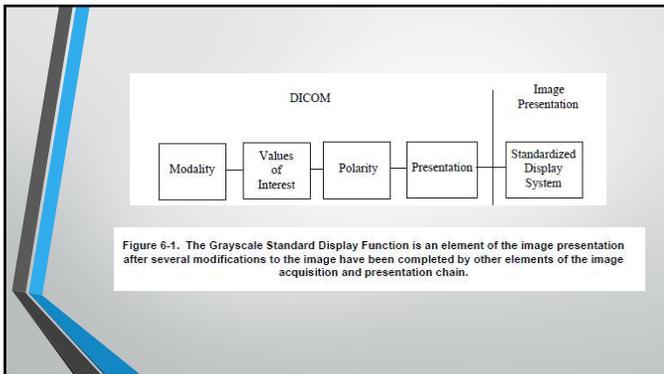
Most digital radiologic images are windowed to attempt to display 256 different shades of gray at any one time, (256 is approximate JND that humans can perceive)

The perceptual linearization implemented with the DICOM Grayscale Standard Display Function (GSDF) ensures that pixel values that are supposed to increase brightness in a linear fashion, say 6, 7, and 8, for example, actually appear that way to the human eye, despite the nonlinearity of our perception.

44



45



46

Luminance

The rate of light (brightness) emitted from a source such as an LCD monitor

- **Maximum luminance** (*maximum brightness*)- checked at same monitor setting over a period of time with a photometer
- **Luminance response** – monitors ability to accurately display different shades of brightness from a test pattern
- **Luminance ratio** – compares maximum luminance to the minimum luminance
- **Luminance uniformity** – consistency of a single brightness level displayed across the area of the screen

47

Luminance Ratio

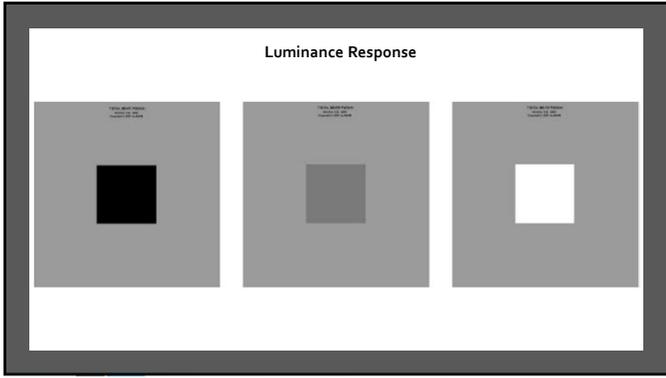
48

Luminance Response

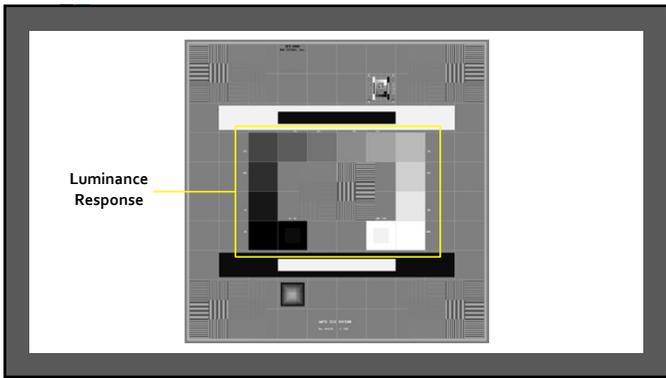
TDS-CT Pattern
Version 2.0, 10/11
Copyright © 2011 by Apple

A

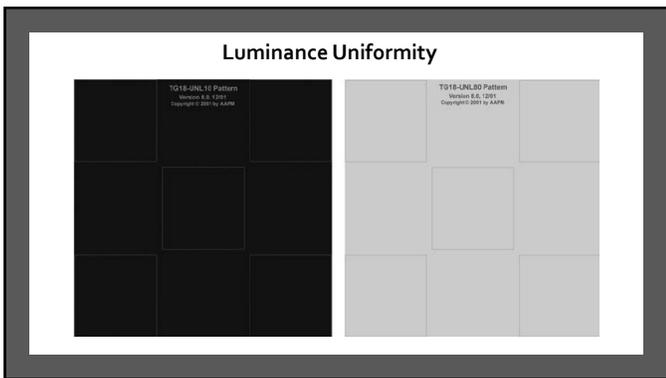
49



50



51



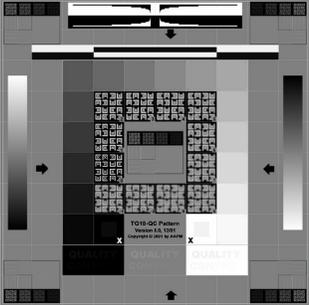
52

Resolution

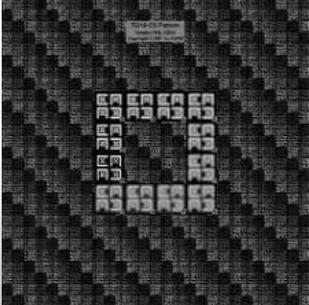
- ACR and AAPM minimum resolution for electronically displayed images of 2.5LP/mm
 - Generic SMPTE test pattern can be used
 - Check for blurring
- AAPM TG18 – QC and TG 18 CX provides an excellent check for resolution across the area of the display screen
 - Evaluate the CX pattern in the middle and in the corners
- Test can be done daily, weekly or monthly

53

TG18 - QC

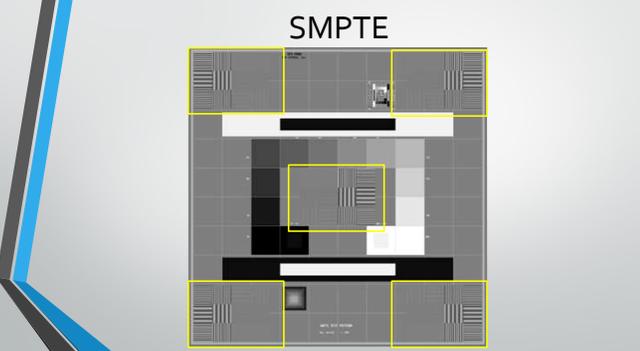


TG18 - CX

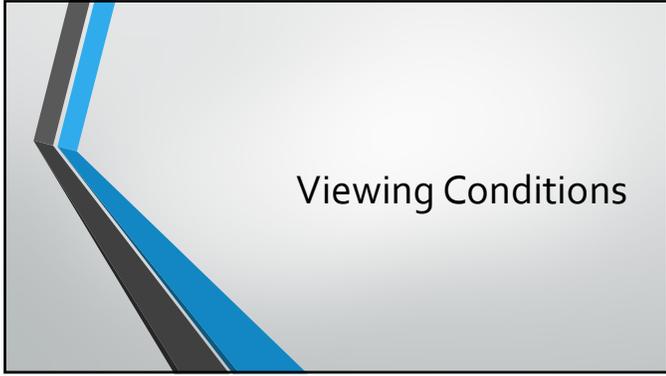


54

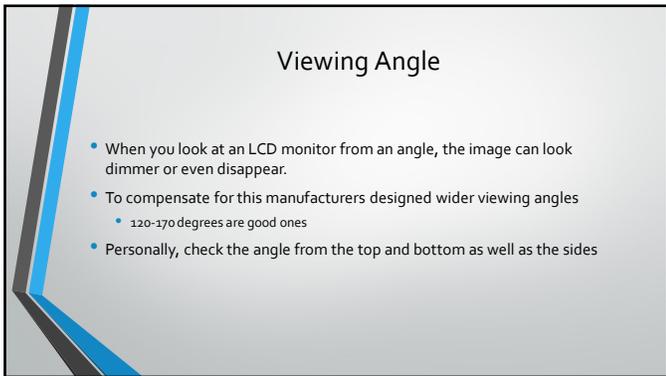
SMPTE



55



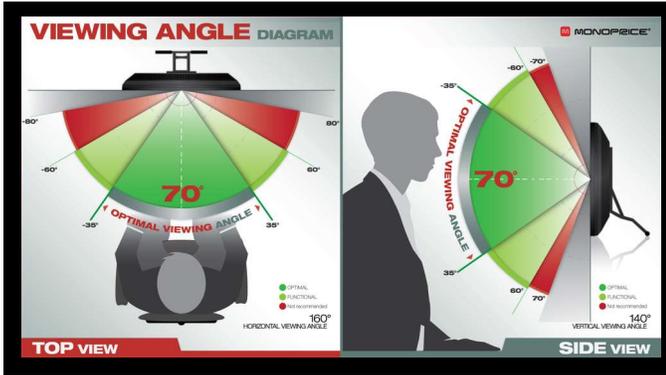
57



58



59



60

Ambient Lighting

Illuminance – the rate of light striking a surface

- The effect of ambient room lighting on the surface of and LCD monitor screen, including **reflectance** off the screen, and the resulting reduction in visible contrast of the image, is a result of **illuminance**
- Diffuse reflectance
 - The cumulative effect of room lighting across the area of the monitor screen
- Specular reflectance
 - The reflection of actual light sources such as a light bulb or window

The ambient lighting within the room must be dimmed to a point where both types of reflectance are below any noticeable level, that would impede full visibility of the image and image contrast

62

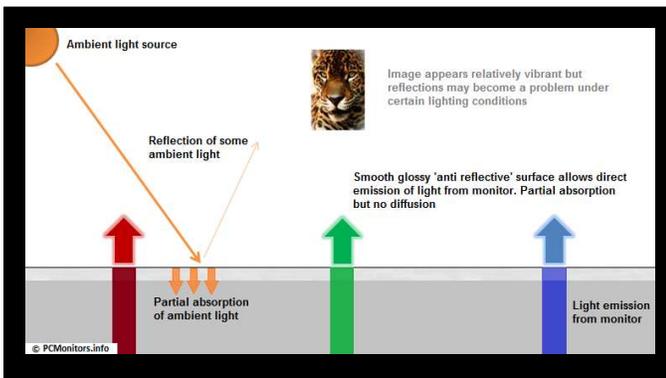
QC Aspect or Ambient Light

- While diagnosis is taking place, the maximum ambient lighting in a reading room should never be more than 25 lux
 - Approximately 1/4 the typical brightness of normal office lighting (75-100 lux)

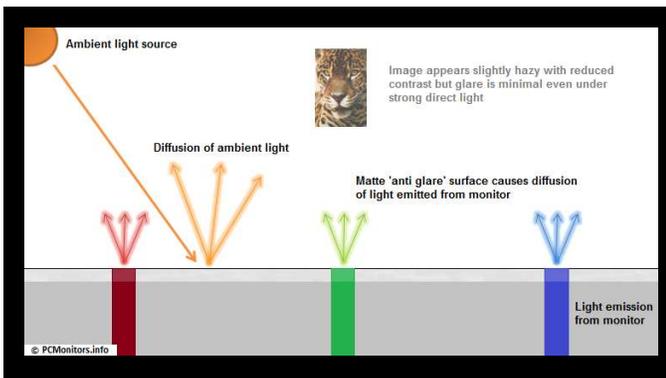
63



64



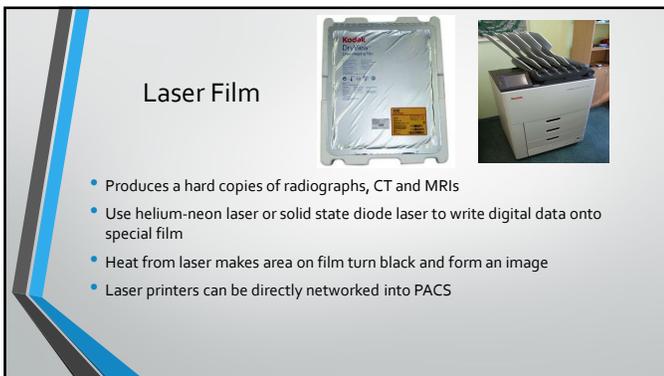
65



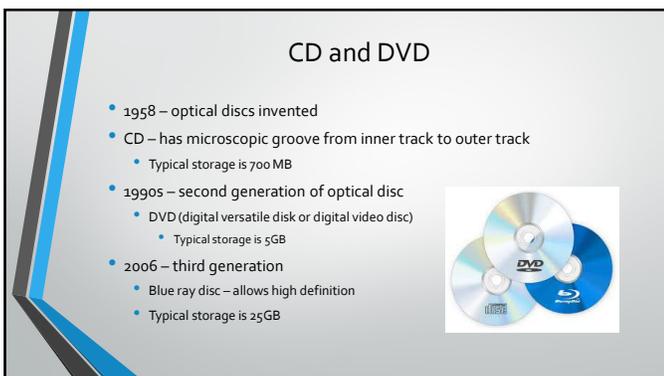
66



67



68



69

Data Management

75

Network Connectivity

- LAN – Local Area Network
 - Computerized communications network generally contained within a single building or business
 - Devices share one server
- WAN – Wide Area Network
 - Extends to other businesses or locations that may be at great distances
 - Publically or commercially owned
 - Uses transmission services provided by common carriers (phone or cable companies)



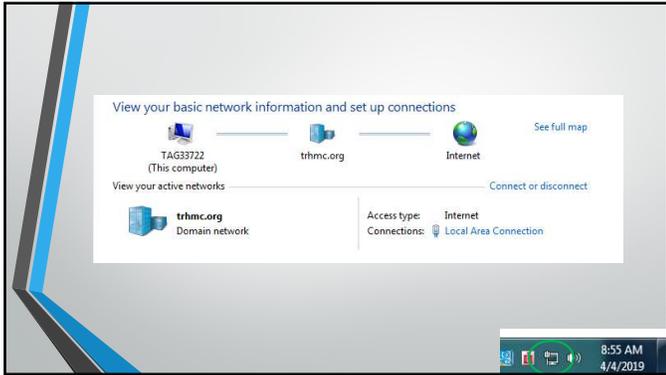
76

Computer Network

- Every computer within a network has a unique internet protocol or IP address
 - Ex. 172.811.3.1
- Every computer must have a network interface card
- Router
 - Connects 2 or more networks
 - Wireless routers – allow "point-of-care" access to a network for physicians and other caregivers via tablet or laptop



77



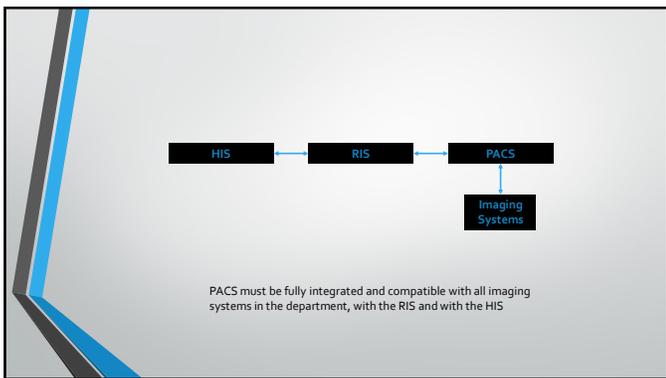
78

Type of LAN

RIS and HIS

- Radiology Information System
 - Data system for patient-related functions in the department, such as scheduling of x-ray appointments, tracking of patients, storage and distribution of reports
 - Makes info accessible from different locations within the radiology department
 - Assigns the **accession number**
- Hospital/Health Information System
 - Performs same functions for the entire institution (patient's general medical file)
 - Assigns a unique identifying number for each patient (**MRN**)

79



80

Picture Archiving and Communications System (PACS)

- Comprehensive computer network that is responsible for the electronic storage and distribution of medical images.
- Makes radiographs, CT and MRI scans, US and Nuclear Med images for a particular patient available within the network
- Allows Radiologists and Technologist to access these images from various locations, improving the efficiency of communication

Soon to be Called....
Medical image management and processing system (MIMPS)

81

PACS

- Digital acquisition (Picture)
- Display workstations
- Storage devices (Archiving)
- Components are interconnected by a network (Communication)

82

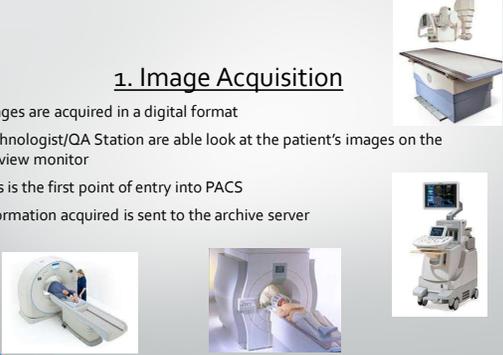
Components of PACS

- Image acquisition
- Display workstations
- Archive servers

83

1. Image Acquisition

- Images are acquired in a digital format
- Technologist/OA Station are able look at the patient's images on the preview monitor
- This is the first point of entry into PACS
- Information acquired is sent to the archive server



84

2. Display Workstations

Any computer used to view digital images

- Radiologists
- Physicians, surgeons, nurses & patients
- Technologists

- Most interactive part of PACS
- Used inside and out of Radiology
- Has PACS application software that allows minor image-manipulation

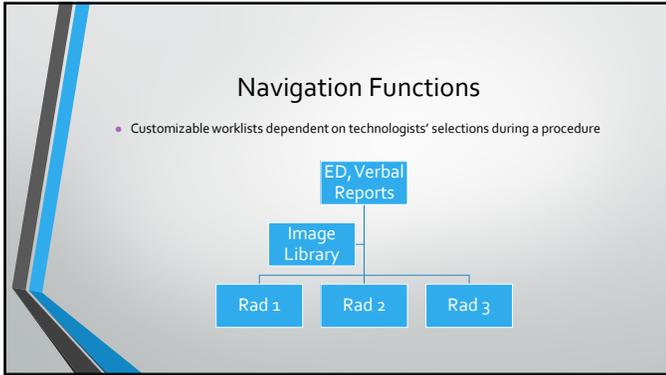


85

Common Workstation Functions

- Navigation Functions
- Hanging Protocol
- Study Navigation
- Image Manipulation & Enhancement
- Image Management

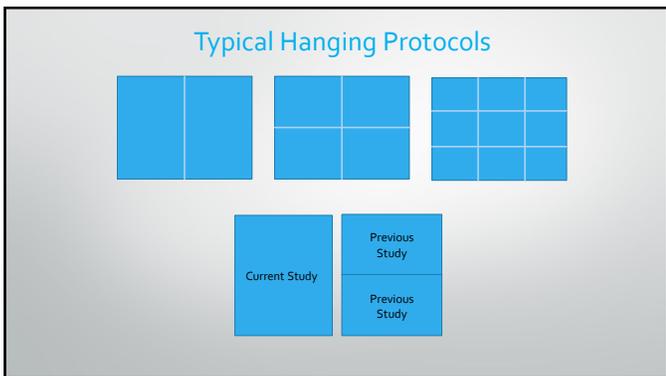
86



87



88



89

Study Navigation

- Allows images to be viewed individually or in a cine run.



90

Image Manipulation & Enhancement

Annotations **SUPINE**

Magnify 

Window/Level 

Flip/Rotate 

Measurements 

91

Key Images



92

Image Management Functions

- Patient demographics
 - Edit patient information for proper correlation with previous studies, billing, etc.
- Query / Retrieve
 - Locate images based on patient demographics
- Hardcopy images
 - Either CD or plain film
 - Usually only image library has this function

93

3. Archive Servers

- File room of PACS
- Contains all historic and current data



94

PACS Archiving

- Consist of:
 - Image manager/controller
 - Image storage/server



95

Image Manager

- Contains master database of everything in the archive
- Controls the receipt, retrieval and distribution of the images it stores
- Controls all the DICOM processes running within the archive
- Communicates with RIS and HIS
- Can populate image information into the EMR

MANAGER

96

97

Image Storage/Archive Server

- Physical storage device for archive system
- Network of servers
- Setup in tiers
 - Short-term
 - Long-term

In the United States, storage requirement of a patient's images is from five to seven years.

98

Short Term Storage

- RAID
 - several magnetic disks or hard drives that are linked together in an array

RAID 5 is the most common level used for a PACS archive because it provides adequate redundancy and fault tolerance

99

Reading Hospital

- Short-term storage is done on servers located in IMS but maintained by Philips
 - Philips monitors the system through remote access
 - All backups and drive redundancy are handled by Philips

100

Long Term Storage

- RAID
- Optical disk
- Tape
- Magnetic disk

101

Cloud-Based Storage

- Offsite storage and servers supported by a secure network
- 3rd party vendor
- Shifts disaster recovery process to the vendor along with maintenance and storage equipment purchase
- You pay for the service and storage space

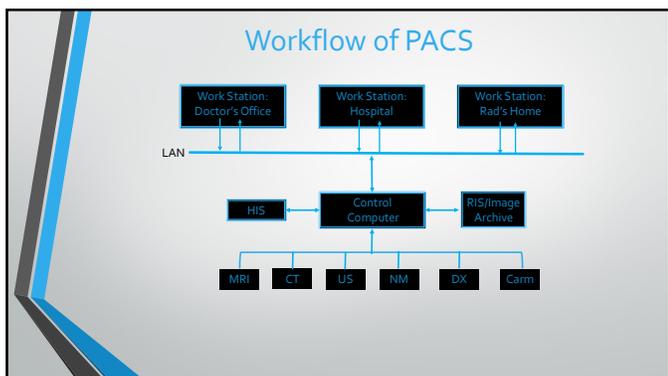
102

Reading Hospital:

- Prior to EPIC - \$1 million budget for record storage
- Legally obligated to retain films:
 - Pediatrics
 - Mammo
 - All other films



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Summary of PACS Functions

- Main function: Act as a *database*
 - Generate and sort according to status (i.e. pending, completed)
 - Various queries – users can search for specific information
- Manipulation – at any workstation
- Storage

105

Vendor Neutral Archives (VNA)

- Allows for images and data from different systems and in different formats to be stored using a singular system on a common infrastructure
- May be used as replacements to existing PACS to avoid very expensive transition costs
- Used to consolidate a number of systems that exist within a single facility or across a system of facilities

106

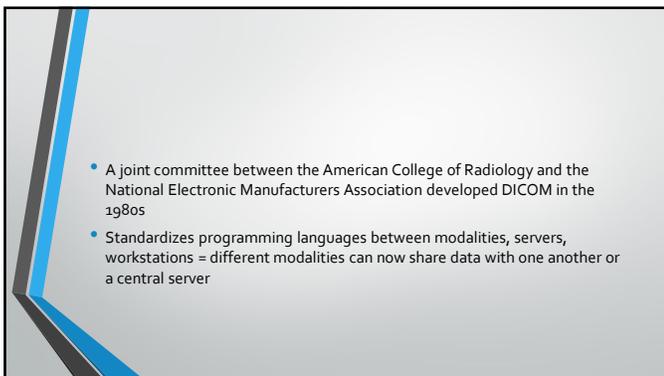
PACS Emergency Contingency Plan

- A backup copy of ALL archived records should be maintained either by the hospital or an Application Service Provider
- RH PACS Downtime Procedure Policy - <https://trh.elucid.com/documents/view/12114/33066/3>

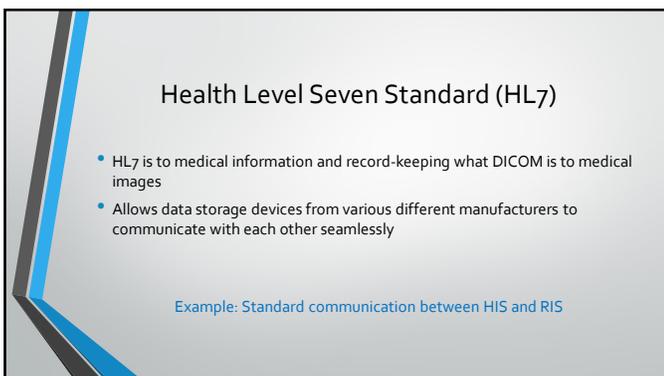
107



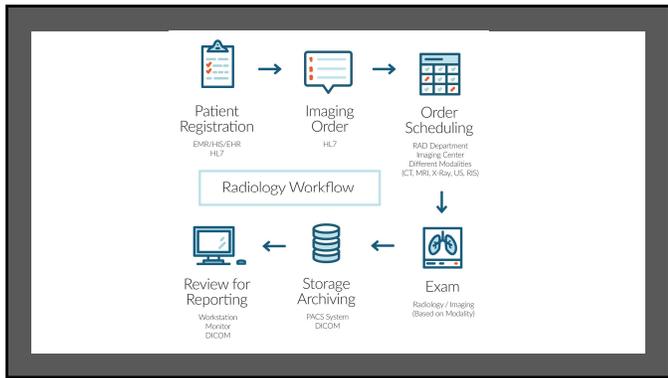
111



112



113



114

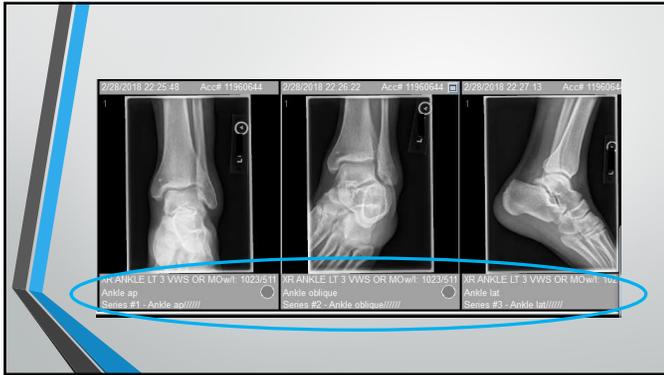
DICOM Header

- A summary of critical identification and study information such as:
 - Date and time of procedure
 - Number of images taken
 - Body part, position
 - Technique used
 - Image format and receptor size
 - Parameters used to digitally process the image
- All this information is stored as **metadata**
 - Should appear in a bar at the top of the screen for each image
 - Shows summary of essential metadata for the image

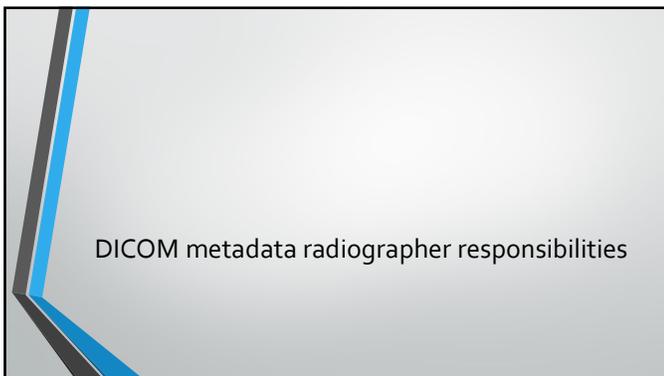
115

Group Tag	Element Tag	Tag Description	Value
0010	0011	Private Tag	MURKIN
0010	0020	Patient ID	12345
0010	0030	Patient's Birth Date	00000000
0010	0040	Patient's Sex	M
0010	1030	Patient's Weight	0
0010	2165	Private Tag	None
0010	2166	Private Tag	None
0010	4000	Patient Comments	
0018	0015	Body Part Examined	THORAX
0018	1000	Device Serial Number	00000000
0018	1020	Software Version(s)	1.0.1.120
0018	1164	Image Field Source	0.16
0018	1508	Positioner Type	COLLIMIN
0018	5100	Patient Position	ANTERIOR - POSTERIOR
0018	7004	Detector Type	DIRECT
0018	7006	Detector Description	
0018	7014	Detector Serial	1.1.1
0020	0020	Study Instance UID	1.2.825.0.1.3680043.2.1330.1000001.1.2213256752.2712337879
0020	000E	Series Instance UID	1.2.825.0.1.3680043.2.1330.1000001.4.2213256752.27123318877
0020	0010	Study ID	None
0020	0011	Series Number	1
0020	0019	Instance Number	29
0020	0020	Patient Orientation	N
0020	0060	Laterality	L
0020	0062	Private Tag	U
0020	4000	Image Comments	
0028	0002	Samples per Pixel	1

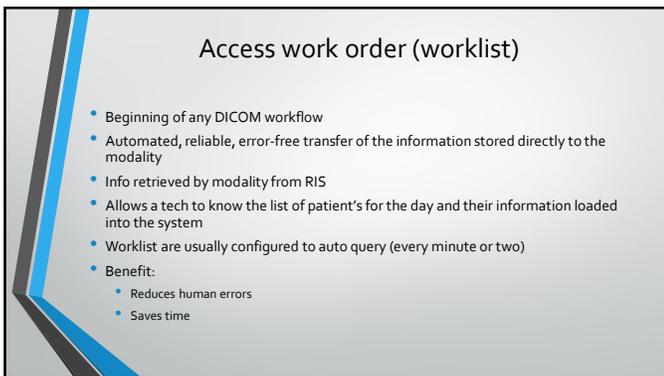
116



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118



119

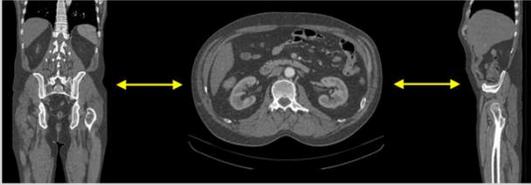
Post Processing – Image operation and manipulation

- Image operation activities
- Multiplanar Reconstruction
- Maximum and Minimum Intensity Projection
- Volume Rendering Technique (VRT)
- Shaded Surface Display (3D technology)
- CAD

120

Multiplanar Reconstruction

- Creates multiple planes of view from a single scan



<https://www.youtube.com/watch?v=H1nPMSVijag>

121

Maximum & Minimum Intensity Projections

- Enhancement of small vessels (MIP) and air-filled structures (MinIP)

MinIP – Minimum Intensity Projections

MIP – Maximum Intensity Projections



MinIP AIP MIP

122

Volume Rendering Technique (VRT)

- Assists in differentiating between anatomical structures by adding color shades based on pixel intensity



123

Shaded Surface Display (SSD)

- Creates a 3D, moveable image based on the pixel intensity of choice



124

CAD (Computer Aided Diagnosis/Detection)

- used as a "second opinion" in assisting radiologists' image interpretations
 - complementary tools that draw the radiologists' attention to certain image areas that need further evaluation
- Uses algorithms
- Used in Mammography at RH



Source: Appl Radiol © 2004 Anderson Publishing, Ltd

125

Annotation Issues: Annotations and Mark Ups

- *Image annotation* – describes the meaning in images
- *Image markup* – visual presentation of the annotation
- AIM Project (Annotation and Image Mark up project)
 - The model contains information about who created the annotation, the equipment with which the annotation was created, when the annotation was created, and the image(s) to which the annotation refers.
 - Once the annotation is defined in the AIM, sophisticated queries are now easily found
 - "Find all studies that contain enhancing right middle lobe lung masses that measure between 5 and 6 cm"

126

- Other concerns are
 - What is more accurate tool to use --- stylus or mouse for marking or measurements?
 - Human error
 - Legal issues

127

Mouse Stylus

128

Case number	Annotation time for mouse (s)	Annotation time for stylus (s)
1	109	86
2	121	71
3	108	70
4	78	74
5	109	91
6	55	57
7	78	77
8	90	54
9	113	60
10	89	85
11	101	98
12	81	41

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Image Transmission

- Concerns of medical data overload
 - CT may produce 300 to 500 images and a CT angiography runoff study may include 1,500 to 2,000 images
- In teleradiology, the header of the DICOM image is first transmitted followed by the compressed image data and then at the receiving end, images are reconstructed from low quality to high (or perfect) quality
- Facilities will compress images to send, this allow it to be sent more efficiently
 - Lossless compression have been defined as "visually acceptable" images by the medical imaging community

130

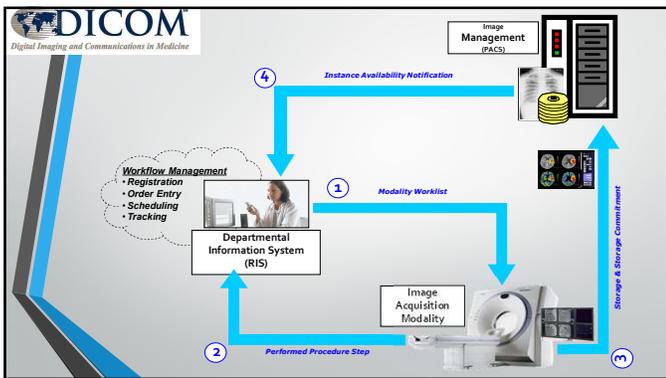
HIPAA

- Health Insurance Portability and Accountability Act of 1996 (HIPAA) Privacy Rule is to ensure you have rights over your own health information, no matter what form it is in.
- The government also created the HIPAA Security Rule to require specific protections to safeguard your electronic health information.
- Federal law requires doctors, hospitals, and other health care providers to notify you of a "breach."
- Facilities should implement high-grade security and encryption in their systems in order to protect records from hackers or theft
- Adhering to HIPAA guidelines often means subjecting software developments to a legal team who can determine whether or not the software falls within HIPAA regulations for security and confidentiality

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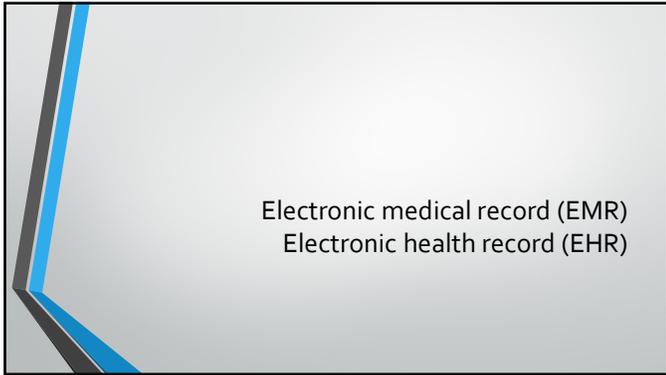
133

DICOM Services for Acquisition Workflow Management

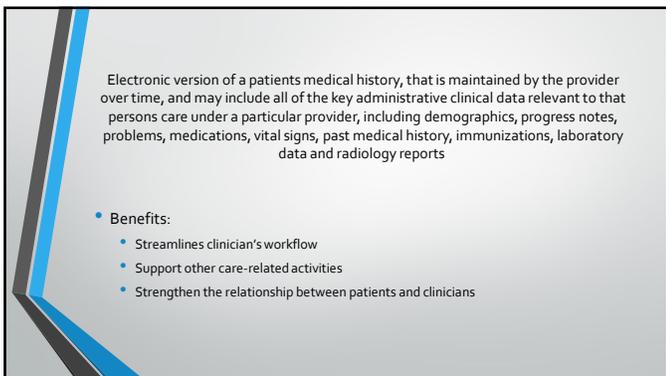
- Improve Interoperability of Imaging Equipment
- Ensure Data Consistency
- Facilitate Reliable Data Management
- Improve Process Efficiency
- Better Quality of Imaging Services

DICOM
Digital Imaging and Communications in Medicine

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135



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137

- Any system which allows remote transmission and viewing of radiographic images via modems over phone or cable lines
- Makes it possible for images to be sent great distances for a specialist to collaborate with a radiologist, and for images stored at a hospital to be accessed almost instantly by doctors at their individual clinics
 - Example: transmit images to radiologist's home during off hours





1



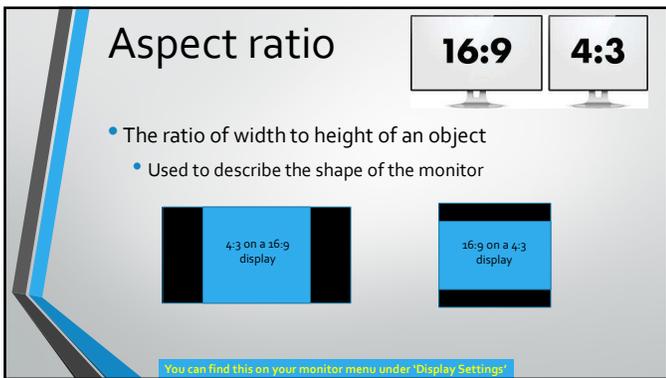
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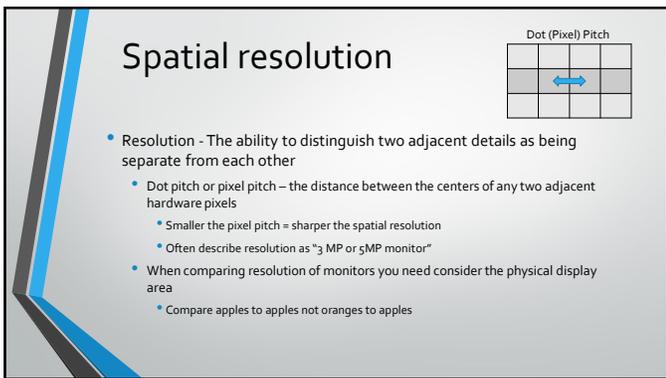
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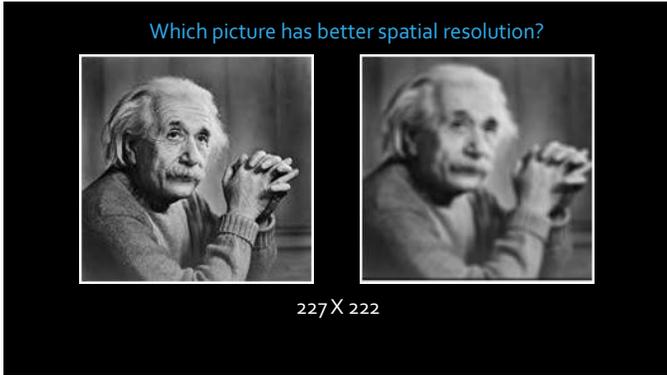
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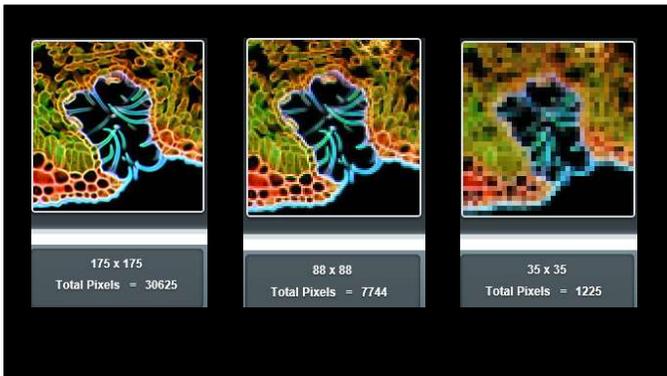
5



6



7



8



9

Brightness

- The black level of a display screen. Although it may sound peculiar, the brightness adjusts the "black level" of the display system (how black the black is) –*Computer Desktop Encyclopedia*
- Photometer is used to measure the brightness output of an LCD
- American College of Radiology (ACR) requires a minimum brightness capability for radiologic display systems of 250 lumens

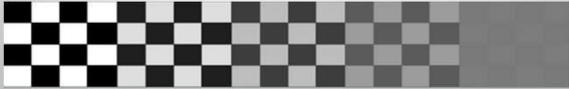


Too dark Good brightness Too bright

10

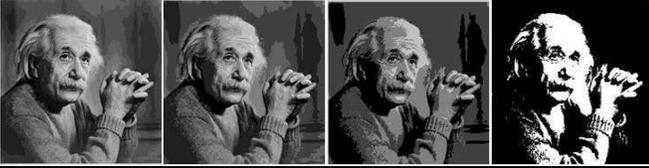
Contrast Ratio

- The difference between the darkest blacks and the brightest whites a given display can produce.
- Contrast ratio for LCD = 600:1, CRT = 3000:1
 - LCD - Inability to produce a "true black" due to backlight leakage



100% Contrast 75% Contrast 50% Contrast 25% Contrast 1% Contrast

12

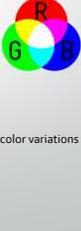


16 Gray Levels 8 Gray Levels 4 Gray Levels 2 Gray Levels

13

Color vs. Grayscale (monochrome)

- **Monochrome monitors**
 - Color images will appear as shades of gray
 - Has only one phosphor of color, but may have the ability to change the brightness causing the illusion of depth
 - Produces sharper text and image because 1 phosphor per pixel than color
- **Color monitors**
 - Monochrome images can be viewed on color monitors
 - Uses alternating intensities of red, green and blue to produce the different color variations
 - Uses 3 phosphors per pixel



15

What color would be seen in a color monitor?

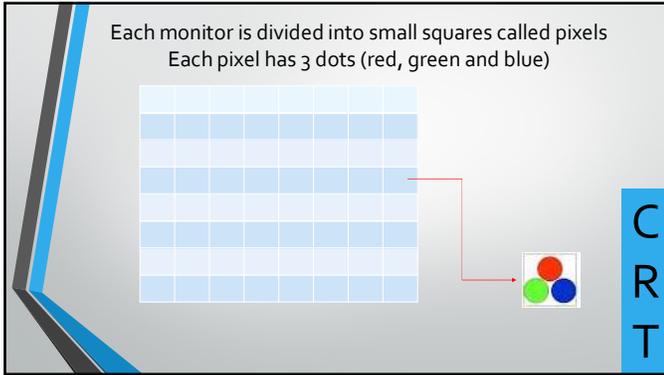
- If all 3 colors set at 0 = **BLACK**
- If all 3 colors set at 255 = **WHITE**
- If red was set at 255 and blue and green at 0 = **RED**

16

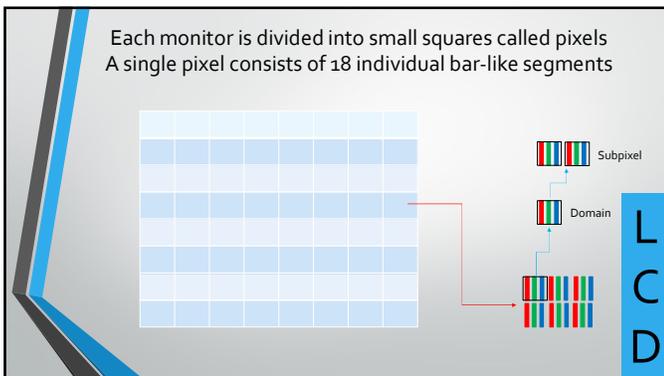
Pixels for Computers

- Pixel – multiple definitions
 - Carroll states it is “the smallest element of the matrix or device that can represent all pixel values within the system’s dynamic range”
- CRT – each triad of color (red, blue, and green) is considered one pixel
- LCD – a single pixel consists of 18 individual bar-like segments
- Hardware pixel in monitor – intersections of flat, transparent wires crossing over each other to form an overall square shape

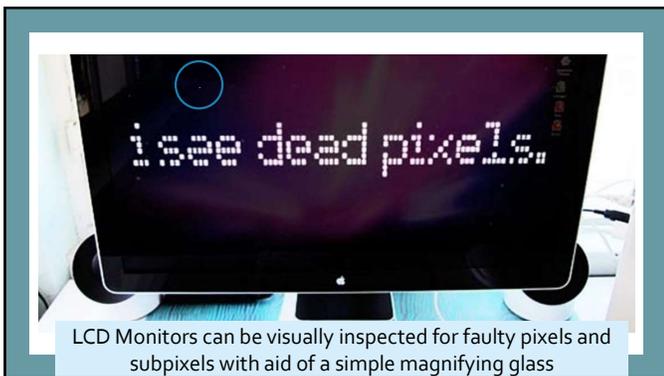
18



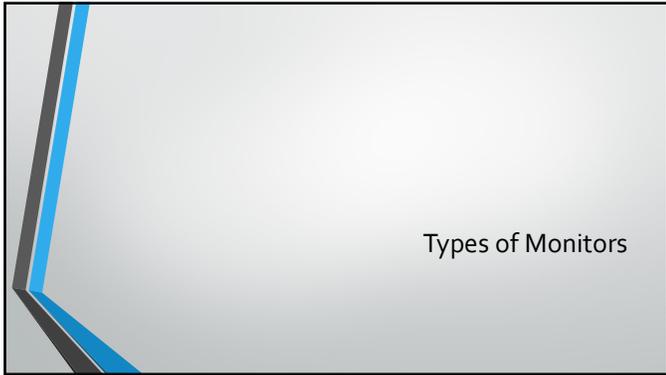
19



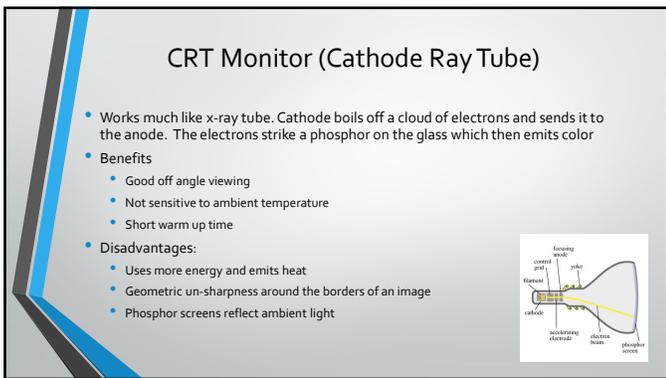
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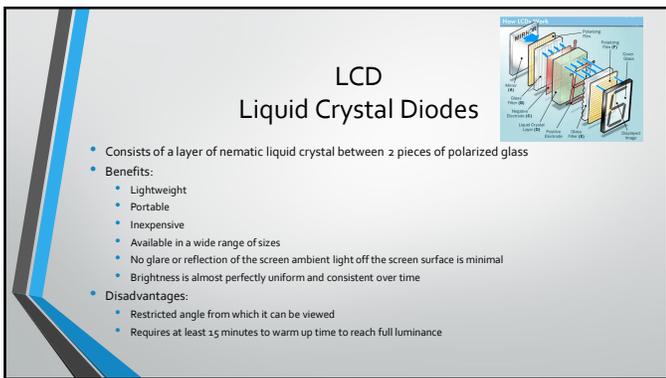
21



23



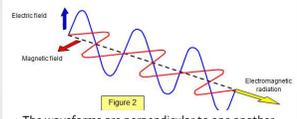
24



25

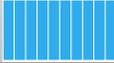
To understand the LCD monitor you must comprehend Light Polarization

- Like an x-ray, a ray of light is electromagnetic radiation that consists of a double wave

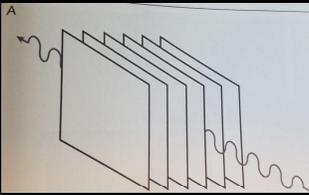


The waveforms are perpendicular to one another

- LCD Monitors use polarized glass
 - Polarized glass contains long chains of iodine molecules, all aligned parallel to each other
 - Just like a grid strips in a grid

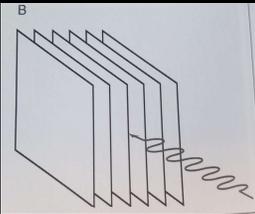


26



Electrical

The electrical component of the double wave can pass through a polarized glass with vertical string molecules because it vibrates parallel to it

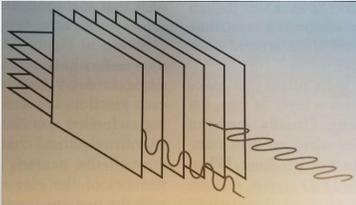


Magnetic

The magnetic component of the double wave cannot pass through a polarized glass with vertical string molecules because it vibrates perpendicular to it

27

What will happen if you layer 2 polarizing glass together so the string molecules are perpendicular to each other?



28

LCD – Light polarization

- LCD monitor consists of:
 - 2 thin sheets of glass
 - Each with a light polarizing layer that are perpendicular to the other sheet

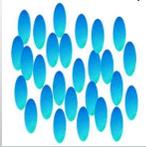
Perpendicular sheets = ALL light being blocked

Don't worry, the LCD process involves "tricking" these layers into allowing light to pass

29

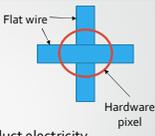
What are nematic liquid crystals?

- This is what is inserted between the polarizing glass sheets/lenses that plays the trick
- A crystalline arrangement of molecules that have a long linear shape and tend to align parallel to each other



30

Before we see the "trick", you need to know one more thing....



- In the polarizing glass there are a layer of thin, flat wires to conduct electricity
- These conductors are also aligned perpendicular to each other when the 2 polarized glass are together
- Each junction forms a single **hardware pixel**
 - Each electrode has a scratch on it
 - Scratches are perpendicular to one another
 - The crystals tend to line up with the "scratch" direction when no electric charge is present -- **known as "on" state**

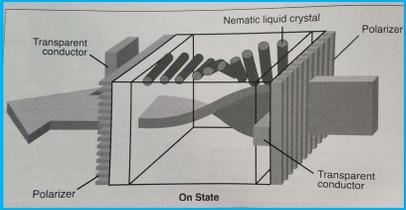
31

And **FINALLY**, Here is the Magic Trick.....



<https://www.youtube.com/watch?v=jiejNAUwcQ8>

32

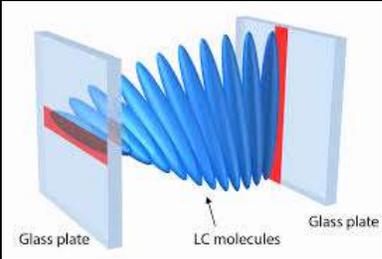


"ON" STATE

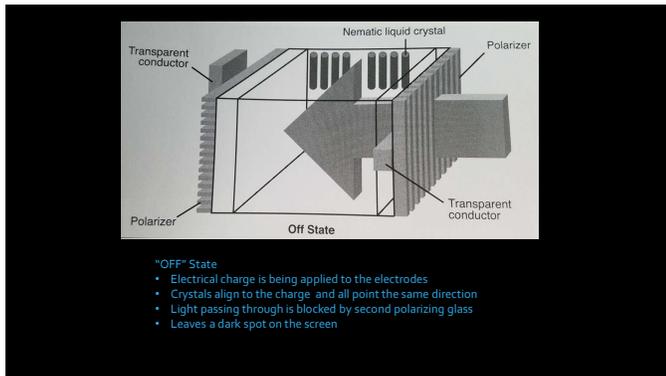
- Since the scratches are perpendicular, the liquid crystals line up in a spiral pattern that twists 90 degrees between the two glass plates
- This lets light waves pass through the nematic liquid crystal and follow the spiral
- Light is able to pass through the second glass plate to the viewer of the monitor

33

Just another way to look at it



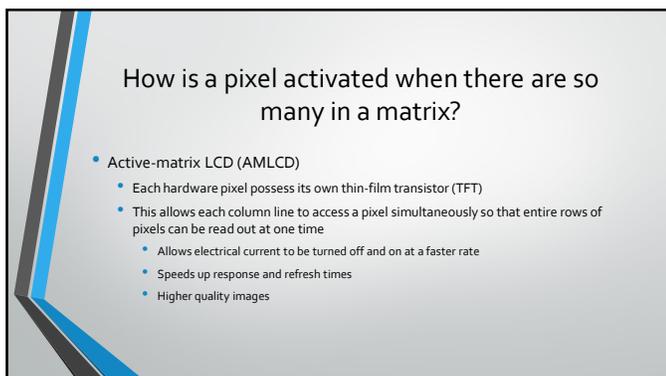
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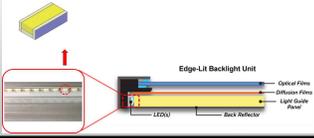
36



37

More info on LCD Monitors

- As LCDs **do not** produce light by themselves—they need illumination to produce a visible image.
 - Without a **backlight**, an LCD display device will remain black, rendering it unviewable
- **Backlighting**
 - Types: Fluorescent bulbs or light-emitting diodes (LEDs)
 - LED - Most common



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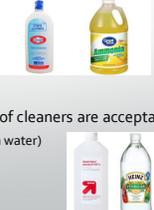
Care and Maintenance

39

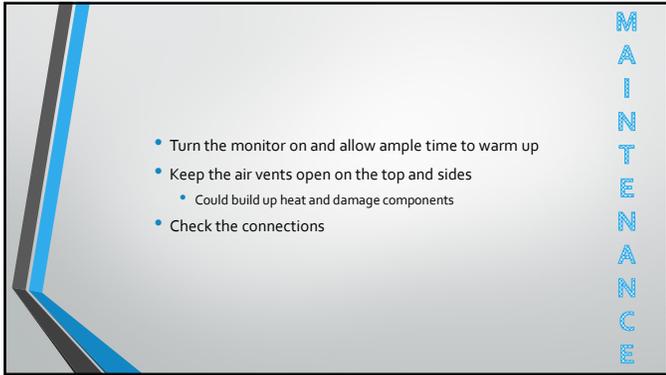
CARE

1. Apply cleaning solution to soft cloth
 - Do not spray solution directly on screen
 - Do not use paper towel can cause scratches
2. Wipe in one direction from top of screen to bottom

- The following cleaners should NOT be used: Acetone
 - Ethyl alcohol
 - Ethyl acid
 - Ammonia
 - Methyl chloride
- The following types of cleaners are acceptable: Water
 - Vinegar (mixed with water)
 - Isopropyl Alcohol
 - Petroleum Benzene



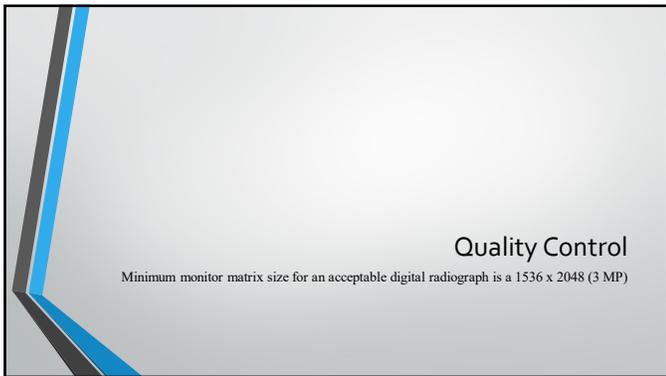
40



M-A-I-N-T-E-N-A-N-C-E

- Turn the monitor on and allow ample time to warm up
- Keep the air vents open on the top and sides
 - Could build up heat and damage components
- Check the connections

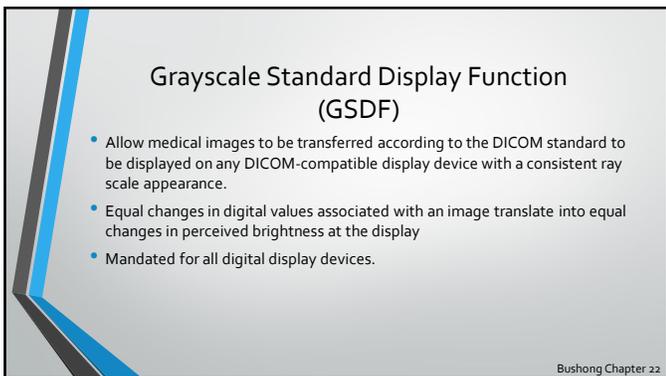
41



Quality Control

Minimum monitor matrix size for an acceptable digital radiograph is a 1536 x 2048 (3 MP)

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Grayscale Standard Display Function (GSDf)

- Allow medical images to be transferred according to the DICOM standard to be displayed on any DICOM-compatible display device with a consistent ray scale appearance.
- Equal changes in digital values associated with an image translate into equal changes in perceived brightness at the display
- Mandated for all digital display devices.

Bushong Chapter 22

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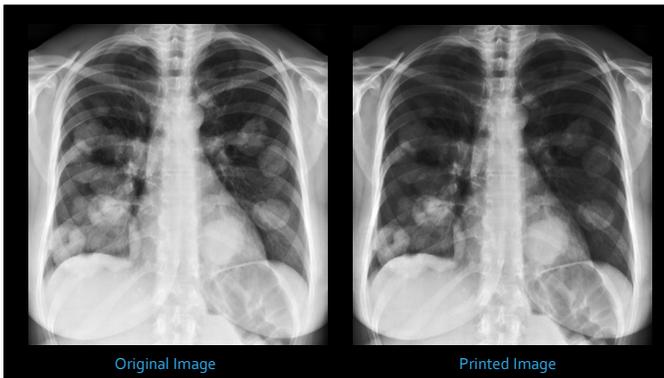
DICOM Grayscale Standard Display Function (GSDF) generates a display function matching the perceptual characteristics of a human observer.

Standard developed having human observer view monitor while luminance output of monitor changed in small steps from black to white and noting when they observed a **Just Noticeable Difference** (JND) in light output as the drive signal is changed.

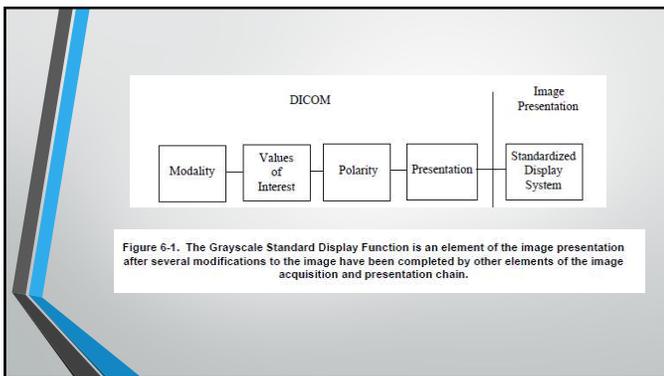
Most digital radiologic images are windowed to attempt to display 256 different shades of gray at any one time, (256 is approximate JND that humans can perceive)

The perceptual linearization implemented with the DICOM Grayscale Standard Display Function (GSDF) ensures that pixel values that are supposed to increase brightness in a linear fashion, say 6, 7, and 8, for example, actually appear that way to the human eye, despite the nonlinearity of our perception.

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Luminance

The rate of light (brightness) emitted from a source such as an LCD monitor

- **Maximum luminance** (*maximum brightness*)- checked at same monitor setting over a period of time with a photometer
- **Luminance response** – monitors ability to accurately display different shades of brightness from a test pattern
- **Luminance ratio** – compares maximum luminance to the minimum luminance
- **Luminance uniformity** – consistency of a single brightness level displayed across the area of the screen

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Luminance Ratio

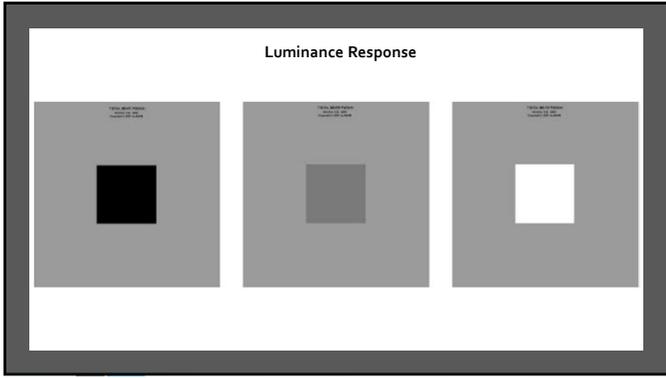
48

Luminance Response

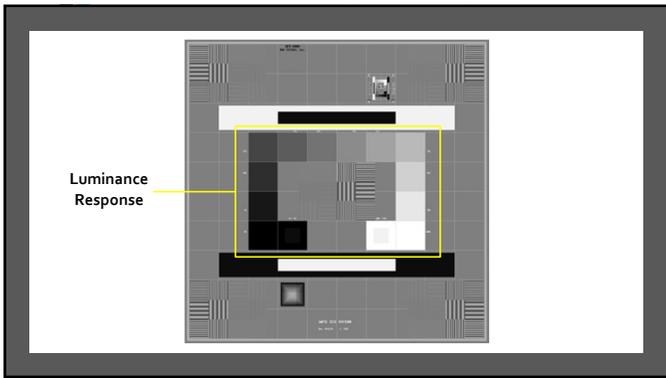
TGS-CT Pattern
Version 2.0, 10/11
Copyright © 2011 by Avance

A

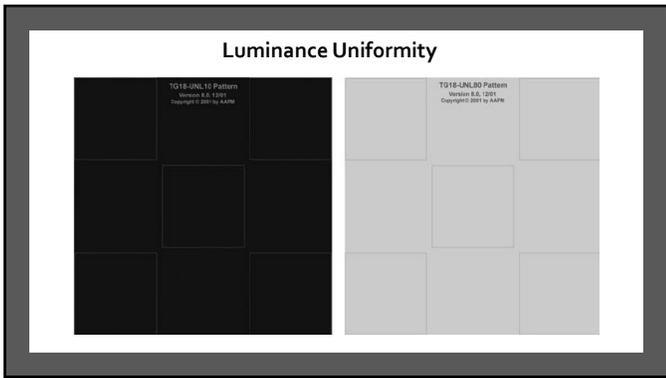
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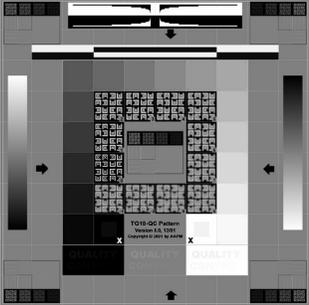
52

Resolution

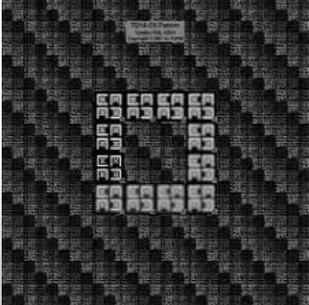
- ACR and AAPM minimum resolution for electronically displayed images of 2.5LP/mm
 - Generic SMPTE test pattern can be used
 - Check for blurring
- AAPM TG18 – QC and TG 18 CX provides an excellent check for resolution across the area of the display screen
 - Evaluate the CX pattern in the middle and in the corners
- Test can be done daily, weekly or monthly

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TG18 - QC

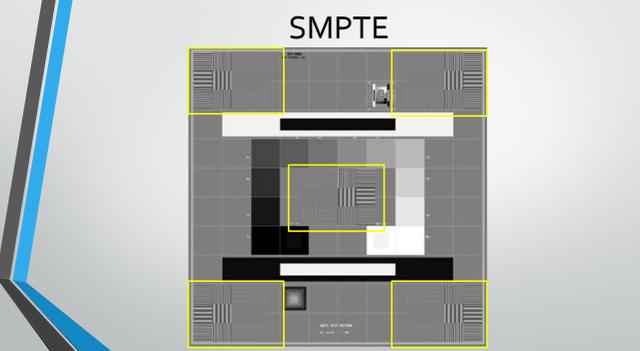


TG18 - CX

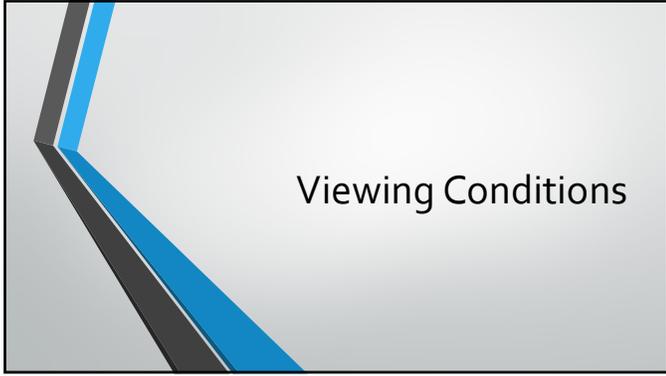


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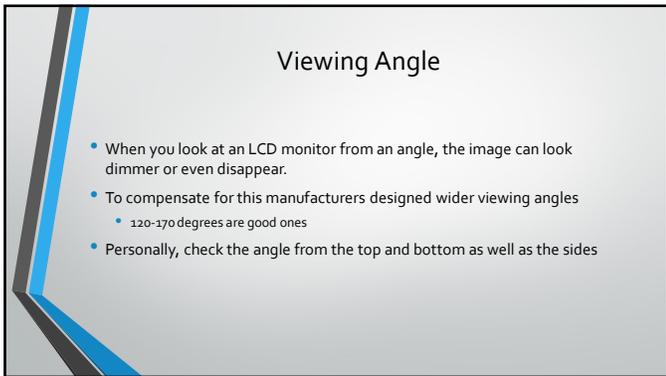
SMPTE



55



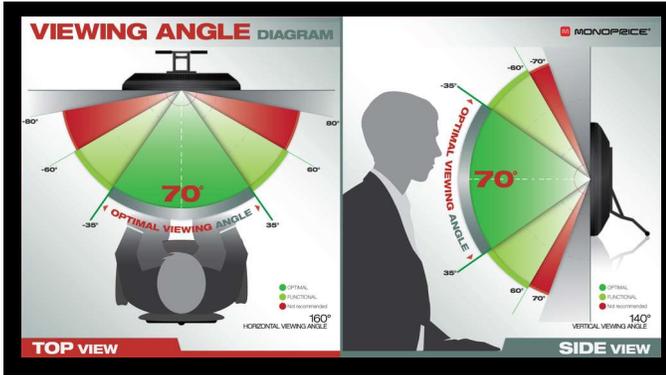
57



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60

Ambient Lighting

Illuminance – the rate of light striking a surface

- The effect of ambient room lighting on the surface of and LCD monitor screen, including **reflectance** off the screen, and the resulting reduction in visible contrast of the image, is a result of **illuminance**
- Diffuse reflectance
 - The cumulative effect of room lighting across the area of the monitor screen
- Specular reflectance
 - The reflection of actual light sources such as a light bulb or window

The ambient lighting within the room must be dimmed to a point where both types of reflectance are below any noticeable level, that would impede full visibility of the image and image contrast

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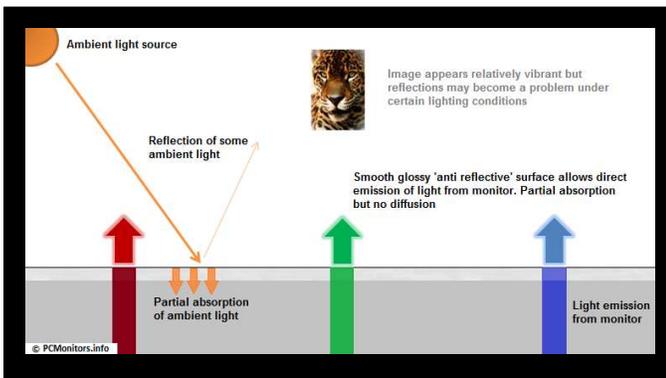
QC Aspect or Ambient Light

- While diagnosis is taking place, the maximum ambient lighting in a reading room should never be more than 25 lux
 - Approximately 1/4 the typical brightness of normal office lighting (75-100 lux)

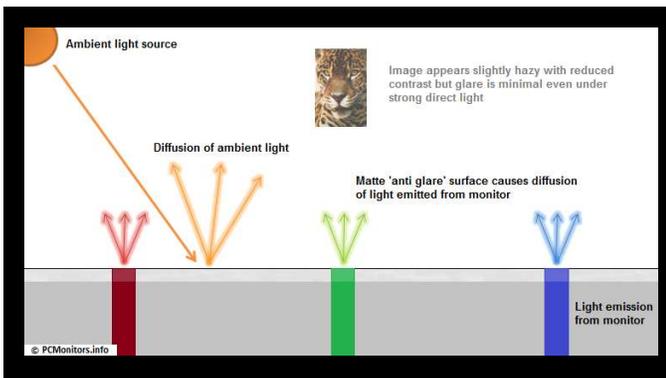
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64



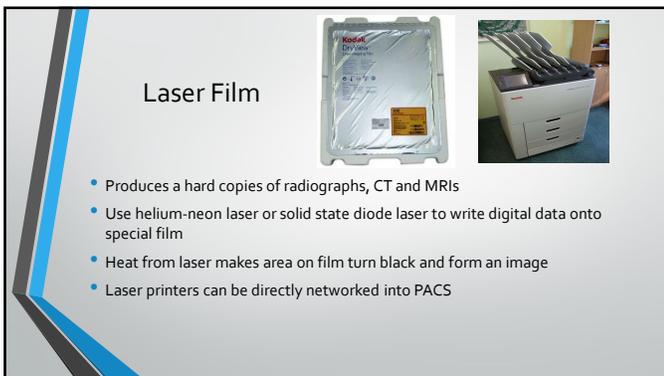
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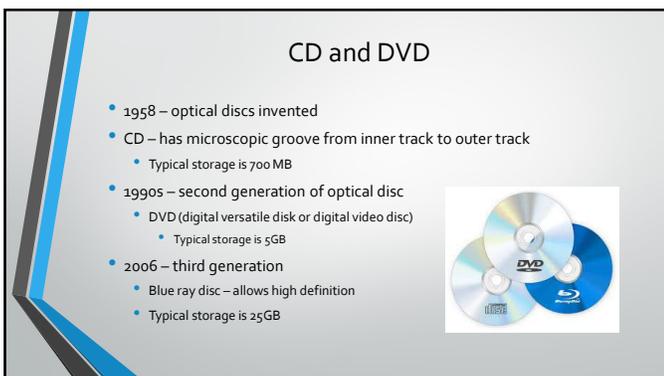
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68



69

Data Management

75

Network Connectivity

- LAN – Local Area Network
 - Computerized communications network generally contained within a single building or business
 - Devices share one server
- WAN – Wide Area Network
 - Extends to other businesses or locations that may be at great distances
 - Publically or commercially owned
 - Uses transmission services provided by common carriers (phone or cable companies)



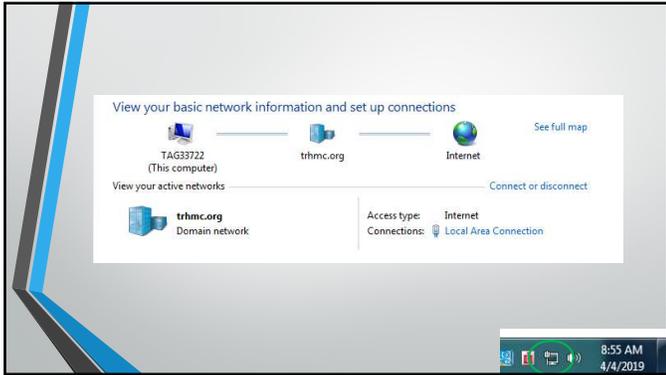
76

Computer Network

- Every computer within a network has a unique internet protocol or IP address
 - Ex. 172.811.3.1
- Every computer must have a network interface card
- Router
 - Connects 2 or more networks
 - Wireless routers – allow "point-of-care" access to a network for physicians and other caregivers via tablet or laptop



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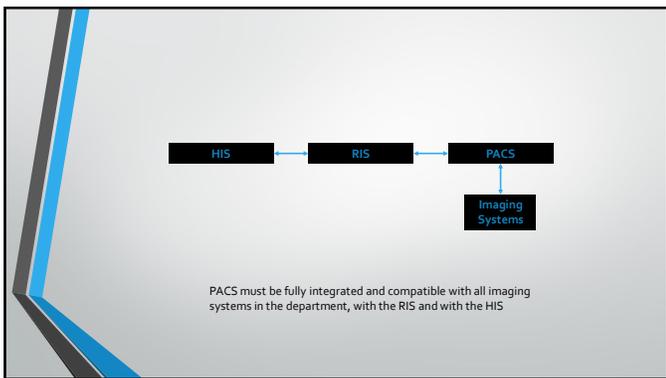
78

Type of LAN

RIS and HIS

- Radiology Information System
 - Data system for patient-related functions in the department, such as scheduling of x-ray appointments, tracking of patients, storage and distribution of reports
 - Makes info accessible from different locations within the radiology department
 - Assigns the **accession number**
- Hospital/Health Information System
 - Performs same functions for the entire institution (patient's general medical file)
 - Assigns a unique identifying number for each patient (**MRN**)

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80

Picture Archiving and Communications System (PACS)

- Comprehensive computer network that is responsible for the electronic storage and distribution of medical images.
- Makes radiographs, CT and MRI scans, US and Nuclear Med images for a particular patient available within the network
- Allows Radiologists and Technologist to access these images from various locations, improving the efficiency of communication

Soon to be Called....
Medical image management and processing system (MIMPS)

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PACS

- Digital acquisition (Picture)
- Display workstations
- Storage devices (Archiving)
- Components are interconnected by a network (Communication)

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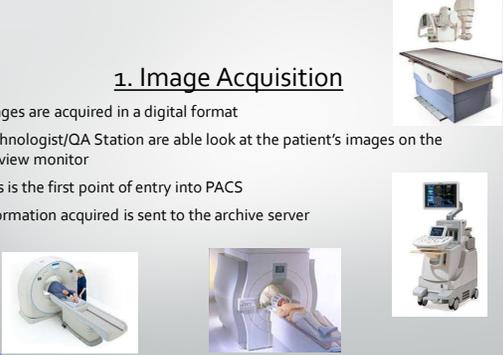
Components of PACS

- Image acquisition
- Display workstations
- Archive servers

83

1. Image Acquisition

- Images are acquired in a digital format
- Technologist/OA Station are able look at the patient's images on the preview monitor
- This is the first point of entry into PACS
- Information acquired is sent to the archive server



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2. Display Workstations

Any computer used to view digital images

- Radiologists
- Physicians, surgeons, nurses & patients
- Technologists

- Most interactive part of PACS
- Used inside and out of Radiology
- Has PACS application software that allows minor image-manipulation

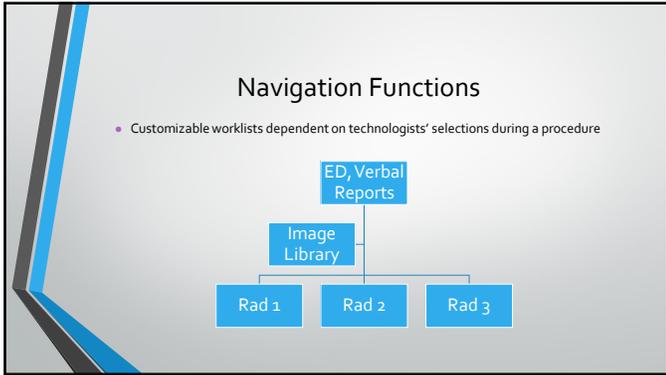


85

Common Workstation Functions

- Navigation Functions
- Hanging Protocol
- Study Navigation
- Image Manipulation & Enhancement
- Image Management

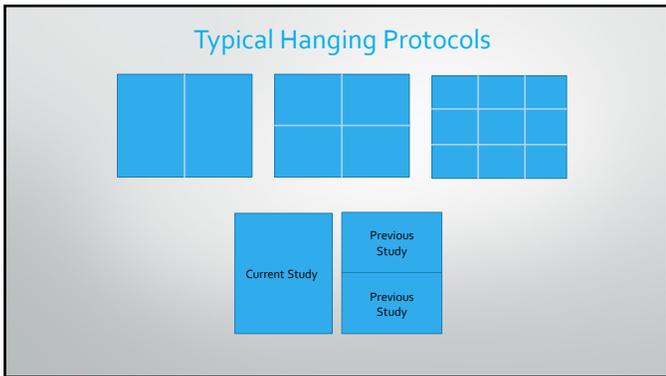
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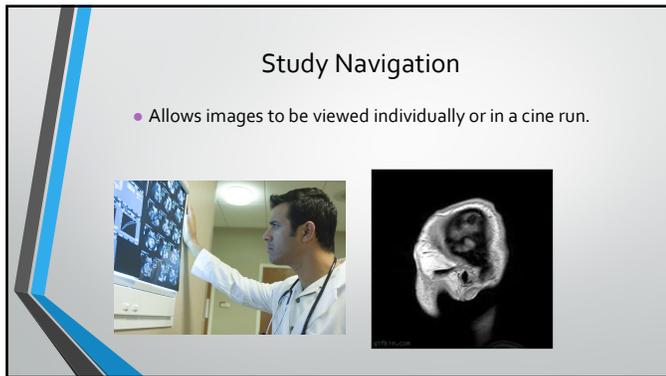
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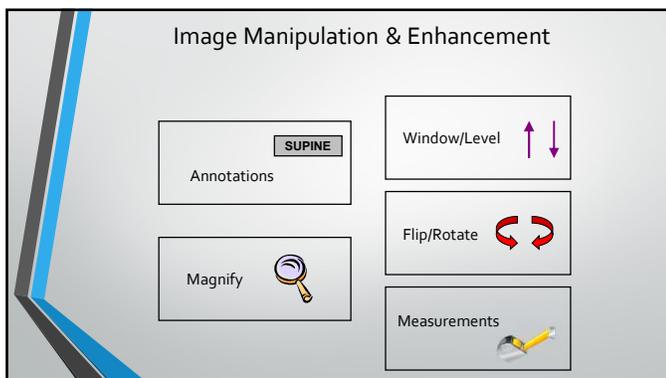
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89



90



91



92

Image Management Functions

- Patient demographics
 - Edit patient information for proper correlation with previous studies, billing, etc.
- Query / Retrieve
 - Locate images based on patient demographics
- Hardcopy images
 - Either CD or plain film
 - Usually only image library has this function

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3. Archive Servers

- File room of PACS
- Contains all historic and current data



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PACS Archiving

- Consist of:
 - Image manager/controller
 - Image storage/server



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Image Manager

- Contains master database of everything in the archive
- Controls the receipt, retrieval and distribution of the images it stores
- Controls all the DICOM processes running within the archive
- Communicates with RIS and HIS
- Can populate image information into the EMR

MANAGER

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97

Image Storage/Archive Server

- Physical storage device for archive system
- Network of servers
- Setup in tiers
 - Short-term
 - Long-term

In the United States, storage requirement of a patient's images is from five to seven years.

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Short Term Storage

- RAID
 - several magnetic disks or hard drives that are linked together in an array

RAID 5 is the most common level used for a PACS archive because it provides adequate redundancy and fault tolerance

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Reading Hospital

- Short-term storage is done on servers located in IMS but maintained by Philips
 - Philips monitors the system through remote access
 - All backups and drive redundancy are handled by Philips

100

Long Term Storage

- RAID
- Optical disk
- Tape
- Magnetic disk

101

Cloud-Based Storage

- Offsite storage and servers supported by a secure network
- 3rd party vendor
- Shifts disaster recovery process to the vendor along with maintenance and storage equipment purchase
- You pay for the service and storage space

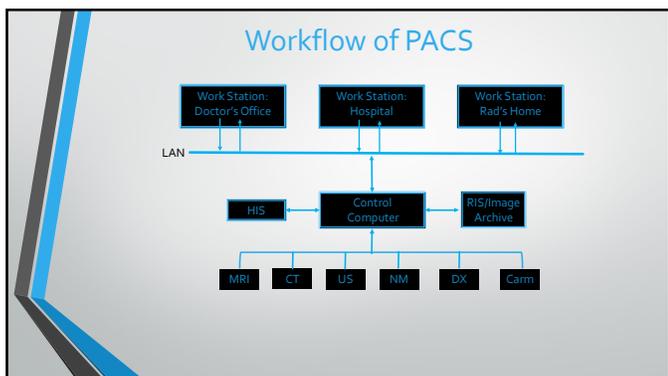
102

Reading Hospital:

- Prior to EPIC - \$1 million budget for record storage
- Legally obligated to retain films:
 - Pediatrics
 - Mammo
 - All other films



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Summary of PACS Functions

- Main function: Act as a *database*
 - Generate and sort according to status (i.e. pending, completed)
 - Various queries – users can search for specific information
- Manipulation – at any workstation
- Storage

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Vendor Neutral Archives (VNA)

- Allows for images and data from different systems and in different formats to be stored using a singular system on a common infrastructure
- May be used as replacements to existing PACS to avoid very expensive transition costs
- Used to consolidate a number of systems that exist within a single facility or across a system of facilities

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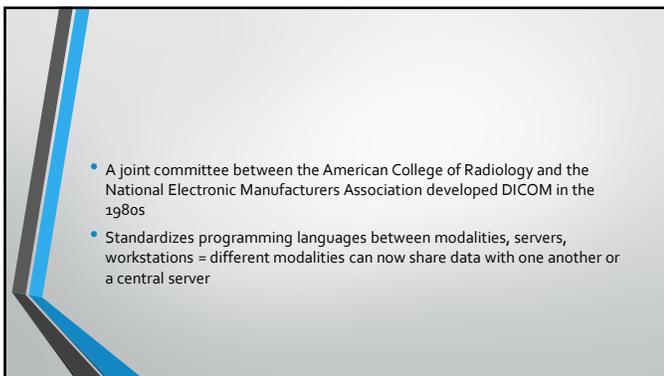
PACS Emergency Contingency Plan

- A backup copy of ALL archived records should be maintained either by the hospital or an Application Service Provider
- RH PACS Downtime Procedure Policy - <https://trh.elucid.com/documents/view/12114/33066/3>

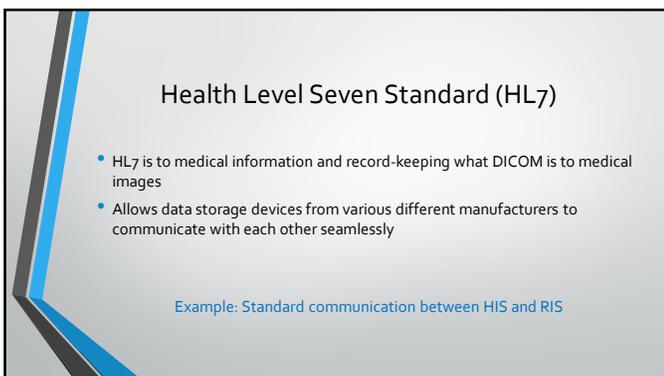
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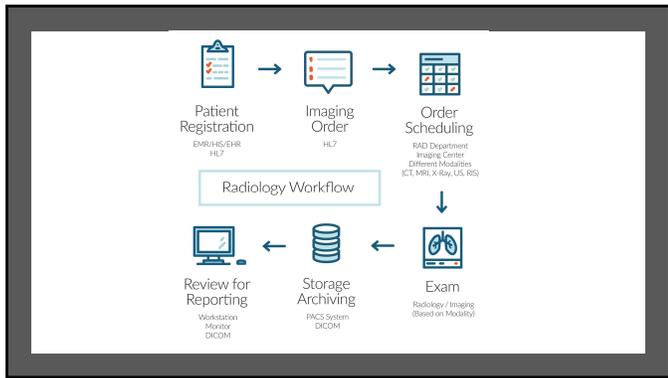
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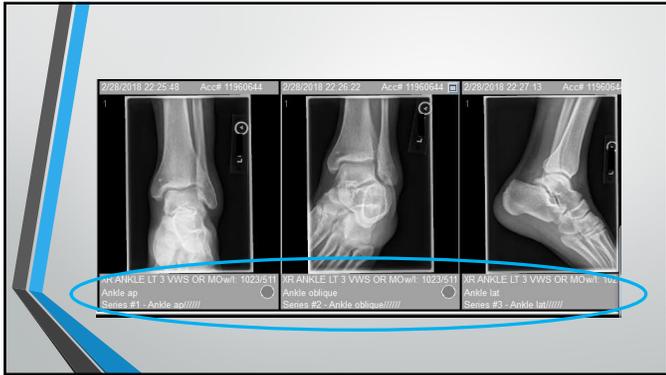
DICOM Header

- A summary of critical identification and study information such as:
 - Date and time of procedure
 - Number of images taken
 - Body part, position
 - Technique used
 - Image format and receptor size
 - Parameters used to digitally process the image
- All this information is stored as **metadata**
 - Should appear in a bar at the top of the screen for each image
 - Shows summary of essential metadata for the image

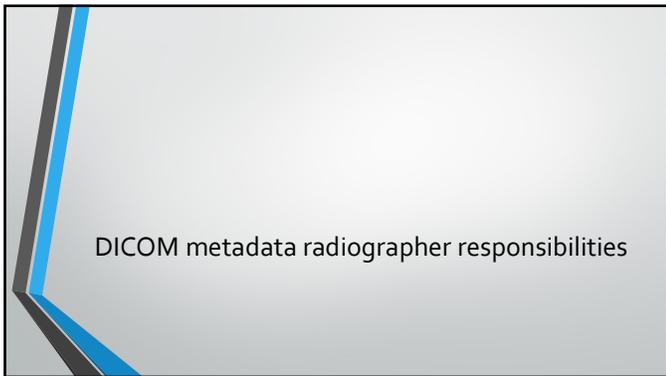
115

Group Tag	Element Tag	Tag Description	Value
0010	0011	Private Tag	MURKIN
0010	0020	Patient ID	12345
0010	0030	Patient's Birth Date	00000000
0010	0040	Patient's Sex	M
0010	1030	Patient's Weight	0
0010	2165	Private Tag	None
0010	2166	Private Tag	None
0010	4000	Patient Comments	
0018	0015	Body Part Examined	THORAX
0018	1000	Device Serial Number	00000000
0018	1020	Software Version(s)	1.0.1.120
0018	1164	Image Field Source	0.16
0018	1508	Positioner Type	COLLIMIN
0018	5100	Patient Position	ANTERIOR - POSTERIOR
0018	7004	Detector Type	DIRECT
0018	7006	Detector Description	
0018	7014	Detector Serial	1.1.1
0020	0020	Study Instance UID	1.2.826.0.1.3680043.2.1330.1000001.1.2211256762.2712337879
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0020	0010	Study ID	None
0020	0011	Series Number	1
0020	0019	Instance Number	29
0020	0020	Patient Orientation	N
0020	0060	Laterality	L
0020	0062	Private Tag	U
0020	4000	Image Comments	
0028	0002	Samples per Pixel	1

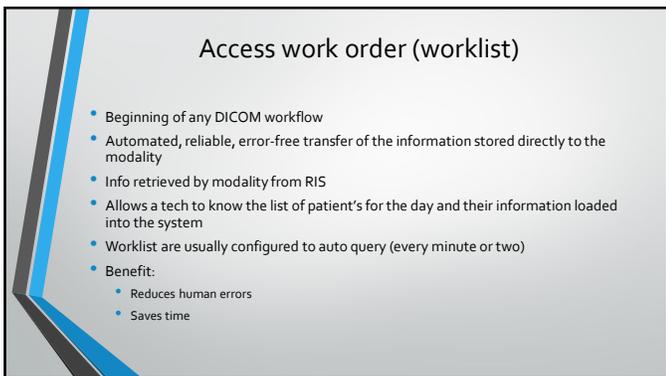
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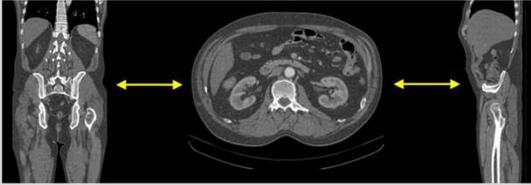
Post Processing – Image operation and manipulation

- Image operation activities
- Multiplanar Reconstruction
- Maximum and Minimum Intensity Projection
- Volume Rendering Technique (VRT)
- Shaded Surface Display (3D technology)
- CAD

120

Multiplanar Reconstruction

- Creates multiple planes of view from a single scan



<https://www.youtube.com/watch?v=H1nPMSVijag>

121

Maximum & Minimum Intensity Projections

- Enhancement of small vessels (MIP) and air-filled structures (MinIP)

MinIP – Minimum Intensity Projections

MIP – Maximum Intensity Projections



MinIP AIP MIP

122

Volume Rendering Technique (VRT)

- Assists in differentiating between anatomical structures by adding color shades based on pixel intensity



123

Shaded Surface Display (SSD)

- Creates a 3D, moveable image based on the pixel intensity of choice



124

CAD (Computer Aided Diagnosis/Detection)

- used as a "second opinion" in assisting radiologists' image interpretations
 - complementary tools that draw the radiologists' attention to certain image areas that need further evaluation
- Uses algorithms
- Used in Mammography at RH



Source: Appl Radiol © 2004 Anderson Publishing, Ltd

125

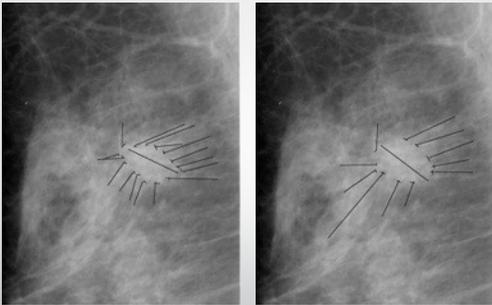
Annotation Issues: Annotations and Mark Ups

- *Image annotation* – describes the meaning in images
- *Image markup* – visual presentation of the annotation
- AIM Project (Annotation and Image Mark up project)
 - The model contains information about who created the annotation, the equipment with which the annotation was created, when the annotation was created, and the image(s) to which the annotation refers.
 - Once the annotation is defined in the AIM, sophisticated queries are now easily found
 - "Find all studies that contain enhancing right middle lobe lung masses that measure between 5 and 6 cm"

126

- Other concerns are
 - What is more accurate tool to use --- stylus or mouse for marking or measurements?
 - Human error
 - Legal issues

127



Mouse Stylus

128

Case number	Annotation time for mouse (s)	Annotation time for stylus (s)
1	109	86
2	121	71
3	108	70
4	78	74
5	109	91
6	55	57
7	78	77
8	90	54
9	113	60
10	89	85
11	101	98
12	81	41

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Image Transmission

- Concerns of medical data overload
 - CT may produce 300 to 500 images and a CT angiography runoff study may include 1,500 to 2,000 images
- In teleradiology, the header of the DICOM image is first transmitted followed by the compressed image data and then at the receiving end, images are reconstructed from low quality to high (or perfect) quality
- Facilities will compress images to send, this allow it to be sent more efficiently
 - Lossless compression have been defined as "visually acceptable" images by the medical imaging community

130

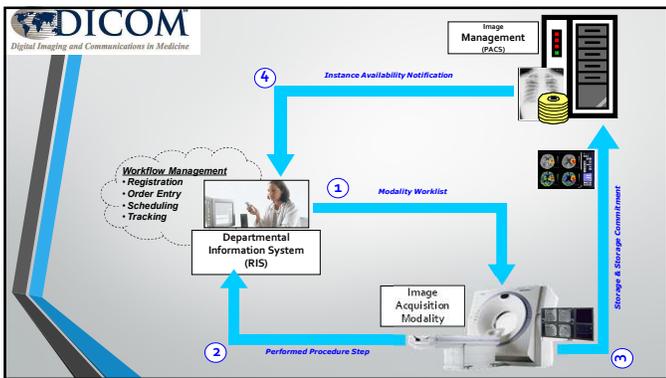
HIPAA

- Health Insurance Portability and Accountability Act of 1996 (HIPAA) Privacy Rule is to ensure you have rights over your own health information, no matter what form it is in.
- The government also created the HIPAA Security Rule to require specific protections to safeguard your electronic health information.
- Federal law requires doctors, hospitals, and other health care providers to notify you of a "breach."
- Facilities should implement high-grade security and encryption in their systems in order to protect records from hackers or theft
- Adhering to HIPAA guidelines often means subjecting software developments to a legal team who can determine whether or not the software falls within HIPAA regulations for security and confidentiality

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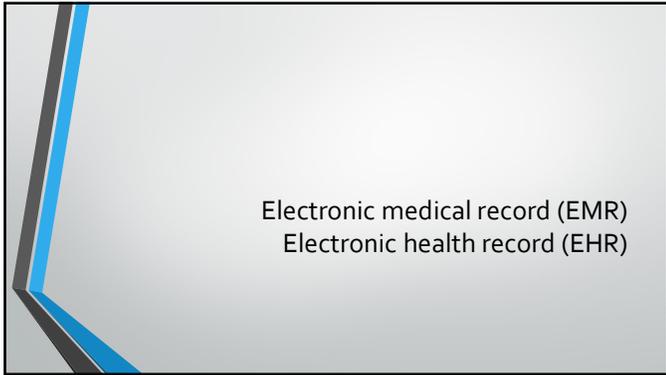
133

DICOM Services for Acquisition Workflow Management

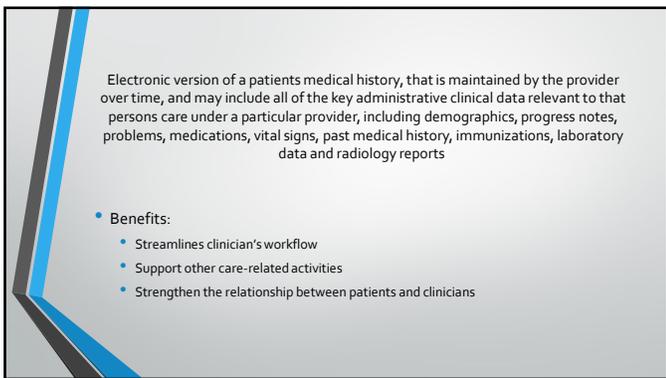
- Improve Interoperability of Imaging Equipment
- Ensure Data Consistency
- Facilitate Reliable Data Management
- Improve Process Efficiency
- Better Quality of Imaging Services

DICOM
Digital Imaging and Communications in Medicine

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135



136



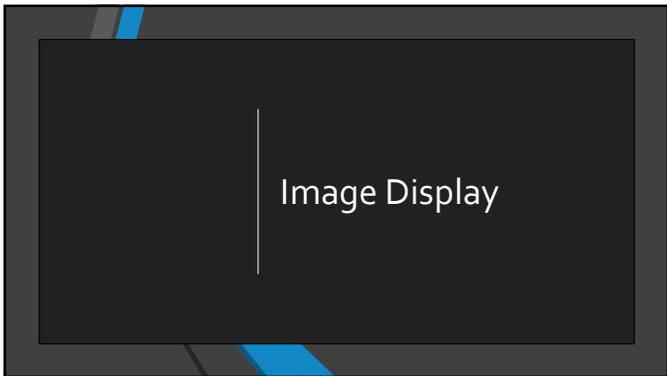
137

- Any system which allows remote transmission and viewing of radiographic images via modems over phone or cable lines
- Makes it possible for images to be sent great distances for a specialist to collaborate with a radiologist, and for images stored at a hospital to be accessed almost instantly by doctors at their individual clinics
 - Example: transmit images to radiologist's home during off hours





1



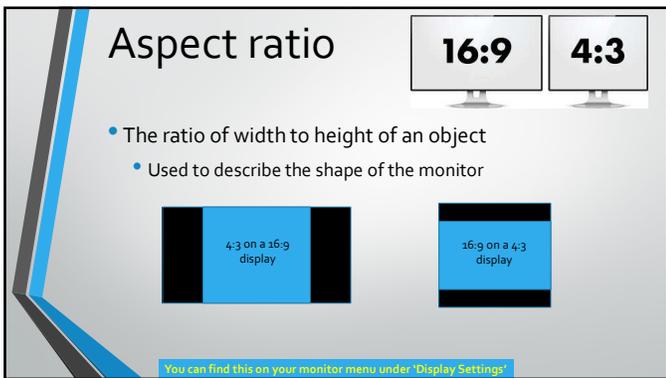
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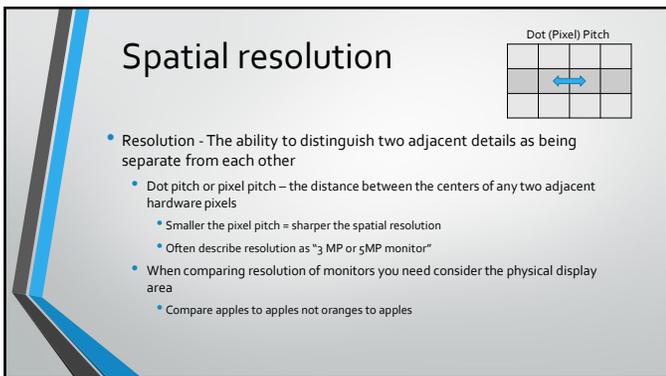
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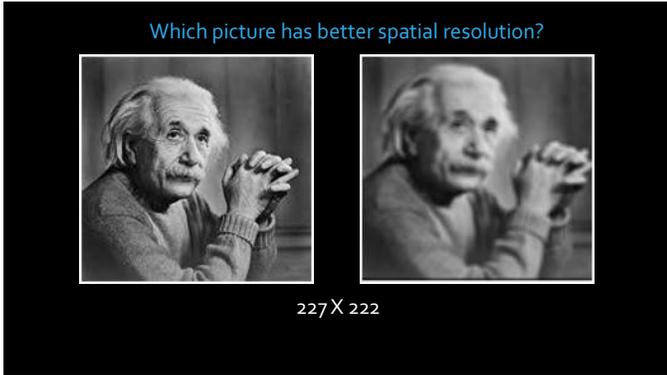
4



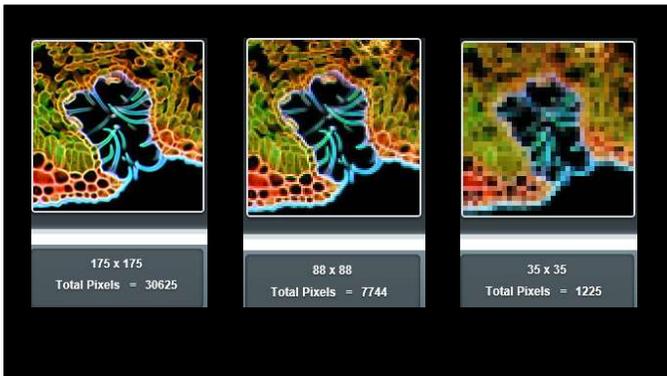
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6



7



8



9

Brightness

- The black level of a display screen. Although it may sound peculiar, the brightness adjusts the "black level" of the display system (how black the black is) –*Computer Desktop Encyclopedia*
- Photometer is used to measure the brightness output of an LCD
- American College of Radiology (ACR) requires a minimum brightness capability for radiologic display systems of 250 lumens



Too dark Good brightness Too bright

10

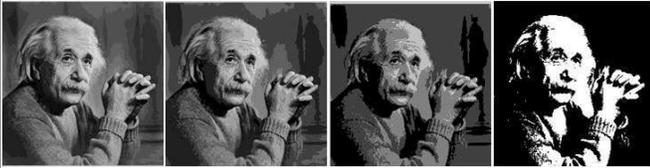
Contrast Ratio

- The difference between the darkest blacks and the brightest whites a given display can produce.
- Contrast ratio for LCD = 600:1, CRT = 3000:1
 - LCD - Inability to produce a "true black" due to backlight leakage



100% Contrast 75% Contrast 50% Contrast 25% Contrast 1% Contrast

12

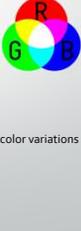


16 Gray Levels 8 Gray Levels 4 Gray Levels 2 Gray Levels

13

Color vs. Grayscale (monochrome)

- **Monochrome monitors**
 - Color images will appear as shades of gray
 - Has only one phosphor of color, but may have the ability to change the brightness causing the illusion of depth
 - Produces sharper text and image because 1 phosphor per pixel than color
- **Color monitors**
 - Monochrome images can be viewed on color monitors
 - Uses alternating intensities of red, green and blue to produce the different color variations
 - Uses 3 phosphors per pixel



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What color would be seen in a color monitor?

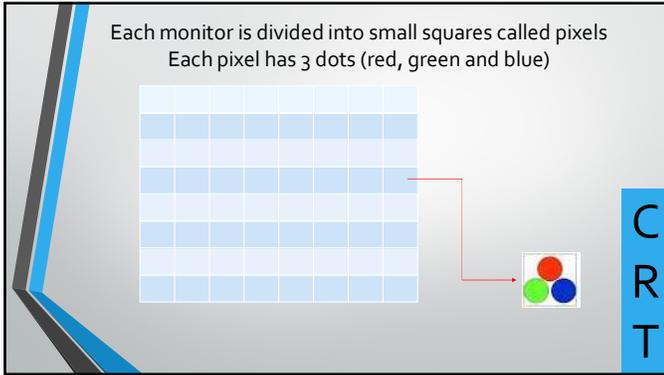
- If all 3 colors set at 0 = **BLACK**
- If all 3 colors set at 255 = **WHITE**
- If red was set at 255 and blue and green at 0 = **RED**

16

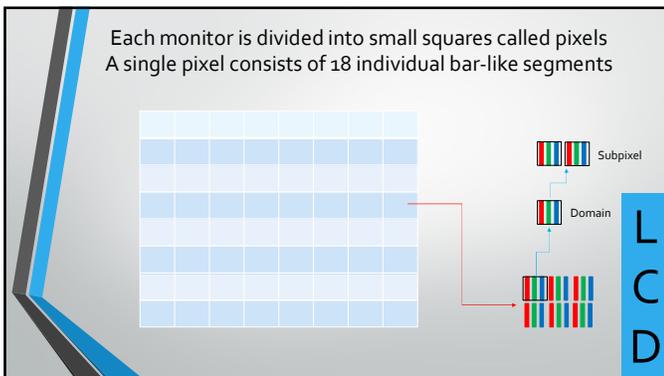
Pixels for Computers

- Pixel – multiple definitions
 - Carroll states it is “the smallest element of the matrix or device that can represent all pixel values within the system’s dynamic range”
- CRT – each triad of color (red, blue, and green) is considered one pixel
- LCD – a single pixel consists of 18 individual bar-like segments
- Hardware pixel in monitor – intersections of flat, transparent wires crossing over each other to form an overall square shape

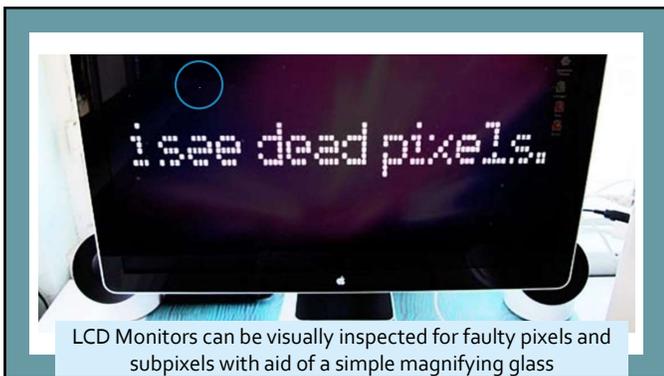
18



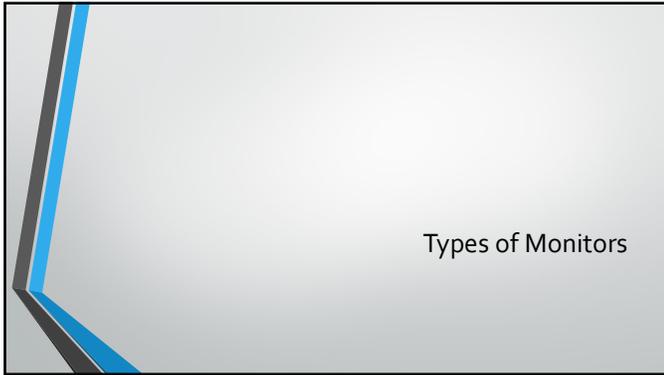
19



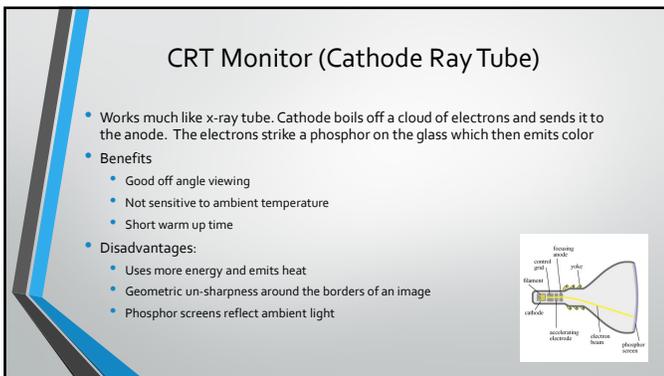
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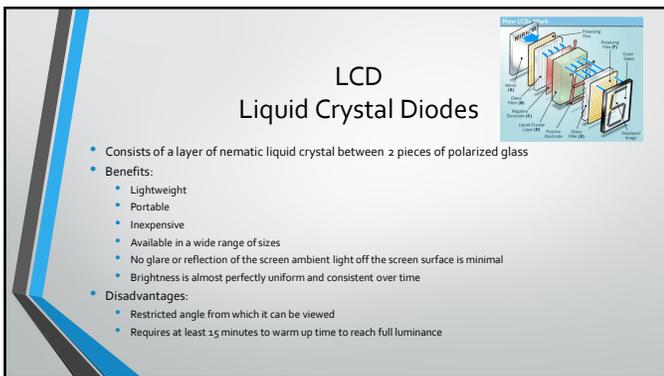
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24



25

To understand the LCD monitor you must comprehend Light Polarization

- Like an x-ray, a ray of light is electromagnetic radiation that consists of a double wave

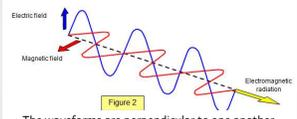
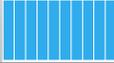
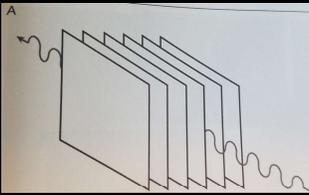


Figure 2
The waveforms are perpendicular to one another

- LCD Monitors use polarized glass
 - Polarized glass contains long chains of iodine molecules, all aligned parallel to each other
 - Just like a grid strips in a grid

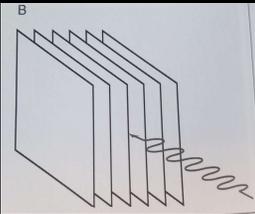


26



Electrical

The electrical component of the double wave can pass through a polarized glass with vertical string molecules because it vibrates parallel to it

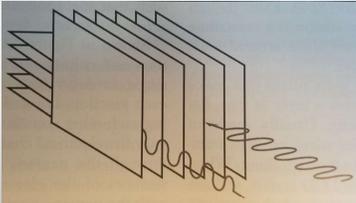


Magnetic

The magnetic component of the double wave cannot pass through a polarized glass with vertical string molecules because it vibrates perpendicular to it

27

What will happen if you layer 2 polarizing glass together so the string molecules are perpendicular to each other?



28

LCD – Light polarization

- LCD monitor consists of:
 - 2 thin sheets of glass
 - Each with a light polarizing layer that are perpendicular to the other sheet

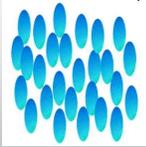
Perpendicular sheets = ALL light being blocked

Don't worry, the LCD process involves "tricking" these layers into allowing light to pass

29

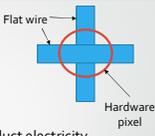
What are nematic liquid crystals?

- This is what is inserted between the polarizing glass sheets/lenses that plays the trick
- A crystalline arrangement of molecules that have a long linear shape and tend to align parallel to each other



30

Before we see the "trick", you need to know one more thing....



- In the polarizing glass there are a layer of thin, flat wires to conduct electricity
- These conductors are also aligned perpendicular to each other when the 2 polarized glass are together
- Each junction forms a single **hardware pixel**
 - Each electrode has a scratch on it
 - Scratches are perpendicular to one another
 - The crystals tend to line up with the "scratch" direction when no electric charge is present -- **known as "on" state**

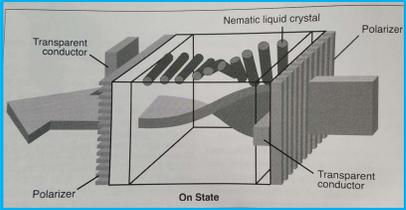
31

And **FINALLY**, Here is the Magic Trick.....



<https://www.youtube.com/watch?v=jiejNAUwcQ8>

32

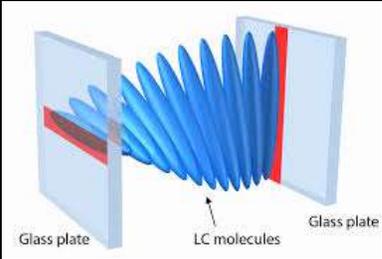


"ON" STATE

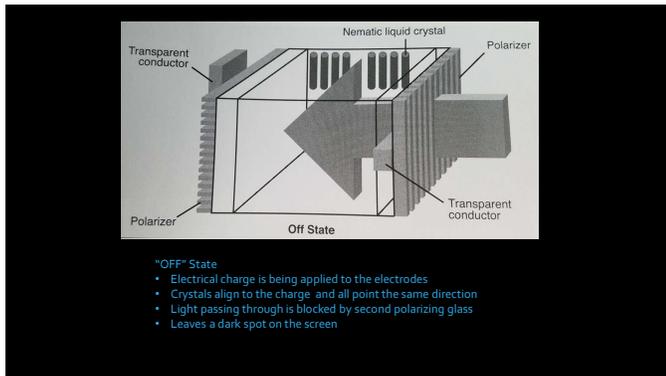
- Since the scratches are perpendicular, the liquid crystals line up in a spiral pattern that twists 90 degrees between the two glass plates
- This lets light waves pass through the nematic liquid crystal and follow the spiral
- Light is able to pass through the second glass plate to the viewer of the monitor

33

Just another way to look at it



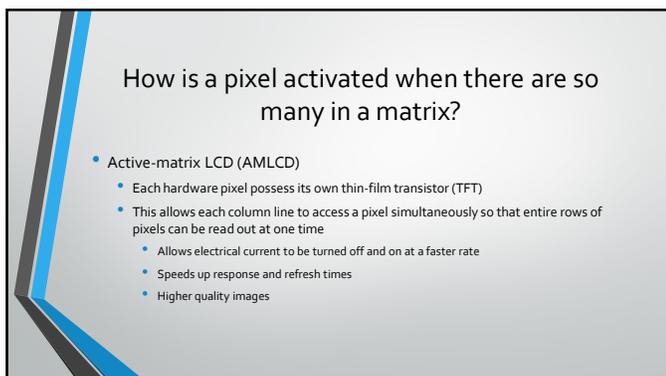
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More info on LCD Monitors

- As LCDs **do not** produce light by themselves—they need illumination to produce a visible image.
 - Without a **backlight**, an LCD display device will remain black, rendering it unviewable
- Backlighting**
 - Types: Fluorescent bulbs or light-emitting diodes (LEDs)
 - LED - Most common

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Care and Maintenance

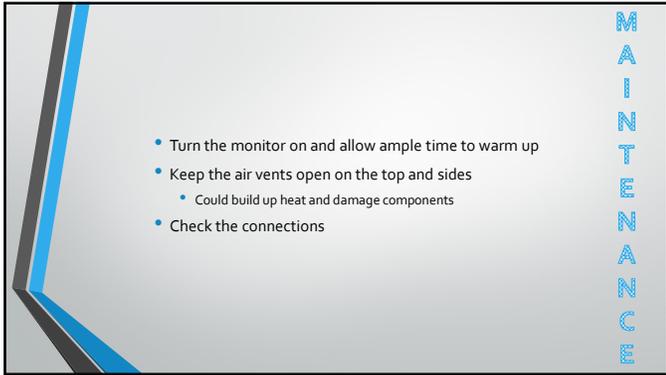
39

CARE

- Apply cleaning solution to soft cloth
 - Do not spray solution directly on screen
 - Do not use paper towel can cause scratches
- Wipe in one direction from top of screen to bottom

- The following cleaners should NOT be used: Acetone
 - Ethyl alcohol
 - Ethyl acid
 - Ammonia
 - Methyl chloride
- The following types of cleaners are acceptable: Water
 - Vinegar (mixed with water)
 - Isopropyl Alcohol
 - Petroleum Benzene

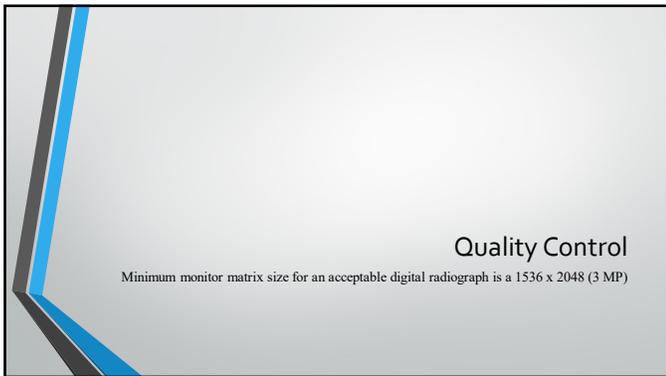
40



M-A-I-N-T-E-N-A-N-C-E

- Turn the monitor on and allow ample time to warm up
- Keep the air vents open on the top and sides
 - Could build up heat and damage components
- Check the connections

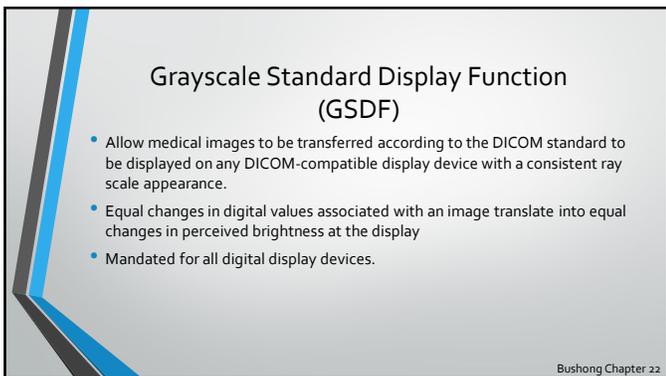
41



Quality Control

Minimum monitor matrix size for an acceptable digital radiograph is a 1536 x 2048 (3 MP)

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Grayscale Standard Display Function (GSDf)

- Allow medical images to be transferred according to the DICOM standard to be displayed on any DICOM-compatible display device with a consistent ray scale appearance.
- Equal changes in digital values associated with an image translate into equal changes in perceived brightness at the display
- Mandated for all digital display devices.

Bushong Chapter 22

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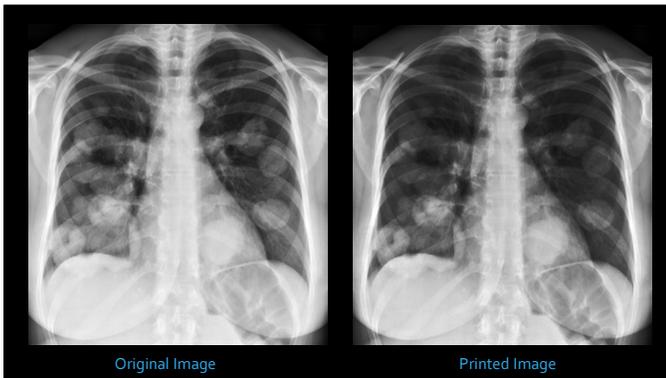
DICOM Grayscale Standard Display Function (GSDF) generates a display function matching the perceptual characteristics of a human observer.

Standard developed having human observer view monitor while luminance output of monitor changed in small steps from black to white and noting when they observed a **Just Noticeable Difference** (JND) in light output as the drive signal is changed.

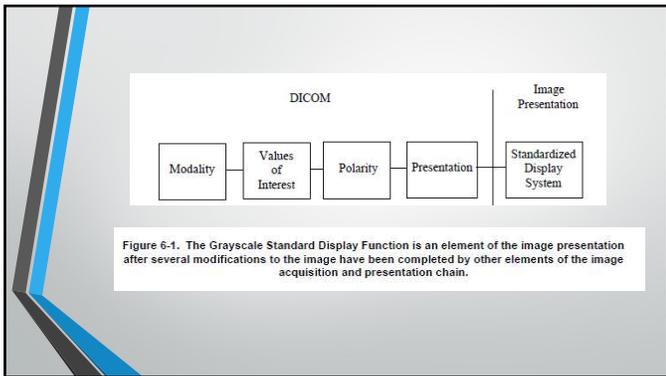
Most digital radiologic images are windowed to attempt to display 256 different shades of gray at any one time, (256 is approximate JND that humans can perceive)

The perceptual linearization implemented with the DICOM Grayscale Standard Display Function (GSDF) ensures that pixel values that are supposed to increase brightness in a linear fashion, say 6, 7, and 8, for example, actually appear that way to the human eye, despite the nonlinearity of our perception.

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45



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Luminance

The rate of light (brightness) emitted from a source such as an LCD monitor

- **Maximum luminance** (*maximum brightness*)- checked at same monitor setting over a period of time with a photometer
- **Luminance response** – monitors ability to accurately display different shades of brightness from a test pattern
- **Luminance ratio** – compares maximum luminance to the minimum luminance
- **Luminance uniformity** – consistency of a single brightness level displayed across the area of the screen

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Luminance Ratio

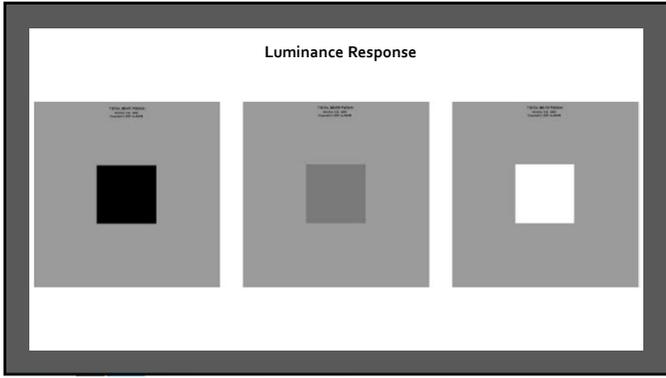
48

Luminance Response

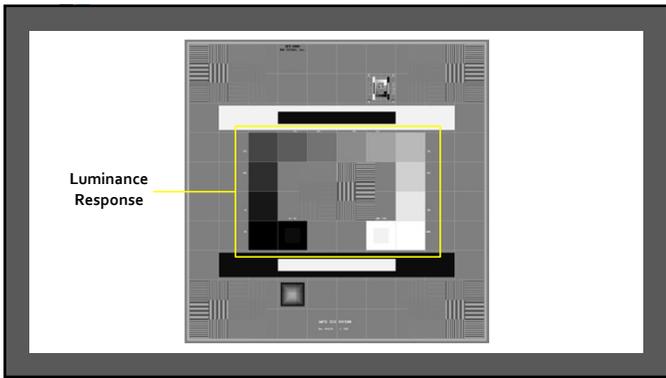
TDS-CT Patterns
Version 2.0, 10/11
Copyright © 2011 by iMAGIX

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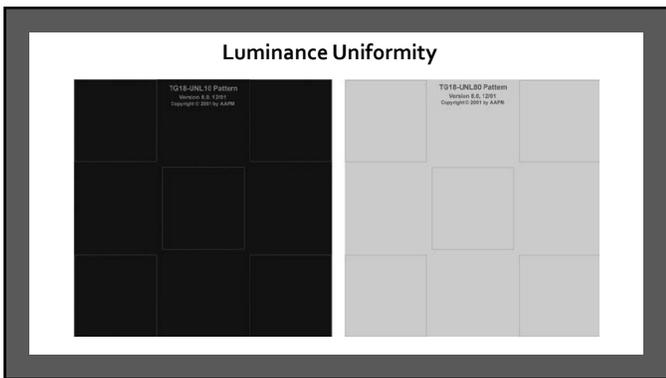
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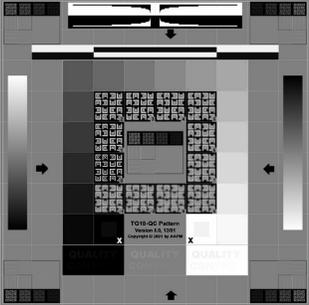
52

Resolution

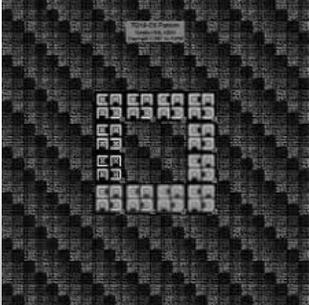
- ACR and AAPM minimum resolution for electronically displayed images of 2.5LP/mm
 - Generic SMPTE test pattern can be used
 - Check for blurring
- AAPM TG18 – QC and TG 18 CX provides an excellent check for resolution across the area of the display screen
 - Evaluate the CX pattern in the middle and in the corners
- Test can be done daily, weekly or monthly

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TG18 - QC

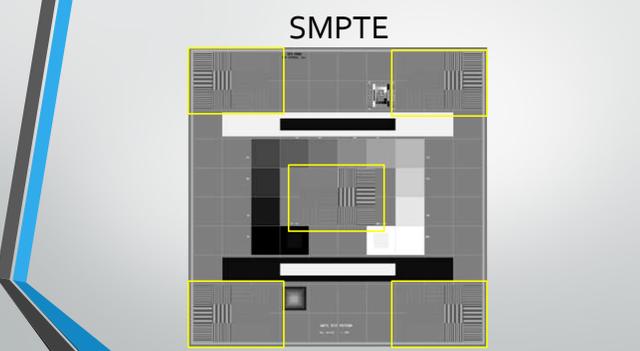


TG18 - CX

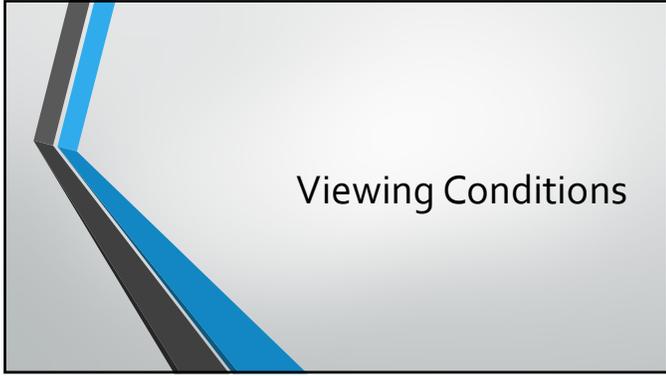


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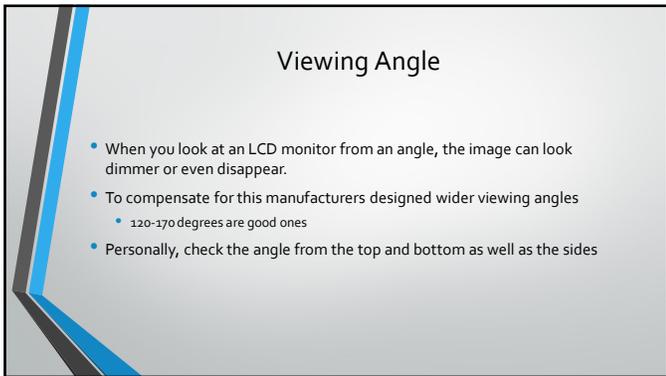
SMPTE



55



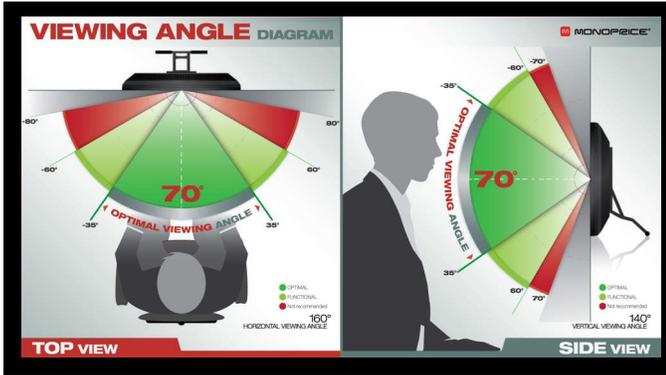
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Ambient Lighting

Illuminance – the rate of light striking a surface

- The effect of ambient room lighting on the surface of and LCD monitor screen, including **reflectance** off the screen, and the resulting reduction in visible contrast of the image, is a result of **illuminance**
- Diffuse reflectance
 - The cumulative effect of room lighting across the area of the monitor screen
- Specular reflectance
 - The reflection of actual light sources such as a light bulb or window

The ambient lighting within the room must be dimmed to a point where both types of reflectance are below any noticeable level, that would impede full visibility of the image and image contrast

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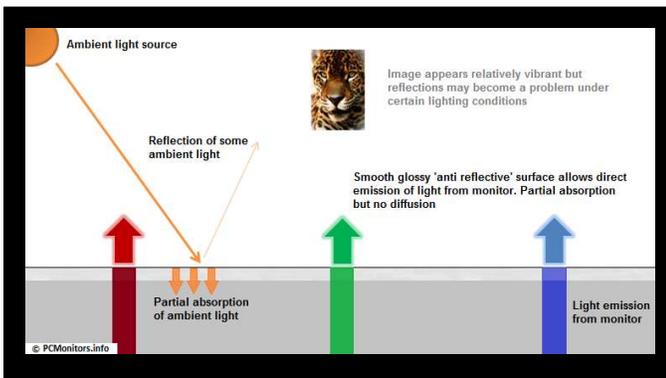
QC Aspect or Ambient Light

- While diagnosis is taking place, the maximum ambient lighting in a reading room should never be more than 25 lux
 - Approximately 1/4 the typical brightness of normal office lighting (75-100 lux)

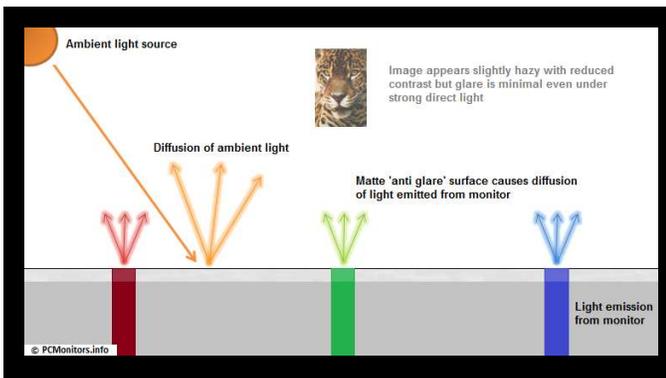
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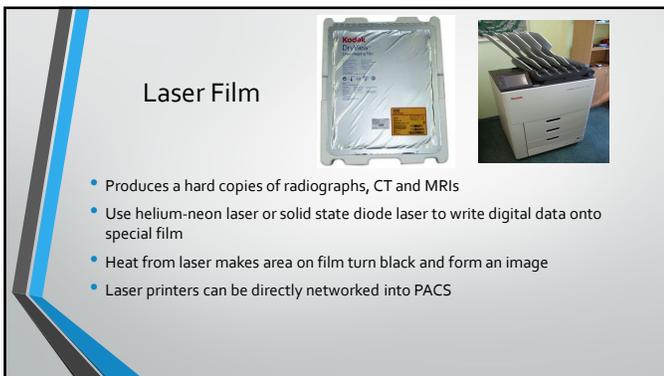
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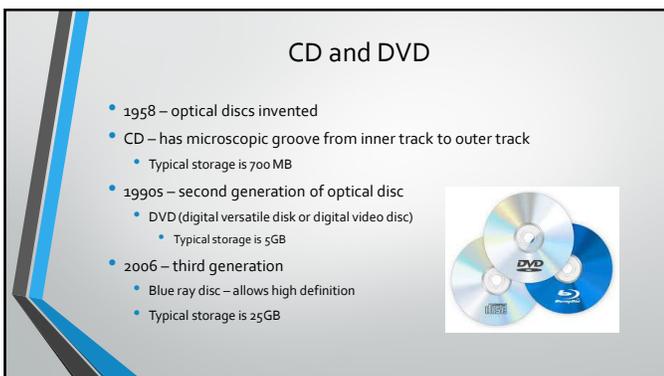
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Data Management

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Network Connectivity

- LAN – Local Area Network
 - Computerized communications network generally contained within a single building or business
 - Devices share one server
- WAN – Wide Area Network
 - Extends to other businesses or locations that may be at great distances
 - Publically or commercially owned
 - Uses transmission services provided by common carriers (phone or cable companies)



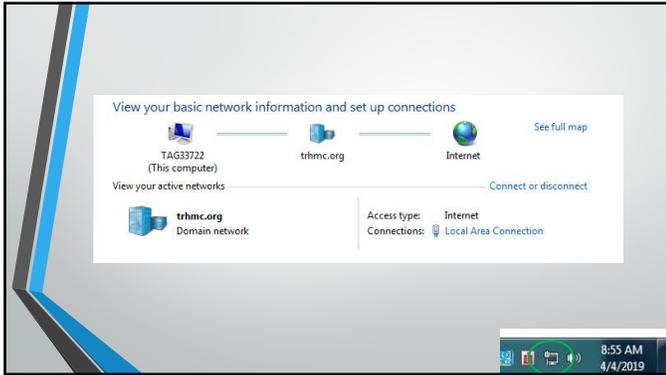
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Computer Network

- Every computer within a network has a unique internet protocol or IP address
 - Ex. 172.811.3.1
- Every computer must have a network interface card
- Router
 - Connects 2 or more networks
 - Wireless routers – allow "point-of-care" access to a network for physicians and other caregivers via tablet or laptop



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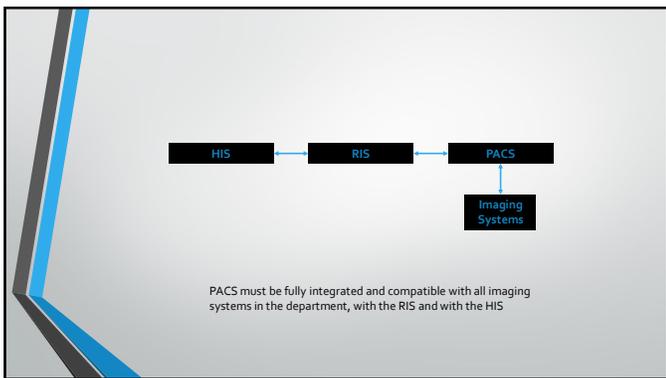
78

Type of LAN

RIS and HIS

- Radiology Information System
 - Data system for patient-related functions in the department, such as scheduling of x-ray appointments, tracking of patients, storage and distribution of reports
 - Makes info accessible from different locations within the radiology department
 - Assigns the **accession number**
- Hospital/Health Information System
 - Performs same functions for the entire institution (patient's general medical file)
 - Assigns a unique identifying number for each patient (**MRN**)

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Picture Archiving and Communications System (PACS)

- Comprehensive computer network that is responsible for the electronic storage and distribution of medical images.
- Makes radiographs, CT and MRI scans, US and Nuclear Med images for a particular patient available within the network
- Allows Radiologists and Technologist to access these images from various locations, improving the efficiency of communication

Soon to be Called....
Medical image management and processing system (MIMPS)

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PACS

- Digital acquisition (Picture)
- Display workstations
- Storage devices (Archiving)
- Components are interconnected by a network (Communication)

82

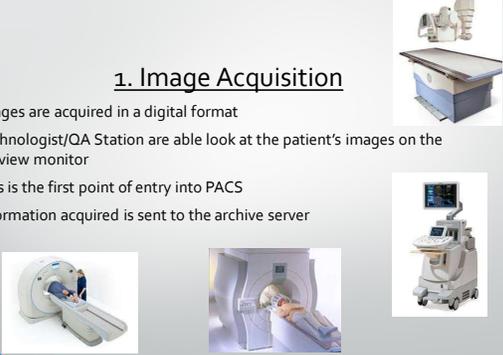
Components of PACS

- Image acquisition
- Display workstations
- Archive servers

83

1. Image Acquisition

- Images are acquired in a digital format
- Technologist/OA Station are able look at the patient's images on the preview monitor
- This is the first point of entry into PACS
- Information acquired is sent to the archive server



84

2. Display Workstations

Any computer used to view digital images

- Radiologists
- Physicians, surgeons, nurses & patients
- Technologists

- Most interactive part of PACS
- Used inside and out of Radiology
- Has PACS application software that allows minor image-manipulation

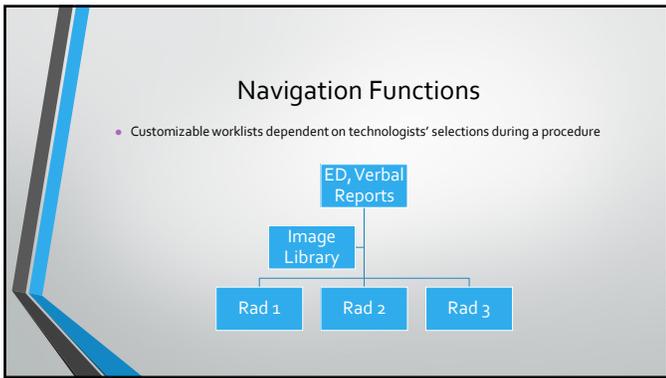


85

Common Workstation Functions

- Navigation Functions
- Hanging Protocol
- Study Navigation
- Image Manipulation & Enhancement
- Image Management

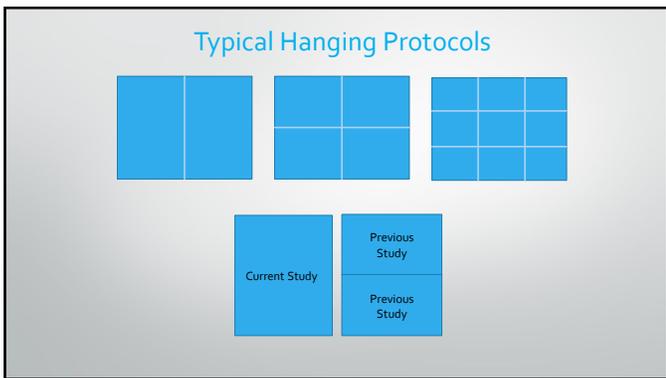
86



87



88



89

Study Navigation

- Allows images to be viewed individually or in a cine run.



90

Image Manipulation & Enhancement

Annotations **SUPINE**

Magnify 

Window/Level 

Flip/Rotate 

Measurements 

91

Key Images



92

Image Management Functions

- Patient demographics
 - Edit patient information for proper correlation with previous studies, billing, etc.
- Query / Retrieve
 - Locate images based on patient demographics
- Hardcopy images
 - Either CD or plain film
 - Usually only image library has this function

93

3. Archive Servers

- File room of PACS
- Contains all historic and current data



94

PACS Archiving

- Consist of:
 - Image manager/controller
 - Image storage/server



95

Image Manager

- Contains master database of everything in the archive
- Controls the receipt, retrieval and distribution of the images it stores
- Controls all the DICOM processes running within the archive
- Communicates with RIS and HIS
- Can populate image information into the EMR

MANAGER

96

97

Image Storage/Archive Server

- Physical storage device for archive system
- Network of servers
- Setup in tiers
 - Short-term
 - Long-term

In the United States, storage requirement of a patient's images is from five to seven years.

98

Short Term Storage

- RAID
 - several magnetic disks or hard drives that are linked together in an array

RAID 5 is the most common level used for a PACS archive because it provides adequate redundancy and fault tolerance

99

Reading Hospital

- Short-term storage is done on servers located in IMS but maintained by Philips
 - Philips monitors the system through remote access
 - All backups and drive redundancy are handled by Philips

100

Long Term Storage

- RAID
- Optical disk
- Tape
- Magnetic disk

101

Cloud-Based Storage

- Offsite storage and servers supported by a secure network
- 3rd party vendor
- Shifts disaster recovery process to the vendor along with maintenance and storage equipment purchase
- You pay for the service and storage space

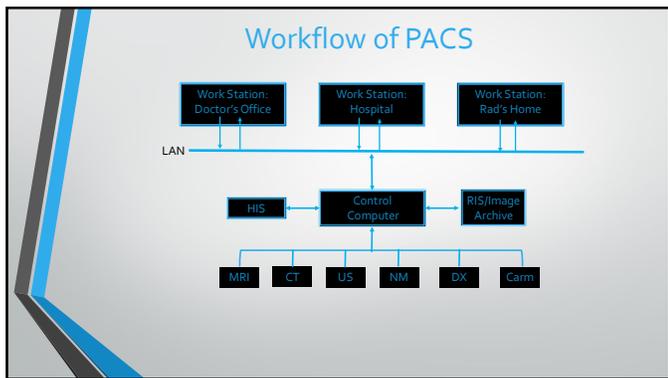
102

Reading Hospital:

- Prior to EPIC - \$1 million budget for record storage
- Legally obligated to retain films:
 - Pediatrics
 - Mammo
 - All other films



103



104

Summary of PACS Functions

- Main function: Act as a *database*
 - Generate and sort according to status (*i.e.* pending, completed)
 - Various queries – users can search for specific information
- Manipulation – at any workstation
- Storage

105

Vendor Neutral Archives (VNA)

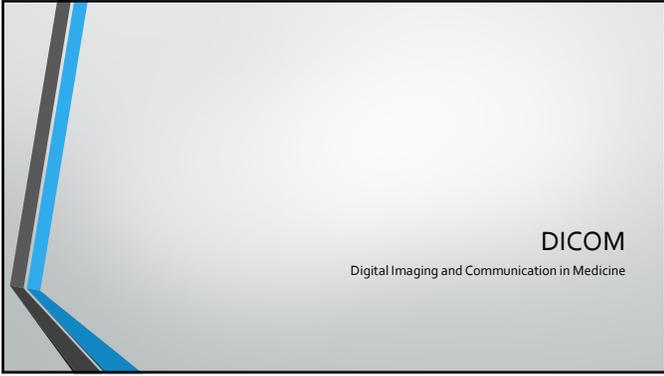
- Allows for images and data from different systems and in different formats to be stored using a singular system on a common infrastructure
- May be used as replacements to existing PACS to avoid very expensive transition costs
- Used to consolidate a number of systems that exist within a single facility or across a system of facilities

106

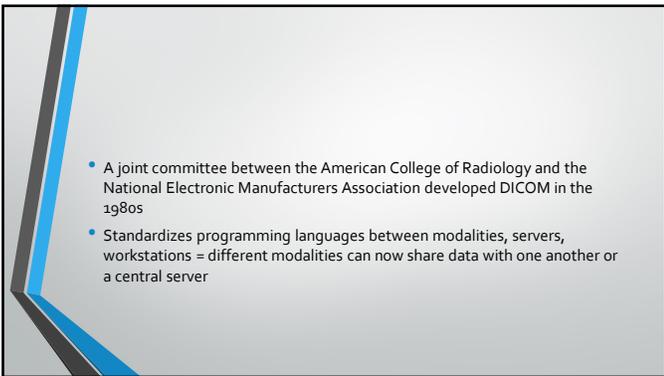
PACS Emergency Contingency Plan

- A backup copy of ALL archived records should be maintained either by the hospital or an Application Service Provider
- RH PACS Downtime Procedure Policy - <https://trh.elucid.com/documents/view/12114/33066/3>

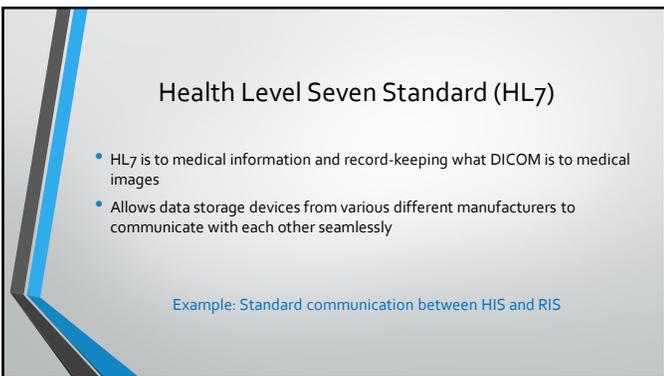
107



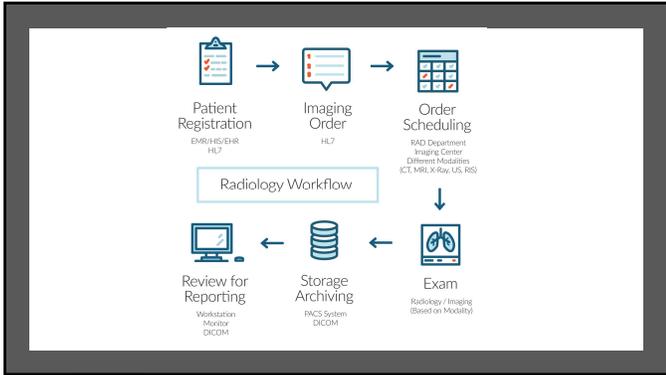
111



112



113



114

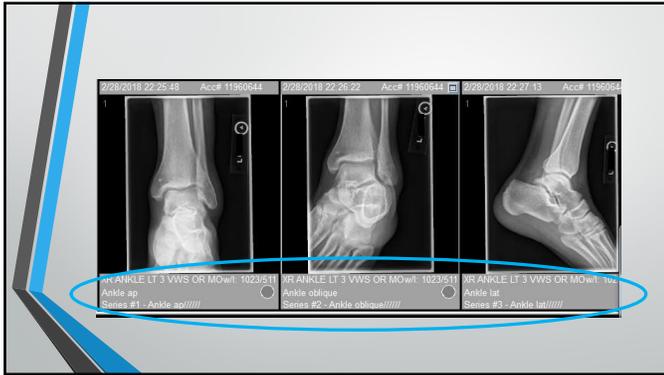
DICOM Header

- A summary of critical identification and study information such as:
 - Date and time of procedure
 - Number of images taken
 - Body part, position
 - Technique used
 - Image format and receptor size
 - Parameters used to digitally process the image
- All this information is stored as **metadata**
 - Should appear in a bar at the top of the screen for each image
 - Shows summary of essential metadata for the image

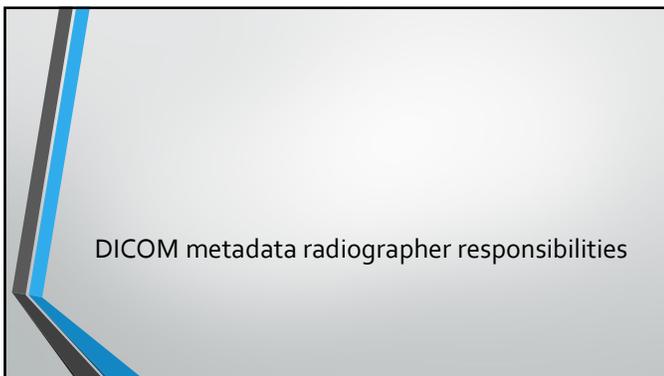
115

Group Tag	Element Tag	Tag Description	Value
0010	0011	Private Tag	MURKIN
0010	0020	Patient ID	12345
0010	0030	Patient's Birth Date	00000000
0010	0040	Patient's Sex	M
0010	1030	Patient's Weight	0
0010	2165	Private Tag	None
0010	2166	Private Tag	None
0010	4000	Patient Comments	
0018	0015	Body Part Examined	THORAX
0018	1000	Device Serial Number	00000000
0018	1020	Software Version(s)	1.0.1.120
0018	1164	Image Field Source	0.16
0018	1508	Positioner Type	COLLIMIN
0018	5100	Patient Position	ANTERIOR - POSTERIOR
0018	7004	Detector Type	DIRECT
0018	7006	Detector Description	
0018	7014	Detector Serial	1.1.1
0020	0020	Study Instance UID	1.2.826.0.1.3680043.2.1330.1000001.1.2211256762.2712337879
0020	000E	Series Instance UID	1.2.826.0.1.3680043.2.1330.1000001.4.2211256762.27123318877
0020	0010	Study ID	None
0020	0011	Series Number	1
0020	0019	Instance Number	29
0020	0020	Patient Orientation	N
0020	0060	Laterality	L
0020	0062	Private Tag	U
0020	4000	Image Comments	
0028	0002	Samples per Pixel	1

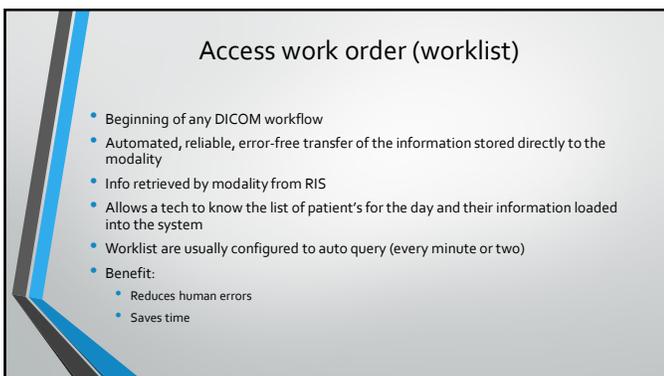
116



117



118



119

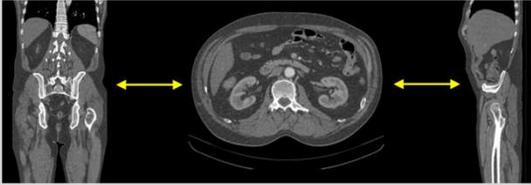
Post Processing – Image operation and manipulation

- Image operation activities
- Multiplanar Reconstruction
- Maximum and Minimum Intensity Projection
- Volume Rendering Technique (VRT)
- Shaded Surface Display (3D technology)
- CAD

120

Multiplanar Reconstruction

- Creates multiple planes of view from a single scan



<https://www.youtube.com/watch?v=H1nPMSVijag>

121

Maximum & Minimum Intensity Projections

- Enhancement of small vessels (MIP) and air-filled structures (MinIP)

MinIP – Minimum Intensity Projections

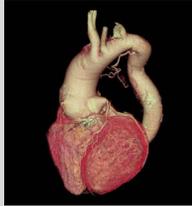
MIP – Maximum Intensity Projections



122

Volume Rendering Technique (VRT)

- Assists in differentiating between anatomical structures by adding color shades based on pixel intensity



123

Shaded Surface Display (SSD)

- Creates a 3D, moveable image based on the pixel intensity of choice



124

CAD (Computer Aided Diagnosis/Detection)

- used as a "second opinion" in assisting radiologists' image interpretations
 - complementary tools that draw the radiologists' attention to certain image areas that need further evaluation
- Uses algorithms
- Used in Mammography at RH



125

Annotation Issues: Annotations and Mark Ups

- *Image annotation* – describes the meaning in images
- *Image markup* – visual presentation of the annotation
- AIM Project (Annotation and Image Mark up project)
 - The model contains information about who created the annotation, the equipment with which the annotation was created, when the annotation was created, and the image(s) to which the annotation refers.
 - Once the annotation is defined in the AIM, sophisticated queries are now easily found
 - "Find all studies that contain enhancing right middle lobe lung masses that measure between 5 and 6 cm"

126

- Other concerns are
 - What is more accurate tool to use --- stylus or mouse for marking or measurements?
 - Human error
 - Legal issues

127

Mouse Stylus

128

Case number	Annotation time for mouse (s)	Annotation time for stylus (s)
1	109	86
2	121	71
3	108	70
4	78	74
5	109	91
6	55	57
7	78	77
8	90	54
9	113	60
10	89	85
11	101	98
12	81	41

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Image Transmission

- Concerns of medical data overload
 - CT may produce 300 to 500 images and a CT angiography runoff study may include 1,500 to 2,000 images
- In teleradiology, the header of the DICOM image is first transmitted followed by the compressed image data and then at the receiving end, images are reconstructed from low quality to high (or perfect) quality
- Facilities will compress images to send, this allow it to be sent more efficiently
 - Lossless compression have been defined as "visually acceptable" images by the medical imaging community

130

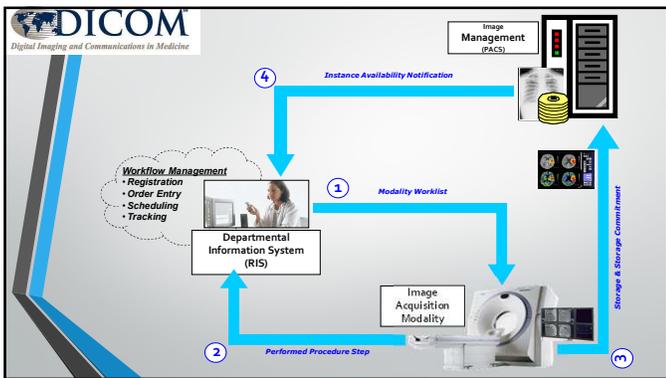
HIPAA

- Health Insurance Portability and Accountability Act of 1996 (HIPAA) Privacy Rule is to ensure you have rights over your own health information, no matter what form it is in.
- The government also created the HIPAA Security Rule to require specific protections to safeguard your electronic health information.
- Federal law requires doctors, hospitals, and other health care providers to notify you of a "breach."
- Facilities should implement high-grade security and encryption in their systems in order to protect records from hackers or theft
- Adhering to HIPAA guidelines often means subjecting software developments to a legal team who can determine whether or not the software falls within HIPAA regulations for security and confidentiality

131



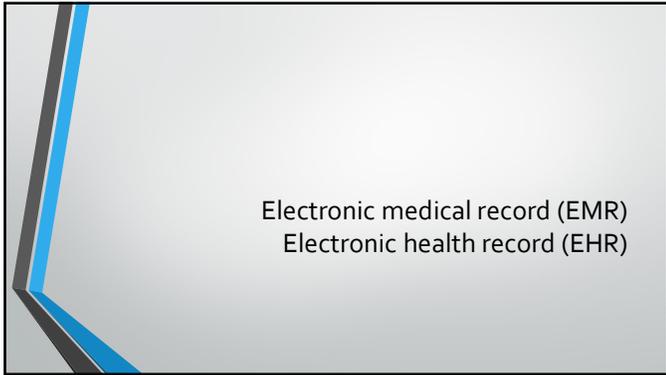
132



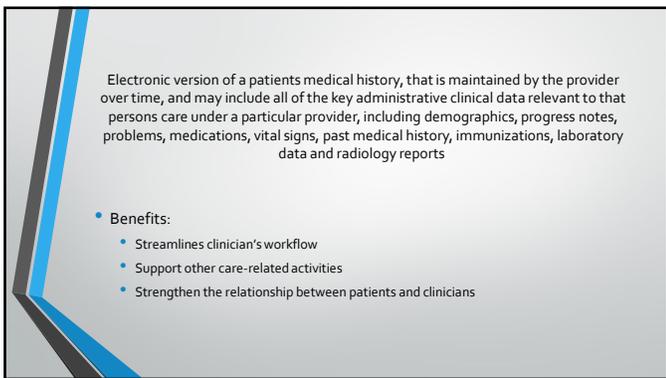
133

- DICOM Services for Acquisition Workflow Management
- Improve Interoperability of Imaging Equipment
 - Ensure Data Consistency
 - Facilitate Reliable Data Management
 - Improve Process Efficiency
 - Better Quality of Imaging Services
- 

134



135



136



137

- Any system which allows remote transmission and viewing of radiographic images via modems over phone or cable lines
- Makes it possible for images to be sent great distances for a specialist to collaborate with a radiologist, and for images stored at a hospital to be accessed almost instantly by doctors at their individual clinics
 - Example: transmit images to radiologist's home during off hours





1



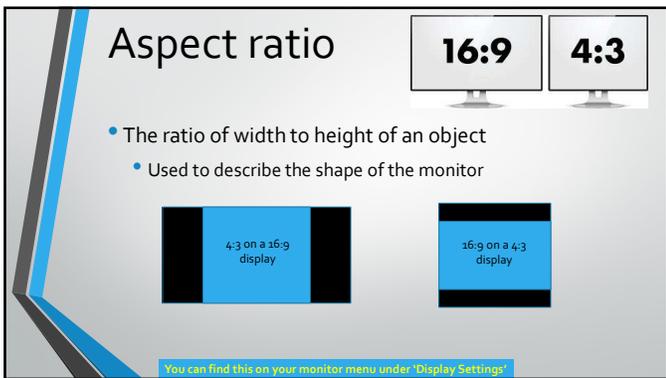
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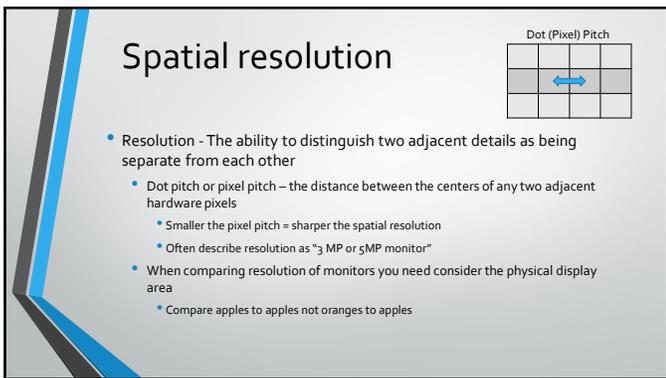
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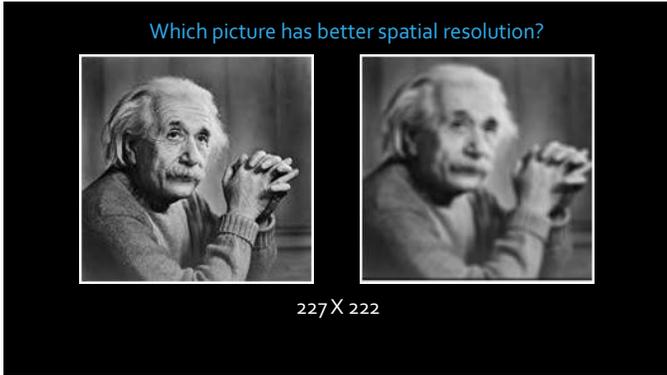
4



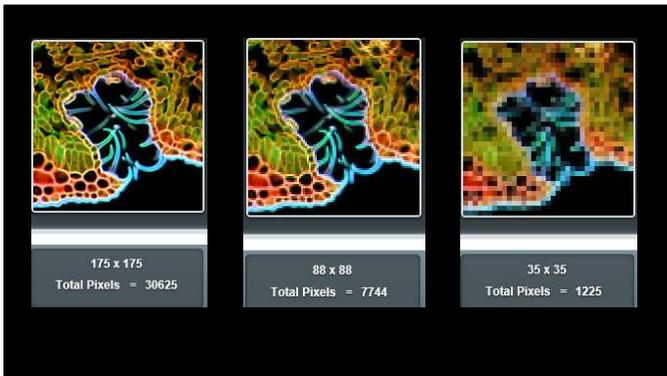
5



6



7



8



9

Brightness

- The black level of a display screen. Although it may sound peculiar, the brightness adjusts the "black level" of the display system (how black the black is) –*Computer Desktop Encyclopedia*
- Photometer is used to measure the brightness output of an LCD
- American College of Radiology (ACR) requires a minimum brightness capability for radiologic display systems of 250 lumens



Too dark Good brightness Too bright

10

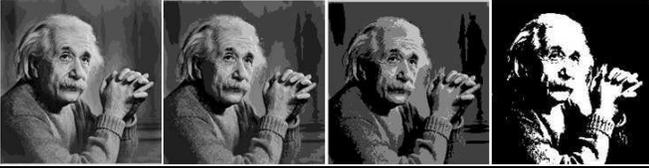
Contrast Ratio

- The difference between the darkest blacks and the brightest whites a given display can produce.
- Contrast ratio for LCD = 600:1, CRT = 3000:1
 - LCD - Inability to produce a "true black" due to backlight leakage



100% Contrast 75% Contrast 50% Contrast 25% Contrast 1% Contrast

12

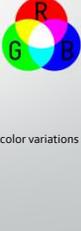


16 Gray Levels 8 Gray Levels 4 Gray Levels 2 Gray Levels

13

Color vs. Grayscale (monochrome)

- **Monochrome monitors**
 - Color images will appear as shades of gray
 - Has only one phosphor of color, but may have the ability to change the brightness causing the illusion of depth
 - Produces sharper text and image because 1 phosphor per pixel than color
- **Color monitors**
 - Monochrome images can be viewed on color monitors
 - Uses alternating intensities of red, green and blue to produce the different color variations
 - Uses 3 phosphors per pixel



15

What color would be seen in a color monitor?

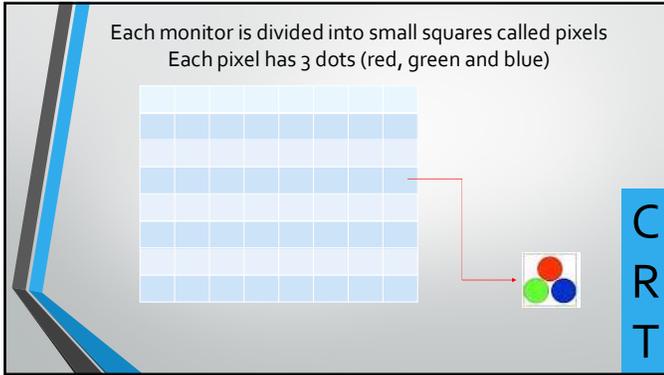
- If all 3 colors set at 0 = **BLACK**
- If all 3 colors set at 255 = **WHITE**
- If red was set at 255 and blue and green at 0 = **RED**

16

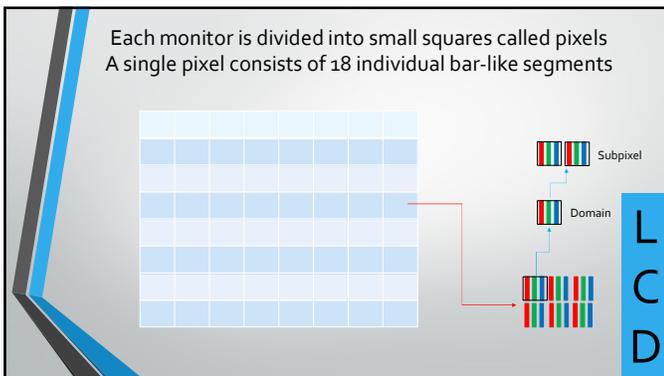
Pixels for Computers

- Pixel – multiple definitions
 - Carroll states it is “the smallest element of the matrix or device that can represent all pixel values within the system’s dynamic range”
- CRT – each triad of color (red, blue, and green) is considered one pixel
- LCD – a single pixel consists of 18 individual bar-like segments
- Hardware pixel in monitor – intersections of flat, transparent wires crossing over each other to form an overall square shape

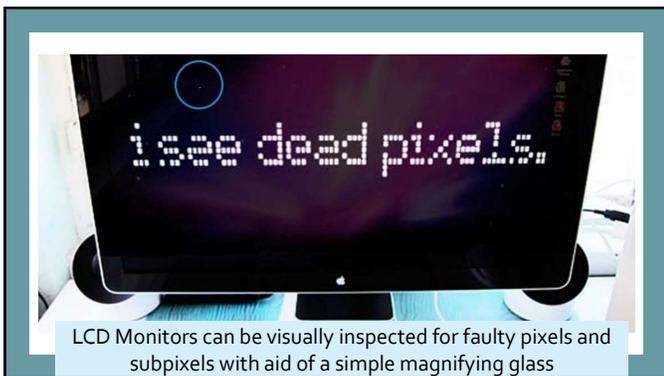
18



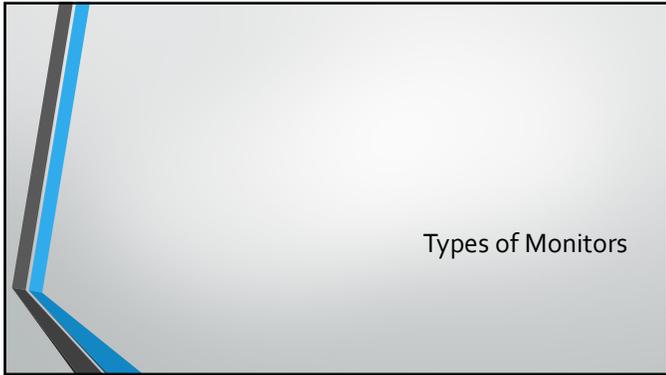
19



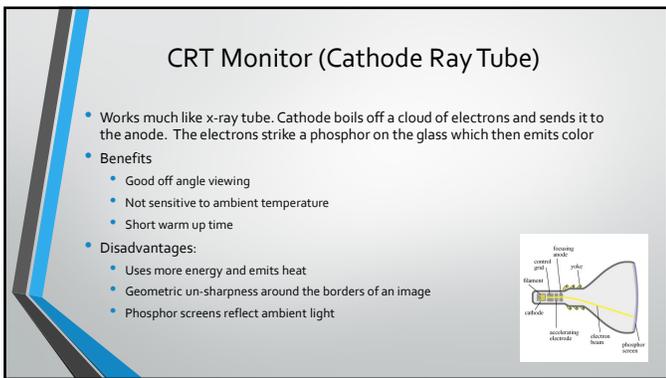
20



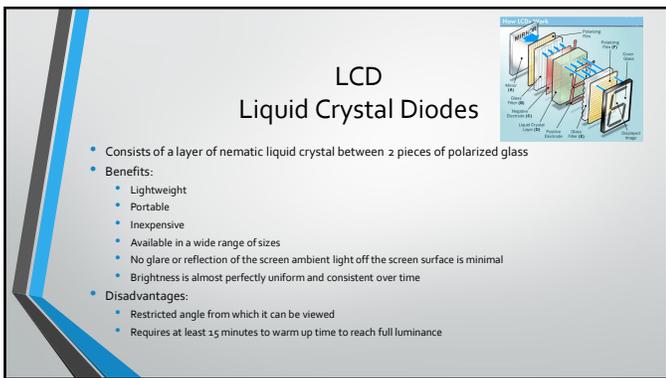
21



23



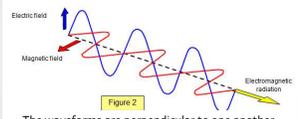
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25

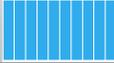
To understand the LCD monitor you must comprehend Light Polarization

- Like an x-ray, a ray of light is electromagnetic radiation that consists of a double wave

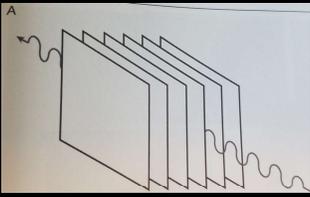


The waveforms are perpendicular to one another

- LCD Monitors use polarized glass
 - Polarized glass contains long chains of iodine molecules, all aligned parallel to each other
 - Just like a grid strips in a grid

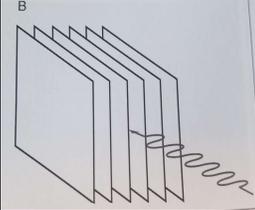


26



Electrical

The electrical component of the double wave can pass through a polarized glass with vertical string molecules because it vibrates parallel to it

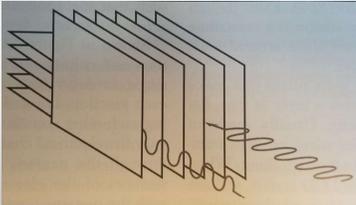


Magnetic

The magnetic component of the double wave cannot pass through a polarized glass with vertical string molecules because it vibrates perpendicular to it

27

What will happen if you layer 2 polarizing glass together so the string molecules are perpendicular to each other?



28

LCD – Light polarization

- LCD monitor consists of:
 - 2 thin sheets of glass
 - Each with a light polarizing layer that are perpendicular to the other sheet

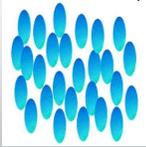
Perpendicular sheets = ALL light being blocked

Don't worry, the LCD process involves "tricking" these layers into allowing light to pass

29

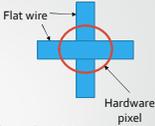
What are nematic liquid crystals?

- This is what is inserted between the polarizing glass sheets/lenses that plays the trick
- A crystalline arrangement of molecules that have a long linear shape and tend to align parallel to each other



30

Before we see the "trick", you need to know one more thing....



Flat wire
Hardware pixel

- In the polarizing glass there are a layer of thin, flat wires to conduct electricity
- These conductors are also aligned perpendicular to each other when the 2 polarized glass are together
- Each junction forms a single **hardware pixel**
 - Each electrode has a scratch on it
 - Scratches are perpendicular to one another
 - The crystals tend to line up with the "scratch" direction when no electric charge is present -- **known as "on" state**

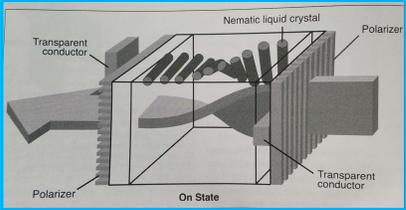
31

And **FINALLY**, Here is the Magic Trick.....



<https://www.youtube.com/watch?v=jiejNAUwcQ8>

32

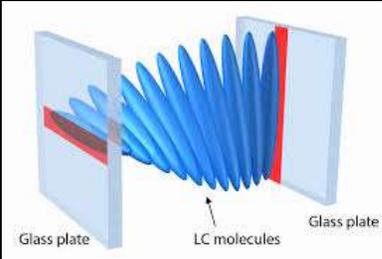


"ON" STATE

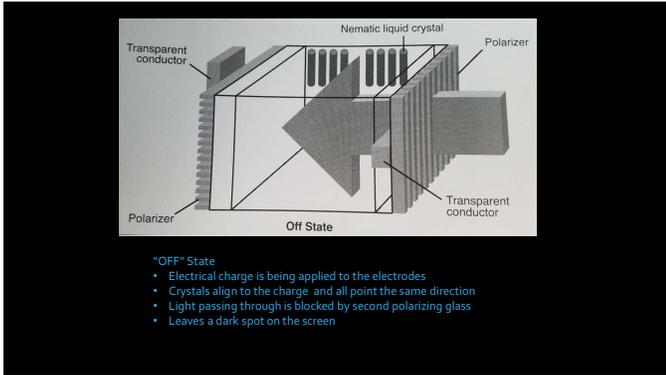
- Since the scratches are perpendicular, the liquid crystals line up in a spiral pattern that twists 90 degrees between the two glass plates
- This lets light waves pass through the nematic liquid crystal and follow the spiral
- Light is able to pass through the second glass plate to the viewer of the monitor

33

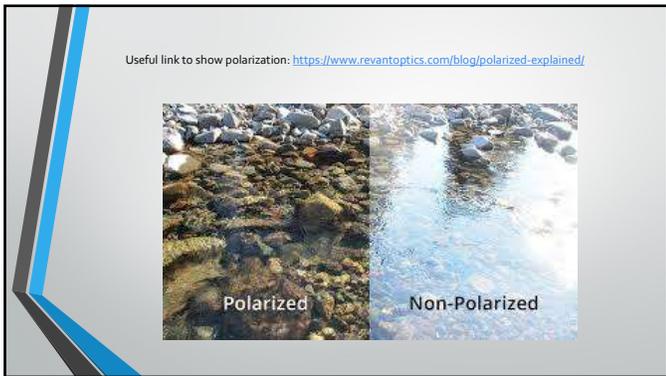
Just another way to look at it



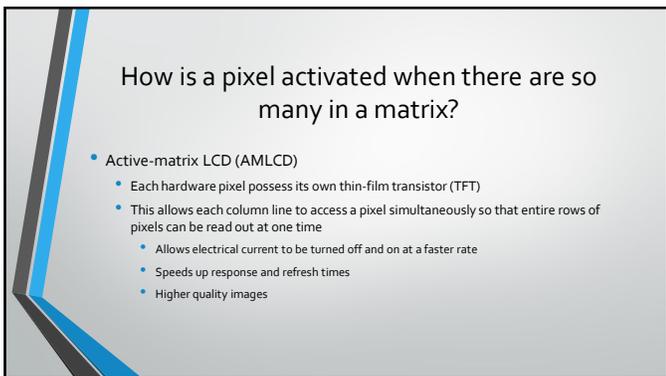
34



35



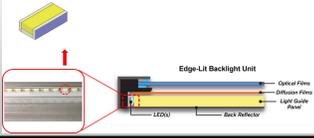
36



37

More info on LCD Monitors

- As LCDs **do not** produce light by themselves—they need illumination to produce a visible image.
 - Without a **backlight**, an LCD display device will remain black, rendering it unviewable
- **Backlighting**
 - Types: Fluorescent bulbs or light-emitting diodes (LEDs)
 - LED - Most common



38

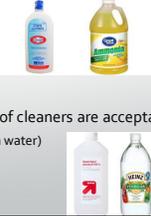
Care and Maintenance

39

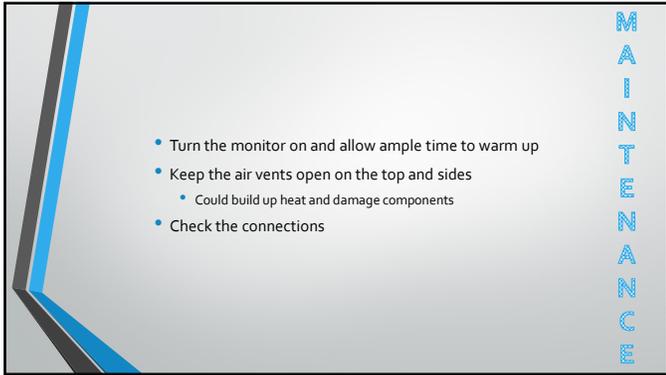
CARE

1. Apply cleaning solution to soft cloth
 - Do not spray solution directly on screen
 - Do not use paper towel can cause scratches
2. Wipe in one direction from top of screen to bottom

- The following cleaners should NOT be used: Acetone
 - Ethyl alcohol
 - Ethyl acid
 - Ammonia
 - Methyl chloride
- The following types of cleaners are acceptable: Water
 - Vinegar (mixed with water)
 - Isopropyl Alcohol
 - Petroleum Benzene



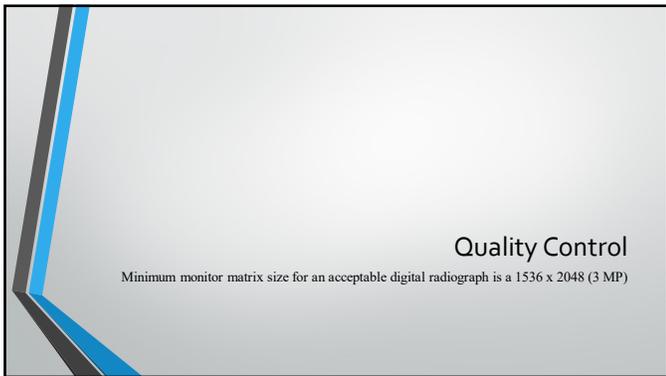
40



M-A-I-N-T-E-N-A-N-C-E

- Turn the monitor on and allow ample time to warm up
- Keep the air vents open on the top and sides
 - Could build up heat and damage components
- Check the connections

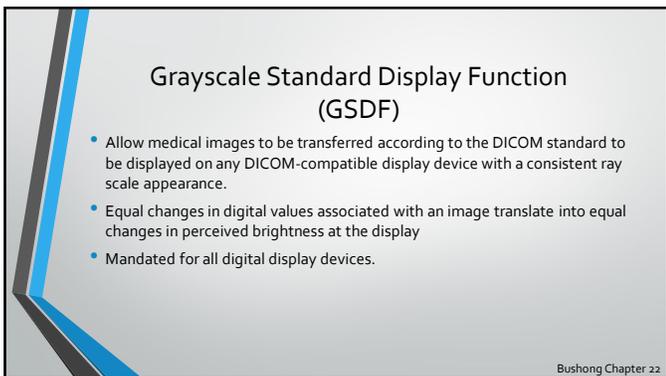
41



Quality Control

Minimum monitor matrix size for an acceptable digital radiograph is a 1536 x 2048 (3 MP)

42



Grayscale Standard Display Function (GSDf)

- Allow medical images to be transferred according to the DICOM standard to be displayed on any DICOM-compatible display device with a consistent ray scale appearance.
- Equal changes in digital values associated with an image translate into equal changes in perceived brightness at the display
- Mandated for all digital display devices.

Bushong Chapter 22

43

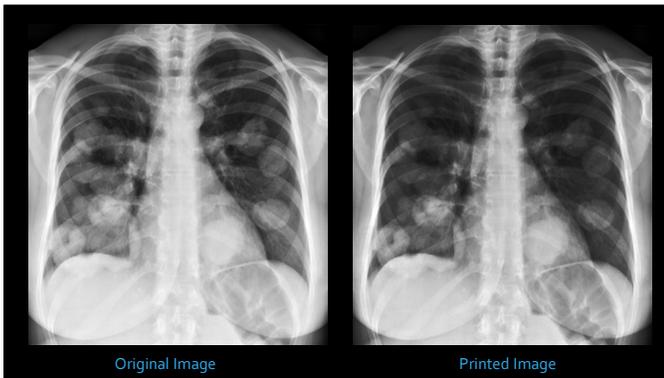
DICOM Grayscale Standard Display Function (GSDF) generates a display function matching the perceptual characteristics of a human observer.

Standard developed having human observer view monitor while luminance output of monitor changed in small steps from black to white and noting when they observed a **Just Noticeable Difference** (JND) in light output as the drive signal is changed.

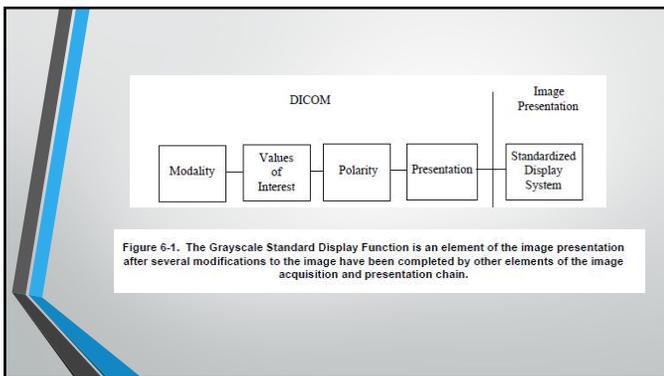
Most digital radiologic images are windowed to attempt to display 256 different shades of gray at any one time, (256 is approximate JND that humans can perceive)

The perceptual linearization implemented with the DICOM Grayscale Standard Display Function (GSDF) ensures that pixel values that are supposed to increase brightness in a linear fashion, say 6, 7, and 8, for example, actually appear that way to the human eye, despite the nonlinearity of our perception.

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45



46

Luminance

The rate of light (brightness) emitted from a source such as an LCD monitor

- **Maximum luminance** (*maximum brightness*)- checked at same monitor setting over a period of time with a photometer
- **Luminance response** – monitors ability to accurately display different shades of brightness from a test pattern
- **Luminance ratio** – compares maximum luminance to the minimum luminance
- **Luminance uniformity** – consistency of a single brightness level displayed across the area of the screen

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Luminance Ratio

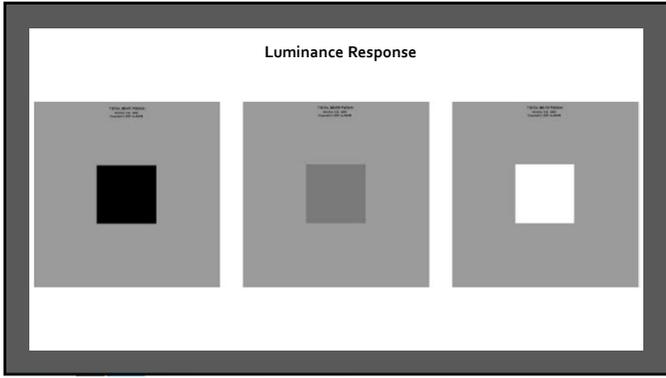
48

Luminance Response

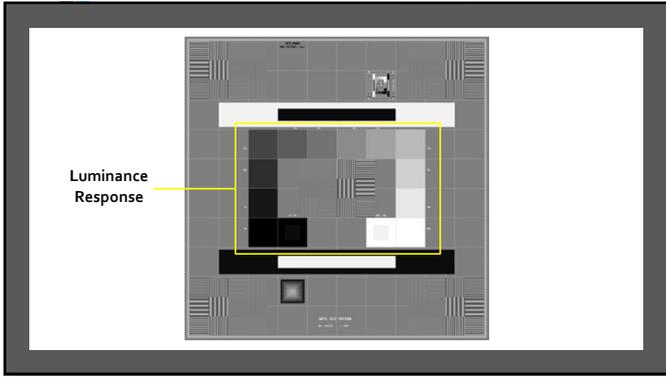
TDS-CT Pattern
Version 2.0, 10/11
Copyright © 2011 by Luster

A

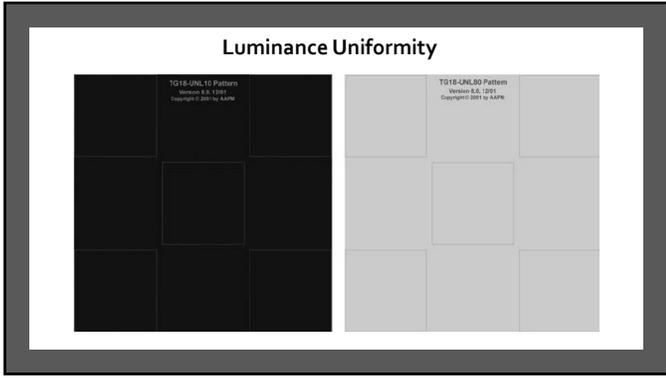
49



50



51



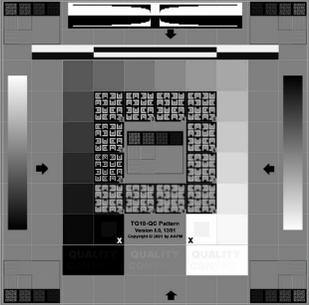
52

Resolution

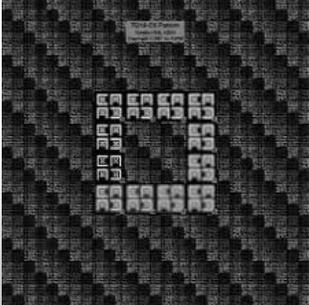
- ACR and AAPM minimum resolution for electronically displayed images of 2.5LP/mm
 - Generic SMPTE test pattern can be used
 - Check for blurring
- AAPM TG18 – QC and TG 18 CX provides an excellent check for resolution across the area of the display screen
 - Evaluate the CX pattern in the middle and in the corners
- Test can be done daily, weekly or monthly

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TG18 - QC

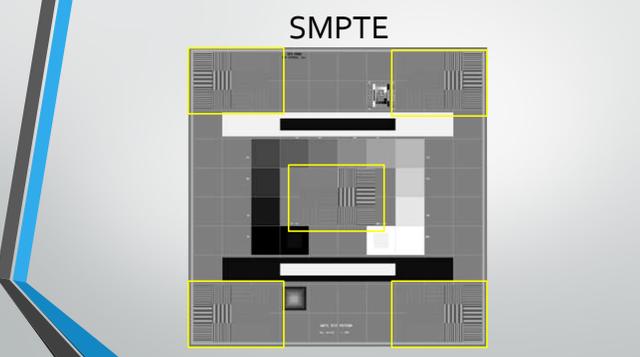


TG18 - CX

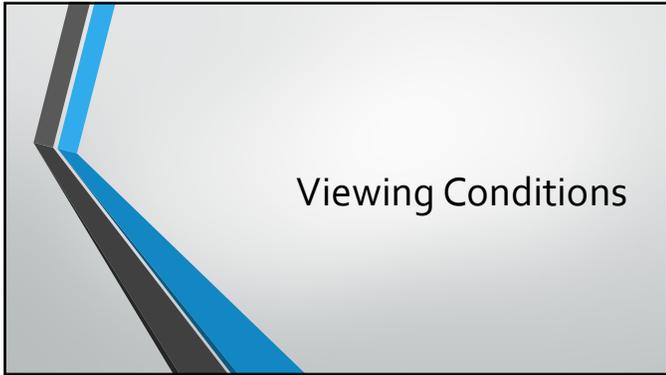


54

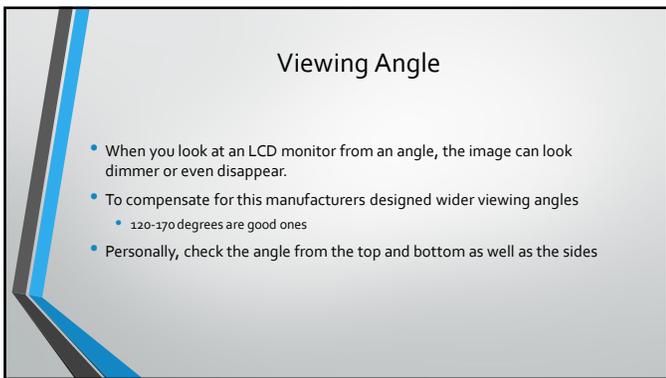
SMPTE



55



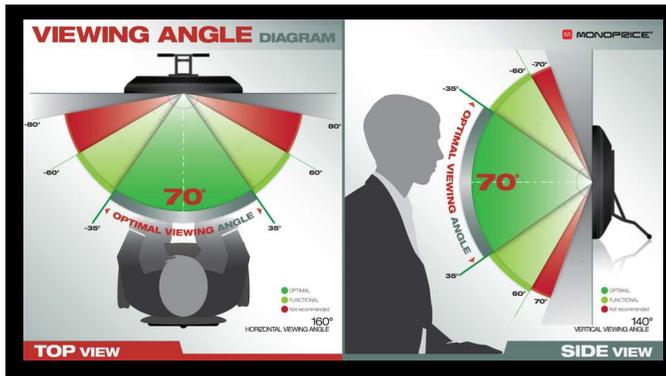
57



58



59



60

Ambient Lighting

Illuminance – the rate of light striking a surface

- The effect of ambient room lighting on the surface of and LCD monitor screen, including **reflectance** off the screen, and the resulting reduction in visible contrast of the image, is a result of **illuminance**
- Diffuse reflectance
 - The cumulative effect of room lighting across the area of the monitor screen
- Specular reflectance
 - The reflection of actual light sources such as a light bulb or window

The ambient lighting within the room must be dimmed to a point where both types of reflectance are below any noticeable level, that would impede full visibility of the image and image contrast

62

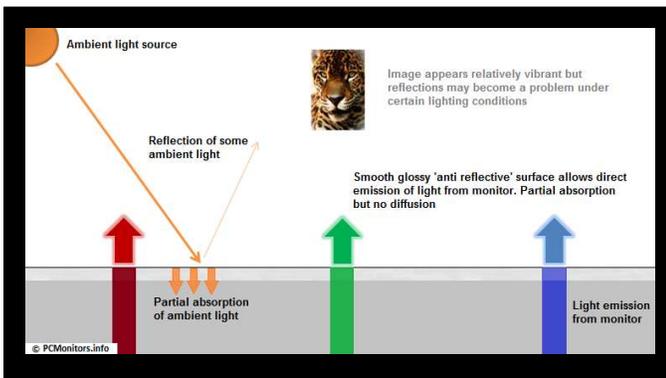
QC Aspect or Ambient Light

- While diagnosis is taking place, the maximum ambient lighting in a reading room should never be more than 25 lux
 - Approximately 1/4 the typical brightness of normal office lighting (75-100 lux)

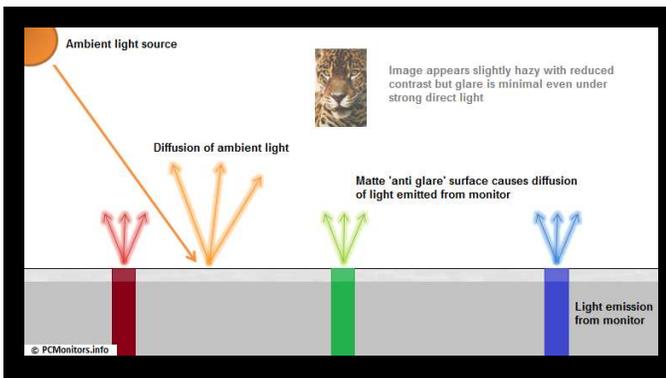
63



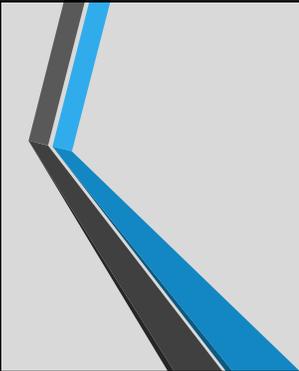
64



65

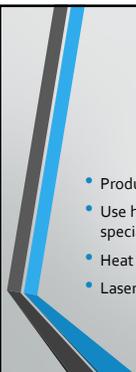


66



Hard Copy

67



Laser Film



- Produces a hard copies of radiographs, CT and MRIs
- Use helium-neon laser or solid state diode laser to write digital data onto special film
- Heat from laser makes area on film turn black and form an image
- Laser printers can be directly networked into PACS

68



CD and DVD

- 1958 – optical discs invented
- CD – has microscopic groove from inner track to outer track
 - Typical storage is 700 MB
- 1990s – second generation of optical disc
 - DVD (digital versatile disk or digital video disc)
 - Typical storage is 5GB
- 2006 – third generation
 - Blue ray disc – allows high definition
 - Typical storage is 25GB



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Data Management

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Network Connectivity

- LAN – Local Area Network
 - Computerized communications network generally contained within a single building or business
 - Devices share one server
- WAN – Wide Area Network
 - Extends to other businesses or locations that may be at great distances
 - Publically or commercially owned
 - Uses transmission services provided by common carriers (phone or cable companies)



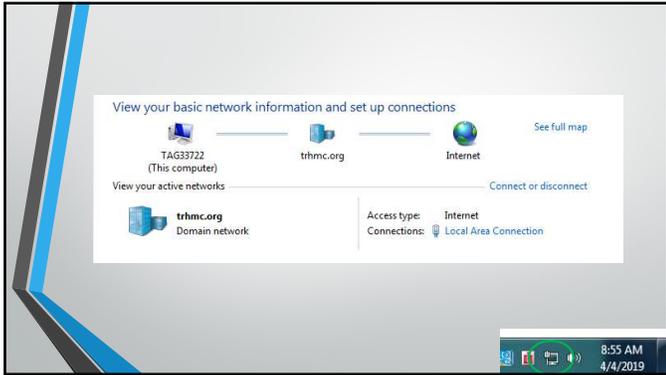
76

Computer Network

- Every computer within a network has a unique internet protocol or IP address
 - Ex. 172.811.3.1
- Every computer must have a network interface card
- Router
 - Connects 2 or more networks
 - Wireless routers – allow "point-of-care" access to a network for physicians and other caregivers via tablet or laptop



77



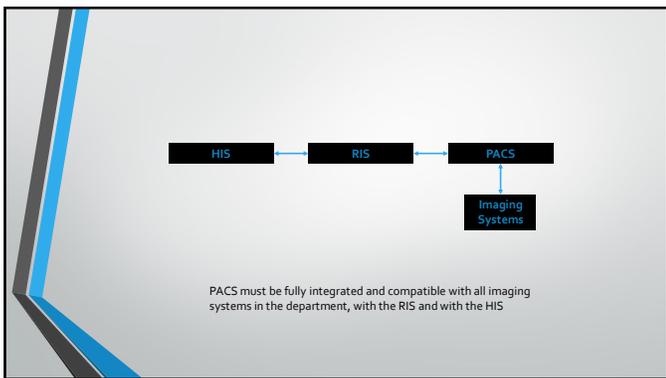
78

Type of LAN

RIS and HIS

- Radiology Information System
 - Data system for patient-related functions in the department, such as scheduling of x-ray appointments, tracking of patients, storage and distribution of reports
 - Makes info accessible from different locations within the radiology department
 - Assigns the **accession number**
- Hospital/Health Information System
 - Performs same functions for the entire institution (patient's general medical file)
 - Assigns a unique identifying number for each patient (**MRN**)

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80

Picture Archiving and Communications System (PACS)

- Comprehensive computer network that is responsible for the electronic storage and distribution of medical images.
- Makes radiographs, CT and MRI scans, US and Nuclear Med images for a particular patient available within the network
- Allows Radiologists and Technologist to access these images from various locations, improving the efficiency of communication

Soon to be Called....
Medical image management and processing system (MIMPS)

81

PACS

- Digital acquisition (Picture)
- Display workstations
- Storage devices (Archiving)
- Components are interconnected by a network (Communication)

82

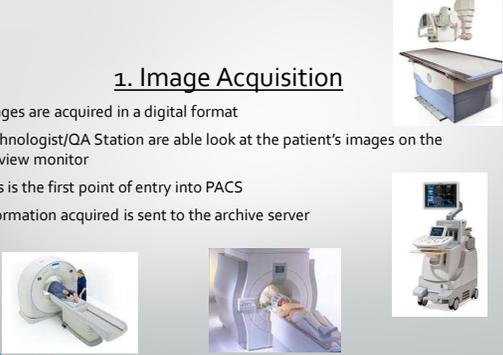
Components of PACS

- Image acquisition
- Display workstations
- Archive servers

83

1. Image Acquisition

- Images are acquired in a digital format
- Technologist/OA Station are able look at the patient's images on the preview monitor
- This is the first point of entry into PACS
- Information acquired is sent to the archive server



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2. Display Workstations

Any computer used to view digital images

- Radiologists
- Physicians, surgeons, nurses & patients
- Technologists

- Most interactive part of PACS
- Used inside and out of Radiology
- Has PACS application software that allows minor image-manipulation

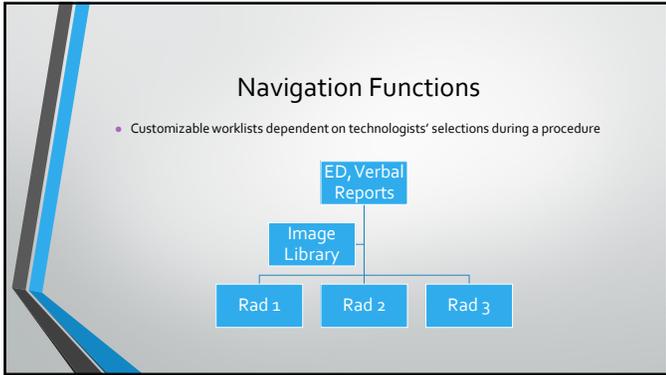


85

Common Workstation Functions

- Navigation Functions
- Hanging Protocol
- Study Navigation
- Image Manipulation & Enhancement
- Image Management

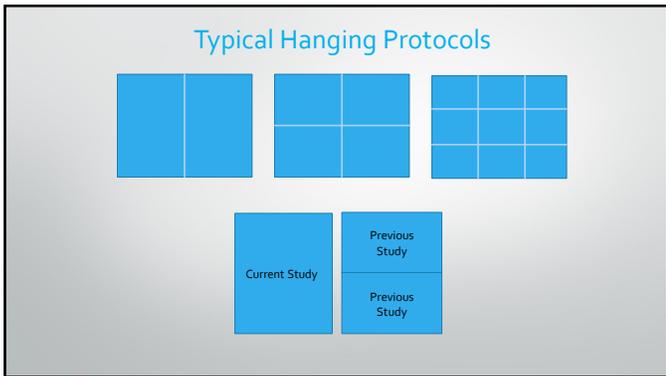
86



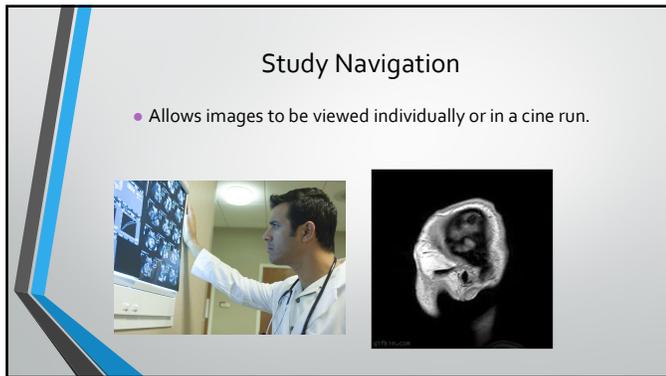
87



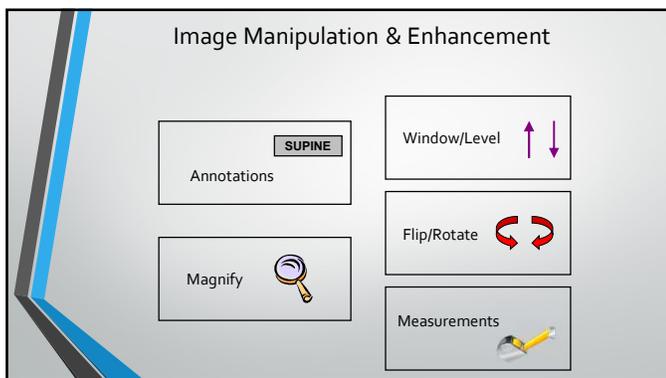
88



89



90



91



92

Image Management Functions

- Patient demographics
 - Edit patient information for proper correlation with previous studies, billing, etc.
- Query / Retrieve
 - Locate images based on patient demographics
- Hardcopy images
 - Either CD or plain film
 - Usually only image library has this function

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3. Archive Servers

- File room of PACS
- Contains all historic and current data



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PACS Archiving

- Consist of:
 - Image manager/controller
 - Image storage/server



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Image Manager

- Contains master database of everything in the archive
- Controls the receipt, retrieval and distribution of the images it stores
- Controls all the DICOM processes running within the archive
- Communicates with RIS and HIS
- Can populate image information into the EMR

MANAGER

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97

Image Storage/Archive Server

- Physical storage device for archive system
- Network of servers
- Setup in tiers
 - Short-term
 - Long-term

In the United States, storage requirement of a patient's images is from five to seven years.

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Short Term Storage

- RAID
 - several magnetic disks or hard drives that are linked together in an array

RAID 5 is the most common level used for a PACS archive because it provides adequate redundancy and fault tolerance

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Reading Hospital

- Short-term storage is done on servers located in IMS but maintained by Philips
 - Philips monitors the system through remote access
 - All backups and drive redundancy are handled by Philips

100

Long Term Storage

- RAID
- Optical disk
- Tape
- Magnetic disk

101

Cloud-Based Storage

- Offsite storage and servers supported by a secure network
- 3rd party vendor
- Shifts disaster recovery process to the vendor along with maintenance and storage equipment purchase
- You pay for the service and storage space

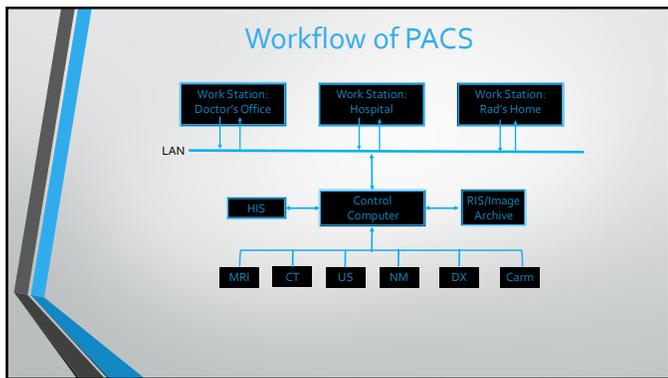
102

Reading Hospital:

- Prior to EPIC - \$1 million budget for record storage
- Legally obligated to retain films:
 - Pediatrics
 - Mammo
 - All other films



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Summary of PACS Functions

- Main function: Act as a *database*
 - Generate and sort according to status (i.e. pending, completed)
 - Various queries – users can search for specific information
- Manipulation – at any workstation
- Storage

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Vendor Neutral Archives (VNA)

- Allows for images and data from different systems and in different formats to be stored using a singular system on a common infrastructure
- May be used as replacements to existing PACS to avoid very expensive transition costs
- Used to consolidate a number of systems that exist within a single facility or across a system of facilities

106

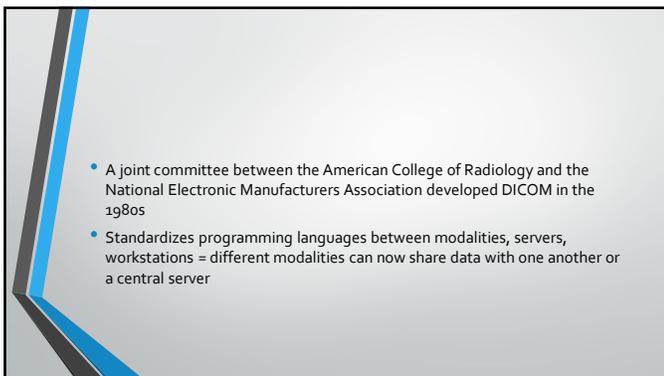
PACS Emergency Contingency Plan

- A backup copy of ALL archived records should be maintained either by the hospital or an Application Service Provider
- RH PACS Downtime Procedure Policy - <https://trh.elucid.com/documents/view/12114/33066/3>

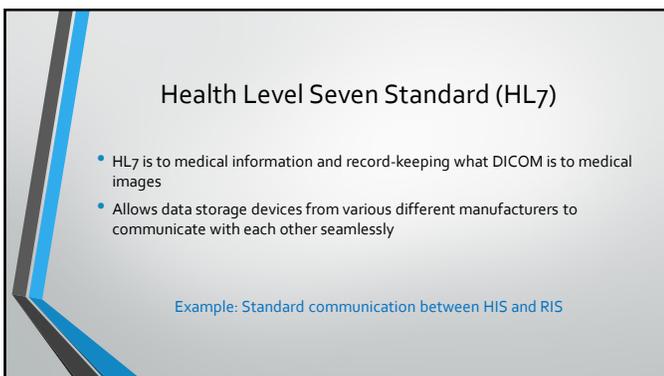
107



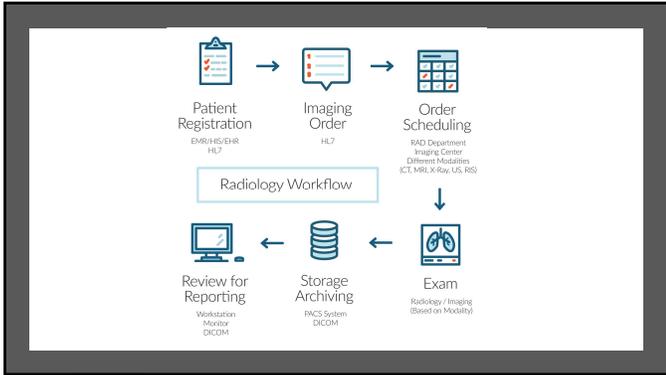
111



112



113



114

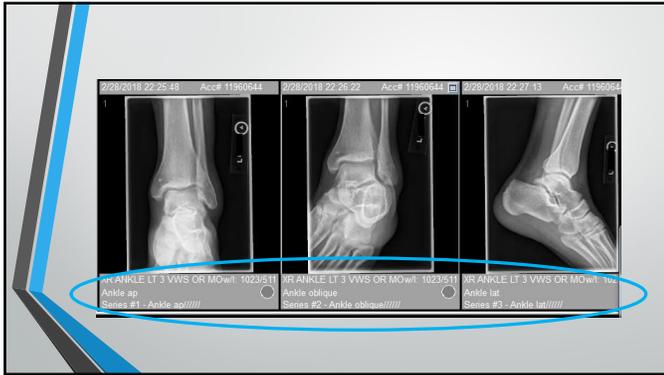
DICOM Header

- A summary of critical identification and study information such as:
 - Date and time of procedure
 - Number of images taken
 - Body part, position
 - Technique used
 - Image format and receptor size
 - Parameters used to digitally process the image
- All this information is stored as **metadata**
 - Should appear in a bar at the top of the screen for each image
 - Shows summary of essential metadata for the image

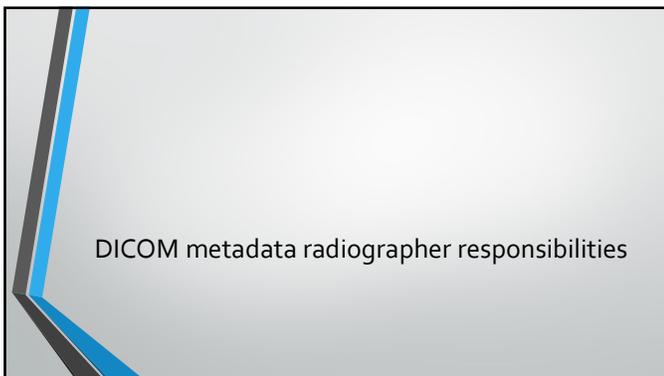
115

Group Tag	Element Tag	Tag Description	Value
0010	0011	Private Tag	MURKIN
0010	0020	Patient ID	12345
0010	0030	Patient's Birth Date	00000000
0010	0040	Patient's Sex	M
0010	1030	Patient's Weight	0
0010	2165	Private Tag	None
0010	2166	Private Tag	None
0010	4000	Patient Comments	
0018	0015	Body Part Examined	THORAX
0018	1000	Device Serial Number	00000000
0018	1020	Software Version(s)	1.0.1.120
0018	1164	Image Field Source	0.16
0018	1508	Positioner Type	COLLIMIN
0018	5100	Patient Position	ANTERIOR - POSTERIOR
0018	7004	Detector Type	DIRECT
0018	7006	Detector Description	
0018	7014	Detector Serial	1.1.1
0020	0020	Study Instance UID	1.2.826.0.1.3680043.2.1330.1000001.1.2211256762.2712337879
0020	000E	Series Instance UID	1.2.826.0.1.3680043.2.1330.1000001.4.2211256762.27123318877
0020	0010	Study ID	None
0020	0011	Series Number	1
0020	0019	Instance Number	29
0020	0020	Patient Orientation	N
0020	0060	Laterality	L
0020	0062	Private Tag	U
0020	4000	Image Comments	
0028	0002	Samples per Pixel	1

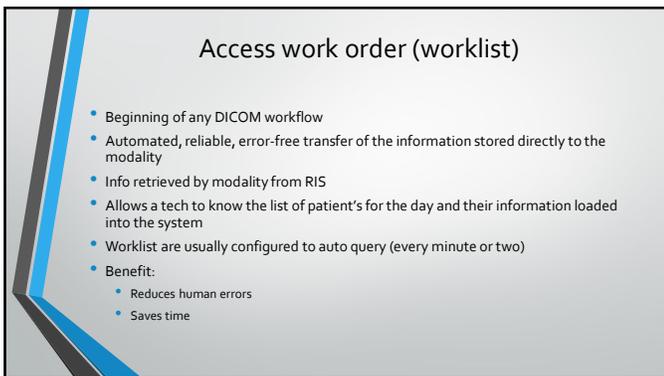
116



117



118



119

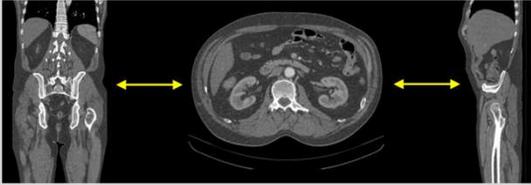
Post Processing – Image operation and manipulation

- Image operation activities
- Multiplanar Reconstruction
- Maximum and Minimum Intensity Projection
- Volume Rendering Technique (VRT)
- Shaded Surface Display (3D technology)
- CAD

120

Multiplanar Reconstruction

- Creates multiple planes of view from a single scan



<https://www.youtube.com/watch?v=H1nPMSVijag>

121

Maximum & Minimum Intensity Projections

- Enhancement of small vessels (MIP) and air-filled structures (MinIP)

MinIP – Minimum Intensity Projections

MIP – Maximum Intensity Projections



MinIP AIP MIP

122

Volume Rendering Technique (VRT)

- Assists in differentiating between anatomical structures by adding color shades based on pixel intensity



123

Shaded Surface Display (SSD)

- Creates a 3D, moveable image based on the pixel intensity of choice



124

CAD (Computer Aided Diagnosis/Detection)

- used as a "second opinion" in assisting radiologists' image interpretations
 - complementary tools that draw the radiologists' attention to certain image areas that need further evaluation
- Uses algorithms
- Used in Mammography at RH



Source: Appl Radiol © 2004 Anderson Publishing, Ltd

125

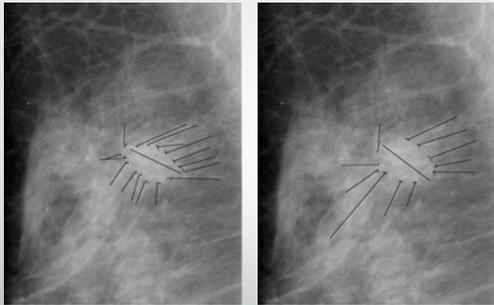
Annotation Issues: Annotations and Mark Ups

- *Image annotation* – describes the meaning in images
- *Image markup* – visual presentation of the annotation
- AIM Project (Annotation and Image Mark up project)
 - The model contains information about who created the annotation, the equipment with which the annotation was created, when the annotation was created, and the image(s) to which the annotation refers.
 - Once the annotation is defined in the AIM, sophisticated queries are now easily found
 - "Find all studies that contain enhancing right middle lobe lung masses that measure between 5 and 6 cm"

126

- Other concerns are
 - What is more accurate tool to use --- stylus or mouse for marking or measurements?
 - Human error
 - Legal issues

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Mouse Stylus

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Case number	Annotation time for mouse (s)	Annotation time for stylus (s)
1	109	86
2	121	71
3	108	70
4	78	74
5	109	91
6	55	57
7	78	77
8	90	54
9	113	60
10	89	85
11	101	98
12	81	41

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Image Transmission

- Concerns of medical data overload
 - CT may produce 300 to 500 images and a CT angiography runoff study may include 1,500 to 2,000 images
- In teleradiology, the header of the DICOM image is first transmitted followed by the compressed image data and then at the receiving end, images are reconstructed from low quality to high (or perfect) quality
- Facilities will compress images to send, this allow it to be sent more efficiently
 - Lossless compression have been defined as "visually acceptable" images by the medical imaging community

130

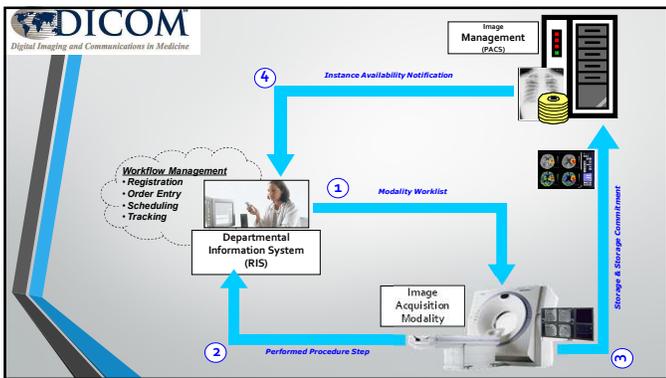
HIPAA

- Health Insurance Portability and Accountability Act of 1996 (HIPAA) Privacy Rule is to ensure you have rights over your own health information, no matter what form it is in.
- The government also created the HIPAA Security Rule to require specific protections to safeguard your electronic health information.
- Federal law requires doctors, hospitals, and other health care providers to notify you of a "breach."
- Facilities should implement high-grade security and encryption in their systems in order to protect records from hackers or theft
- Adhering to HIPAA guidelines often means subjecting software developments to a legal team who can determine whether or not the software falls within HIPAA regulations for security and confidentiality

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132



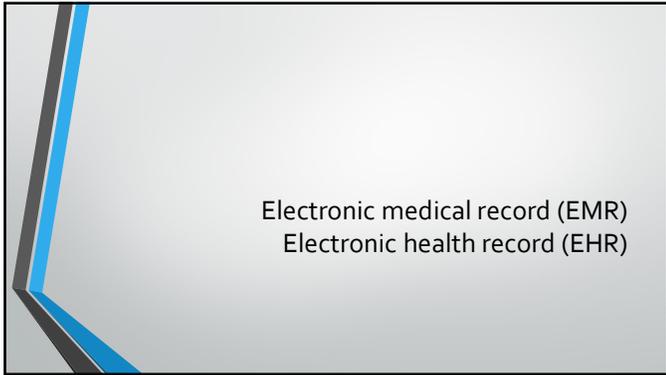
133

DICOM Services for Acquisition Workflow Management

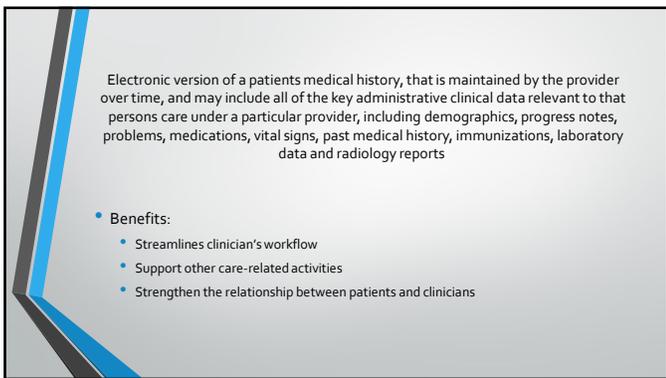
- Improve Interoperability of Imaging Equipment
- Ensure Data Consistency
- Facilitate Reliable Data Management
- Improve Process Efficiency
- Better Quality of Imaging Services

DICOM
Digital Imaging and Communications in Medicine

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- Any system which allows remote transmission and viewing of radiographic images via modems over phone or cable lines
- Makes it possible for images to be sent great distances for a specialist to collaborate with a radiologist, and for images stored at a hospital to be accessed almost instantly by doctors at their individual clinics
 - Example: transmit images to radiologist's home during off hours





1



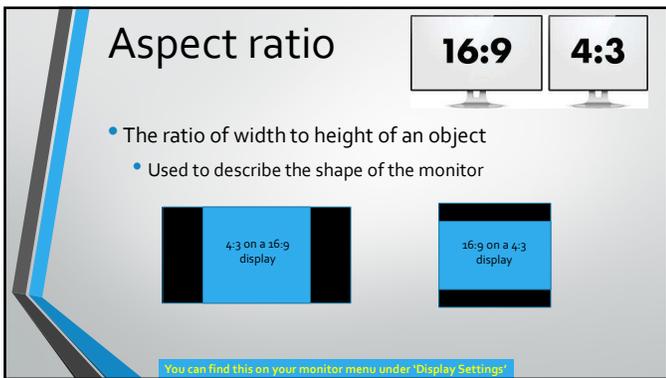
2



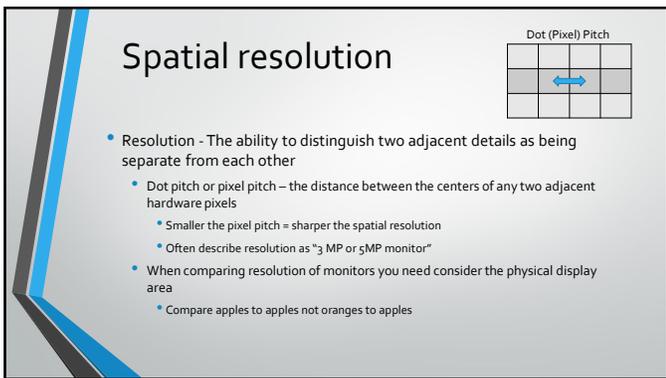
3



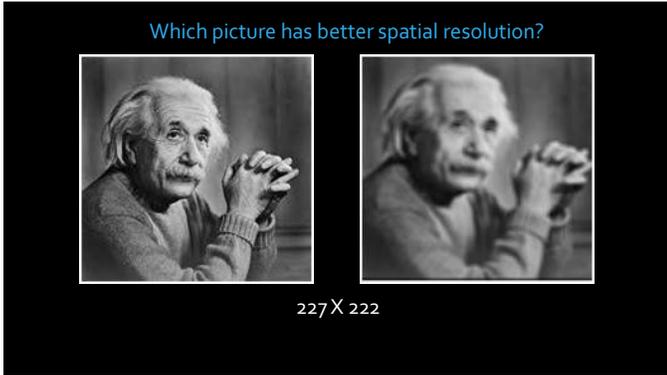
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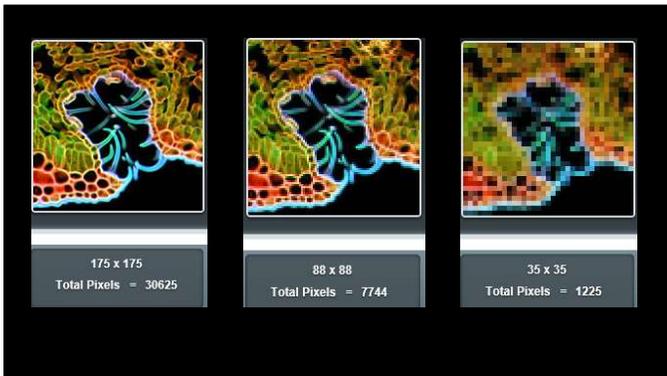
5



6



7



8



9

Brightness

- The black level of a display screen. Although it may sound peculiar, the brightness adjusts the "black level" of the display system (how black the black is) –*Computer Desktop Encyclopedia*
- Photometer is used to measure the brightness output of an LCD
- American College of Radiology (ACR) requires a minimum brightness capability for radiologic display systems of 250 lumens



Too dark Good brightness Too bright

10

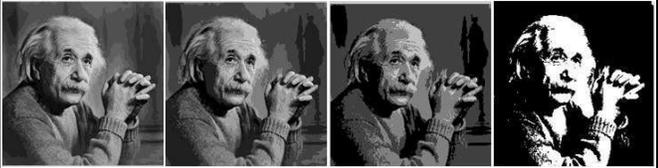
Contrast Ratio

- The difference between the darkest blacks and the brightest whites a given display can produce.
- Contrast ratio for LCD = 600:1, CRT = 3000:1
 - LCD - Inability to produce a "true black" due to backlight leakage



100% Contrast 75% Contrast 50% Contrast 25% Contrast 1% Contrast

12

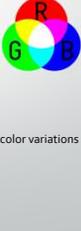


16 Gray Levels 8 Gray Levels 4 Gray Levels 2 Gray Levels

13

Color vs. Grayscale (monochrome)

- **Monochrome monitors**
 - Color images will appear as shades of gray
 - Has only one phosphor of color, but may have the ability to change the brightness causing the illusion of depth
 - Produces sharper text and image because 1 phosphor per pixel than color
- **Color monitors**
 - Monochrome images can be viewed on color monitors
 - Uses alternating intensities of red, green and blue to produce the different color variations
 - Uses 3 phosphors per pixel



15

What color would be seen in a color monitor?

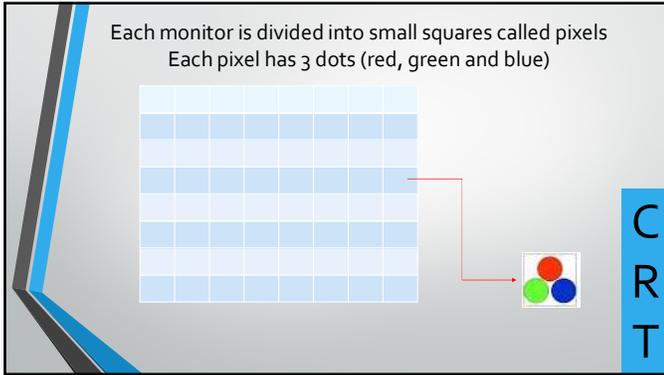
- If all 3 colors set at 0 = **BLACK**
- If all 3 colors set at 255 = **WHITE**
- If red was set at 255 and blue and green at 0 = **RED**

16

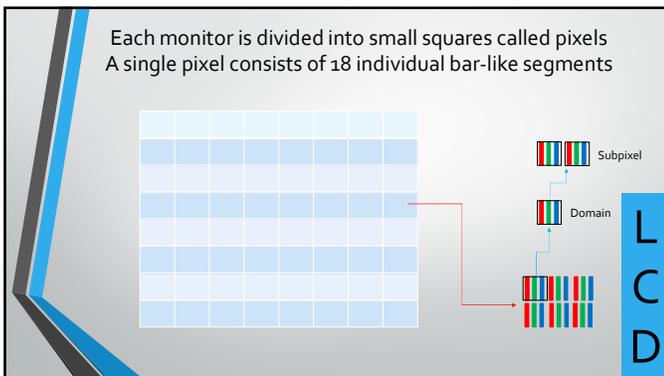
Pixels for Computers

- Pixel – multiple definitions
 - Carroll states it is “the smallest element of the matrix or device that can represent all pixel values within the system’s dynamic range”
- CRT – each triad of color (red, blue, and green) is considered one pixel
- LCD – a single pixel consists of 18 individual bar-like segments
- Hardware pixel in monitor – intersections of flat, transparent wires crossing over each other to form an overall square shape

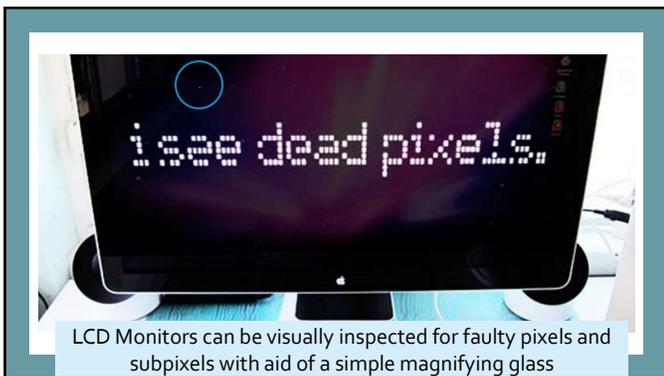
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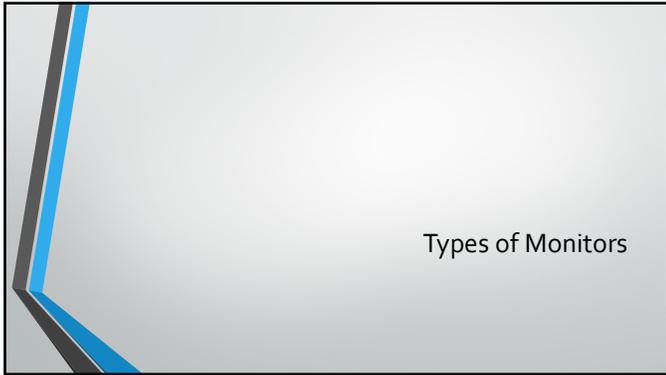
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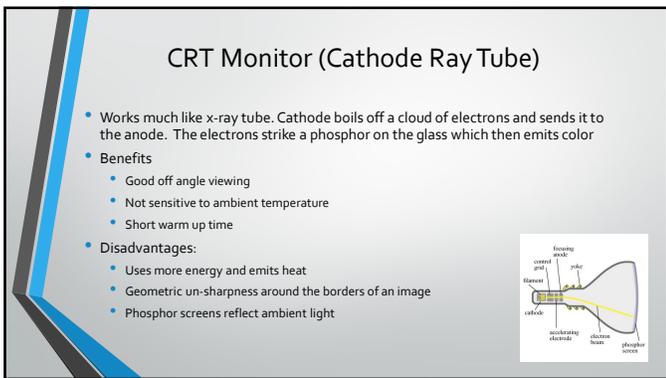
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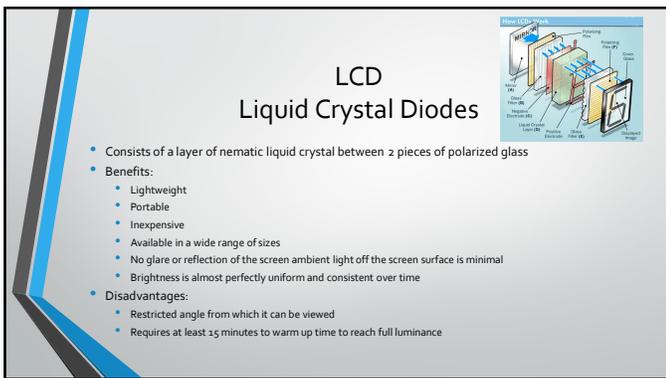
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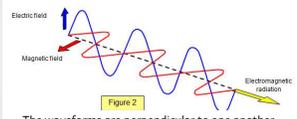
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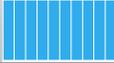
To understand the LCD monitor you must comprehend Light Polarization

- Like an x-ray, a ray of light is electromagnetic radiation that consists of a double wave

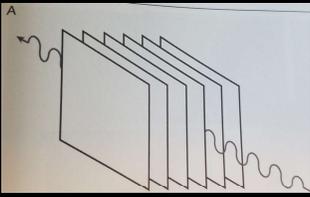


The waveforms are perpendicular to one another

- LCD Monitors use polarized glass
 - Polarized glass contains long chains of iodine molecules, all aligned parallel to each other
 - Just like a grid strips in a grid

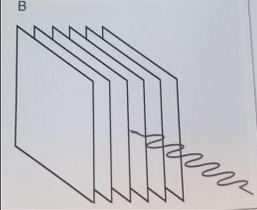


26



Electrical

The electrical component of the double wave can pass through a polarized glass with vertical string molecules because it vibrates parallel to it

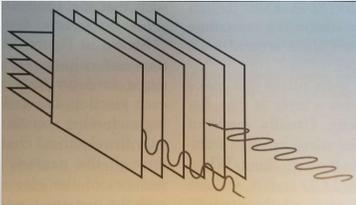


Magnetic

The magnetic component of the double wave cannot pass through a polarized glass with vertical string molecules because it vibrates perpendicular to it

27

What will happen if you layer 2 polarizing glass together so the string molecules are perpendicular to each other?



28

LCD – Light polarization

- LCD monitor consists of:
 - 2 thin sheets of glass
 - Each with a light polarizing layer that are perpendicular to the other sheet

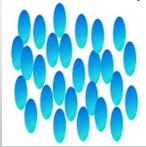
Perpendicular sheets = ALL light being blocked

Don't worry, the LCD process involves "tricking" these layers into allowing light to pass

29

What are nematic liquid crystals?

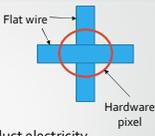
- This is what is inserted between the polarizing glass sheets/lenses that plays the trick
- A crystalline arrangement of molecules that have a long linear shape and tend to align parallel to each other



The diagram shows a cluster of blue, rod-shaped molecules, representing nematic liquid crystals, which are used in LCDs to control light polarization.

30

Before we see the "trick", you need to know one more thing....



Flat wire
Hardware pixel

- In the polarizing glass there are a layer of thin, flat wires to conduct electricity
- These conductors are also aligned perpendicular to each other when the 2 polarized glass are together
- Each junction forms a single **hardware pixel**
 - Each electrode has a scratch on it
 - Scratches are perpendicular to one another
 - The crystals tend to line up with the "scratch" direction when no electric charge is present -- **known as "on" state**

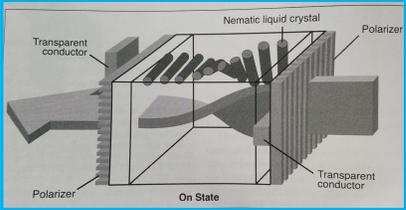
31

And **FINALLY**, Here is the Magic Trick.....



<https://www.youtube.com/watch?v=jiejNAUwcQ8>

32

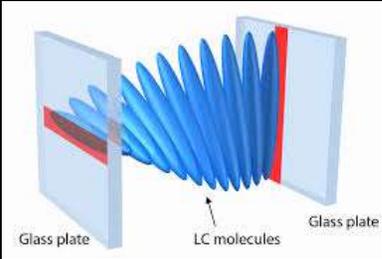


"ON" STATE

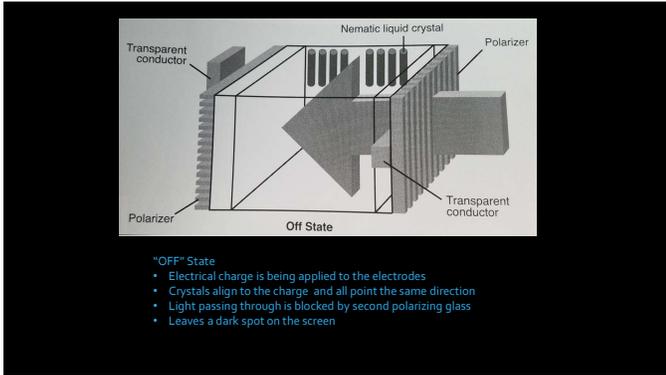
- Since the scratches are perpendicular, the liquid crystals line up in a spiral pattern that twists 90 degrees between the two glass plates
- This lets light waves pass through the nematic liquid crystal and follow the spiral
- Light is able to pass through the second glass plate to the viewer of the monitor

33

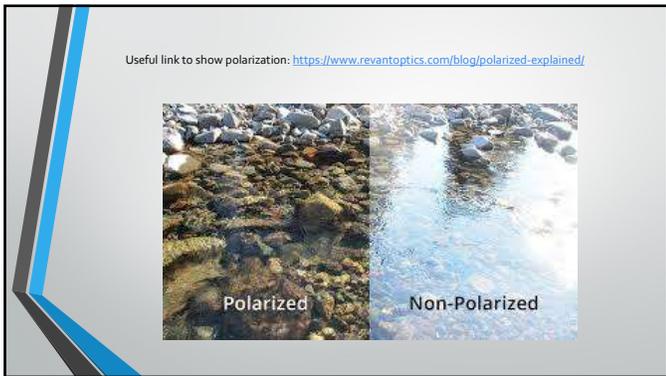
Just another way to look at it



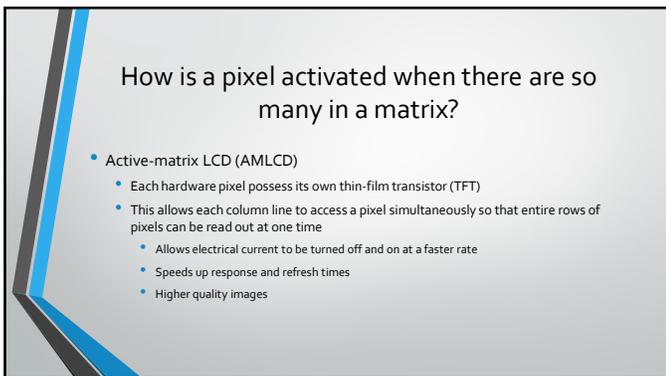
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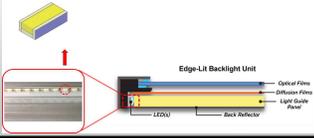
36



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More info on LCD Monitors

- As LCDs **do not** produce light by themselves—they need illumination to produce a visible image.
 - Without a **backlight**, an LCD display device will remain black, rendering it unviewable
- **Backlighting**
 - Types: Fluorescent bulbs or light-emitting diodes (LEDs)
 - LED - Most common



38

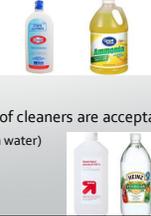
Care and Maintenance

39

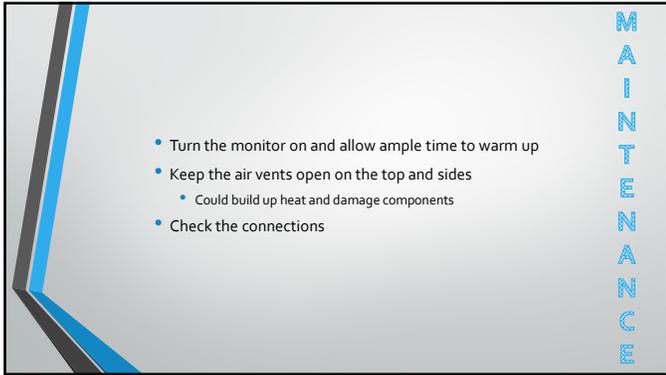
CARE

1. Apply cleaning solution to soft cloth
 - Do not spray solution directly on screen
 - Do not use paper towel can cause scratches
2. Wipe in one direction from top of screen to bottom

- The following cleaners should NOT be used: Acetone
 - Ethyl alcohol
 - Ethyl acid
 - Ammonia
 - Methyl chloride
- The following types of cleaners are acceptable: Water
 - Vinegar (mixed with water)
 - Isopropyl Alcohol
 - Petroleum Benzene



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• Turn the monitor on and allow ample time to warm up

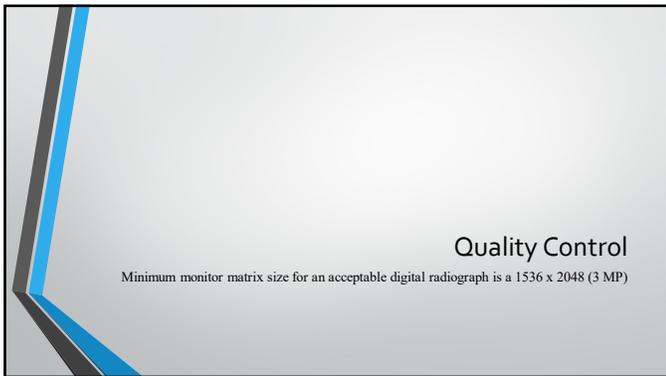
• Keep the air vents open on the top and sides

- Could build up heat and damage components

• Check the connections

M-A-I-N-T-E-N-A-N-C-E

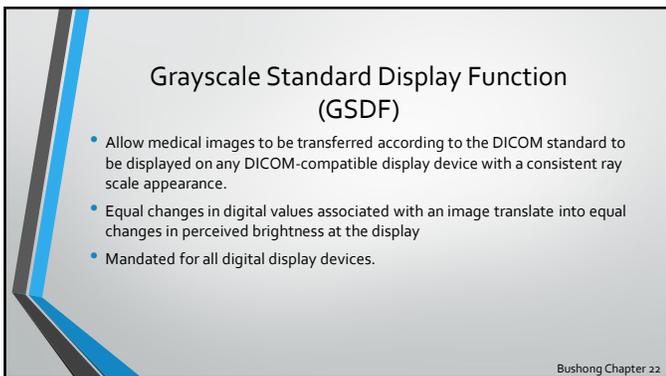
41



Quality Control

Minimum monitor matrix size for an acceptable digital radiograph is a 1536 x 2048 (3 MP)

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Grayscale Standard Display Function (GSDf)

- Allow medical images to be transferred according to the DICOM standard to be displayed on any DICOM-compatible display device with a consistent ray scale appearance.
- Equal changes in digital values associated with an image translate into equal changes in perceived brightness at the display
- Mandated for all digital display devices.

Bushong Chapter 22

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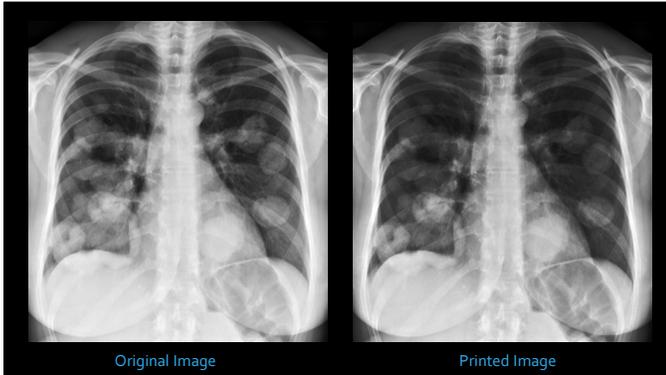
DICOM Grayscale Standard Display Function (GSDF) generates a display function matching the perceptual characteristics of a human observer.

Standard developed having human observer view monitor while luminance output of monitor changed in small steps from black to white and noting when they observed a **Just Noticeable Difference** (JND) in light output as the drive signal is changed.

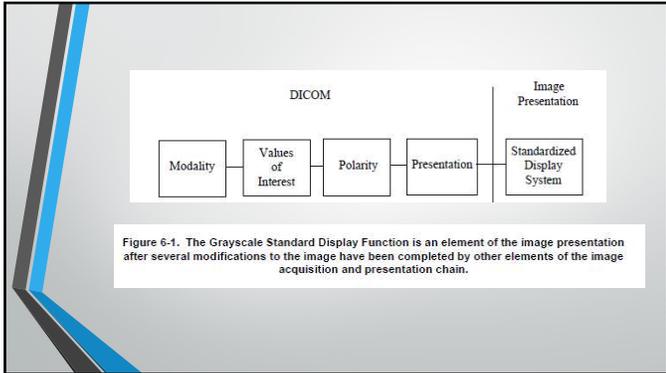
Most digital radiologic images are windowed to attempt to display 256 different shades of gray at any one time, (256 is approximate JND that humans can perceive)

The perceptual linearization implemented with the DICOM Grayscale Standard Display Function (GSDF) ensures that pixel values that are supposed to increase brightness in a linear fashion, say 6, 7, and 8, for example, actually appear that way to the human eye, despite the nonlinearity of our perception.

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Luminance

The rate of light (brightness) emitted from a source such as an LCD monitor

- **Maximum luminance** (*maximum brightness*)- checked at same monitor setting over a period of time with a photometer
- **Luminance response** – monitors ability to accurately display different shades of brightness from a test pattern
- **Luminance ratio** – compares maximum luminance to the minimum luminance
- **Luminance uniformity** – consistency of a single brightness level displayed across the area of the screen

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Luminance Ratio

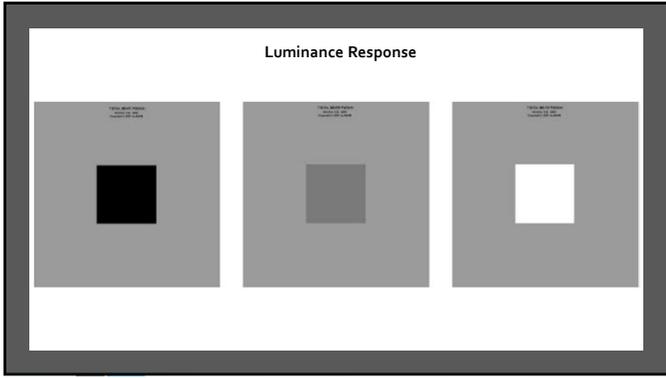
48

Luminance Response

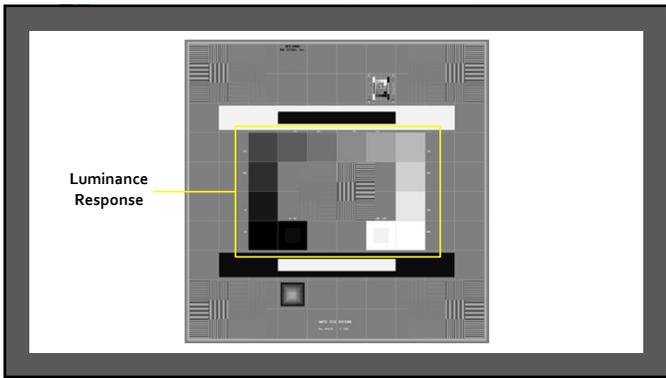
TDS-CT Patterns
Version 2.0, 10/11
Copyright © 2011 by iMotions

A

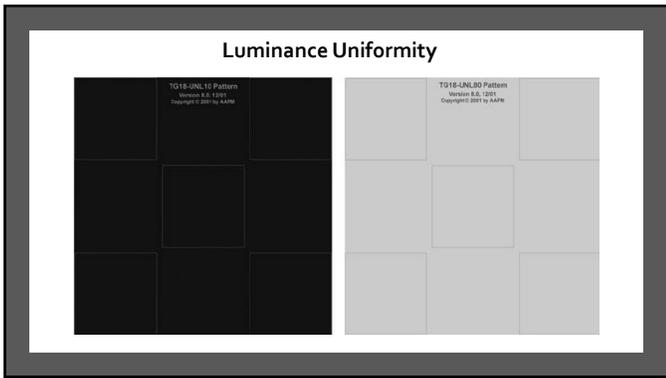
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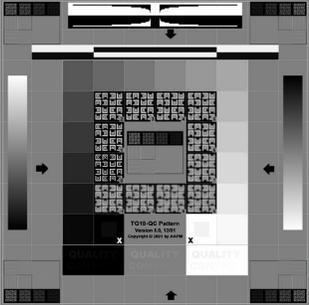
52

Resolution

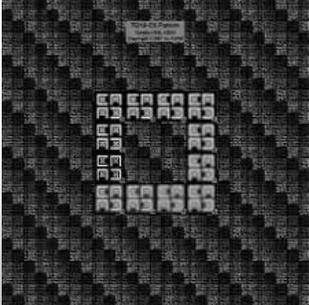
- ACR and AAPM minimum resolution for electronically displayed images of 2.5LP/mm
 - Generic SMPTE test pattern can be used
 - Check for blurring
- AAPM TG18 – QC and TG 18 CX provides an excellent check for resolution across the area of the display screen
 - Evaluate the CX pattern in the middle and in the corners
- Test can be done daily, weekly or monthly

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TG18 - QC

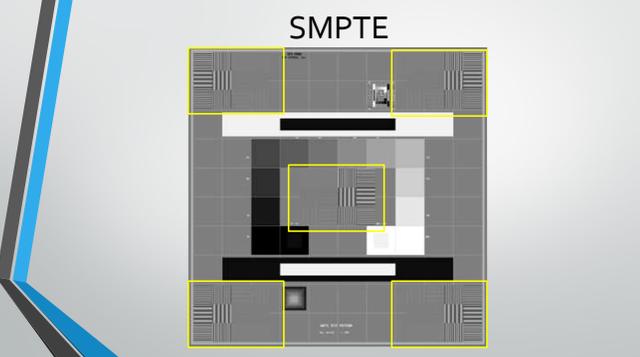


TG18 - CX

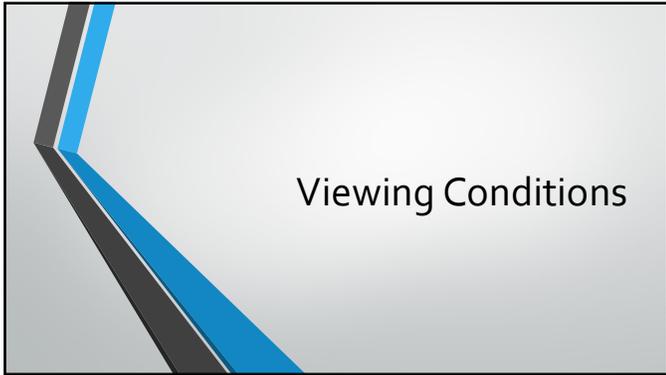


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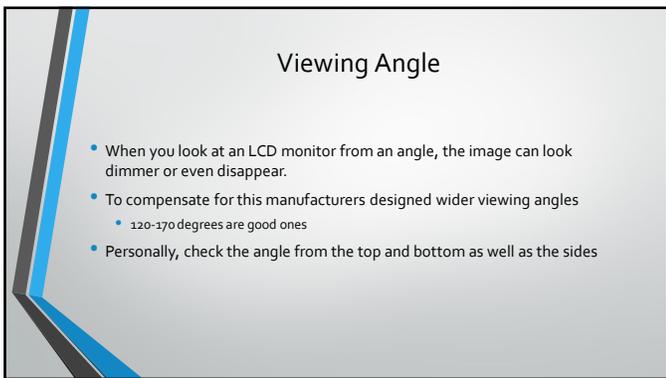
SMPTE



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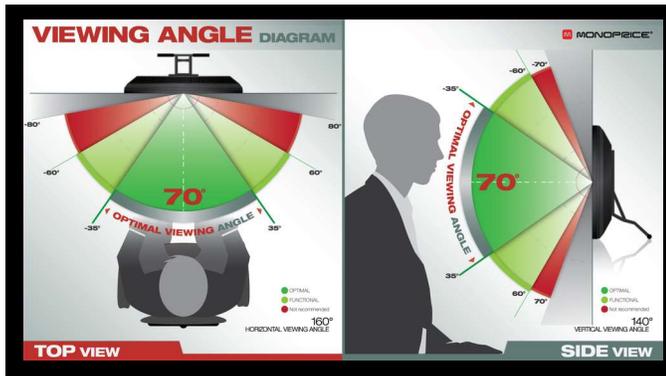
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Ambient Lighting

Illuminance – the rate of light striking a surface

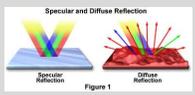


Figure 1

- The effect of ambient room lighting on the surface of and LCD monitor screen, including **reflectance** off the screen, and the resulting reduction in visible contrast of the image, is a result of **illuminance**
- Diffuse reflectance
 - The cumulative effect of room lighting across the area of the monitor screen
- Specular reflectance
 - The reflection of actual light sources such as a light bulb or window

The ambient lighting within the room must be dimmed to a point where both types of reflectance are below any noticeable level, that would impede full visibility of the image and image contrast

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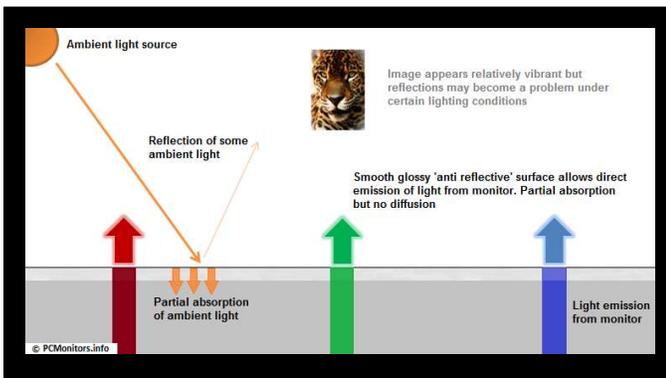
QC Aspect or Ambient Light

- While diagnosis is taking place, the maximum ambient lighting in a reading room should never be more than 25 lux
 - Approximately 1/4 the typical brightness of normal office lighting (75-100 lux)

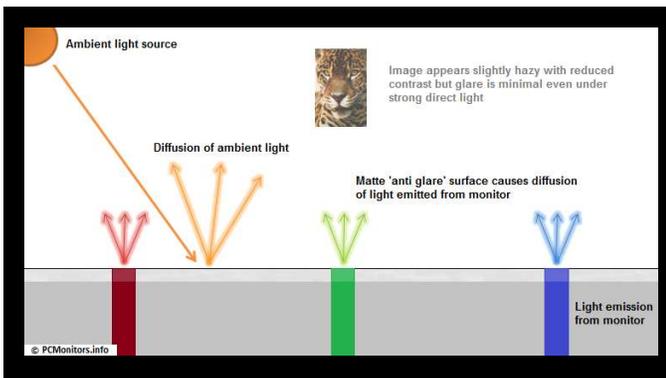
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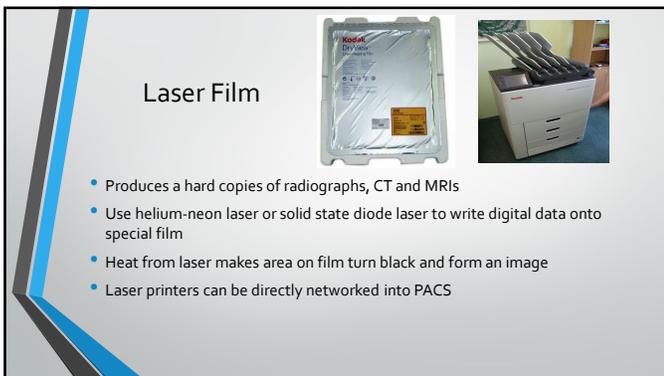
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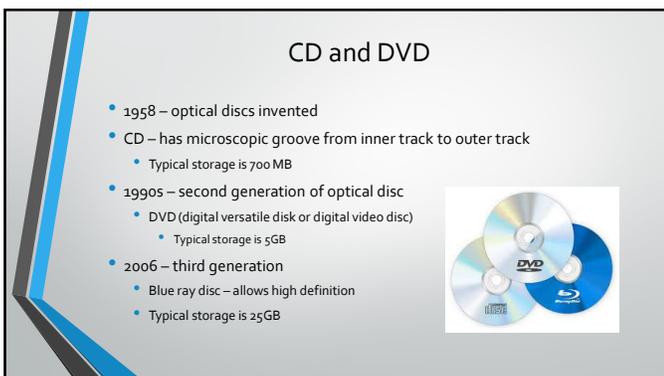
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Data Management

75

Network Connectivity

- LAN – Local Area Network
 - Computerized communications network generally contained within a single building or business
 - Devices share one server
- WAN – Wide Area Network
 - Extends to other businesses or locations that may be at great distances
 - Publically or commercially owned
 - Uses transmission services provided by common carriers (phone or cable companies)



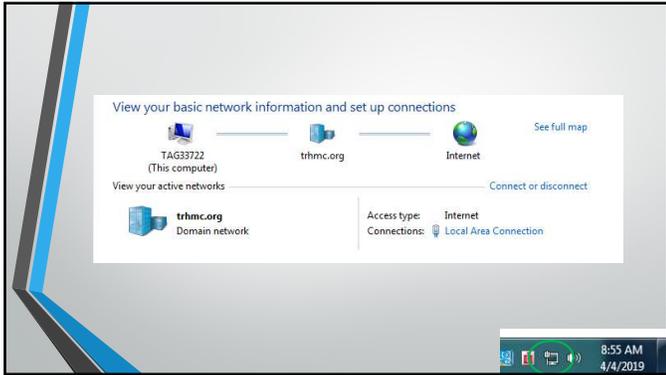
76

Computer Network

- Every computer within a network has a unique internet protocol or IP address
 - Ex. 172.811.3.1
- Every computer must have a network interface card
- Router
 - Connects 2 or more networks
 - Wireless routers – allow "point-of-care" access to a network for physicians and other caregivers via tablet or laptop



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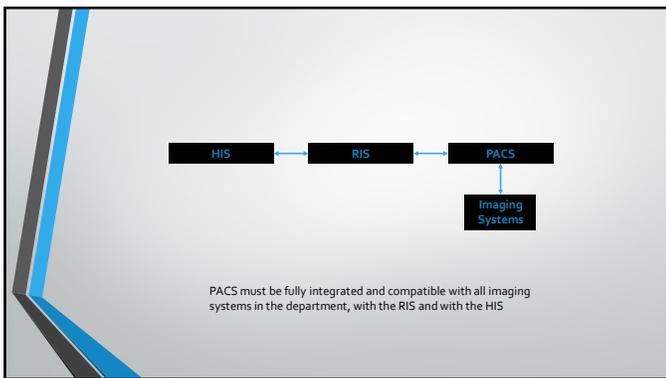
78

Type of LAN

RIS and HIS

- Radiology Information System
 - Data system for patient-related functions in the department, such as scheduling of x-ray appointments, tracking of patients, storage and distribution of reports
 - Makes info accessible from different locations within the radiology department
 - Assigns the **accession number**
- Hospital/Health Information System
 - Performs same functions for the entire institution (patient's general medical file)
 - Assigns a unique identifying number for each patient (**MRN**)

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Picture Archiving and Communications System (PACS)

- Comprehensive computer network that is responsible for the electronic storage and distribution of medical images.
- Makes radiographs, CT and MRI scans, US and Nuclear Med images for a particular patient available within the network
- Allows Radiologists and Technologist to access these images from various locations, improving the efficiency of communication

Soon to be Called....
Medical image management and processing system (MIMPS)

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PACS

- Digital acquisition (Picture)
- Display workstations
- Storage devices (Archiving)
- Components are interconnected by a network (Communication)

82

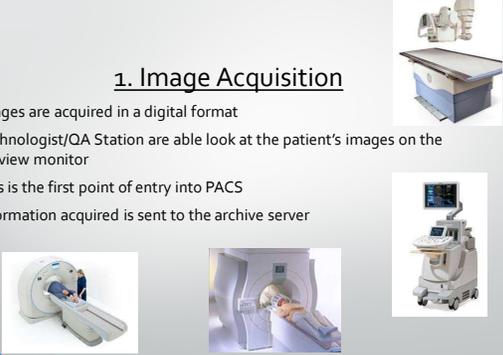
Components of PACS

- Image acquisition
- Display workstations
- Archive servers

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1. Image Acquisition

- Images are acquired in a digital format
- Technologist/OA Station are able look at the patient's images on the preview monitor
- This is the first point of entry into PACS
- Information acquired is sent to the archive server



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2. Display Workstations

Any computer used to view digital images

- Radiologists
- Physicians, surgeons, nurses & patients
- Technologists

- Most interactive part of PACS
- Used inside and out of Radiology
- Has PACS application software that allows minor image-manipulation

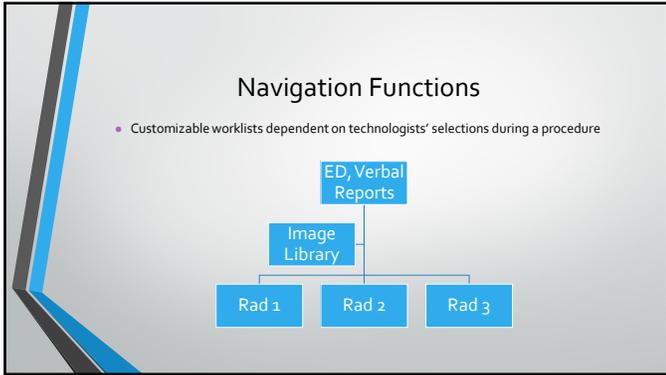


85

Common Workstation Functions

- Navigation Functions
- Hanging Protocol
- Study Navigation
- Image Manipulation & Enhancement
- Image Management

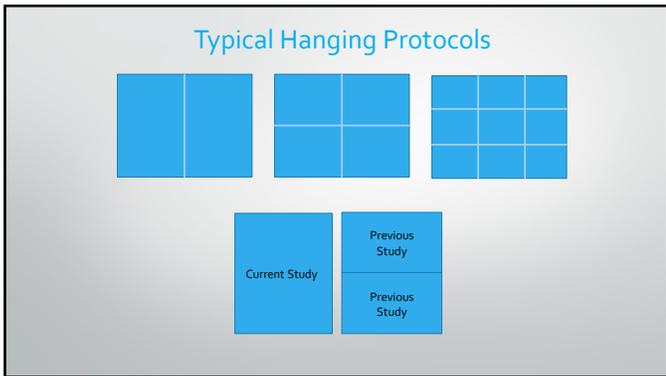
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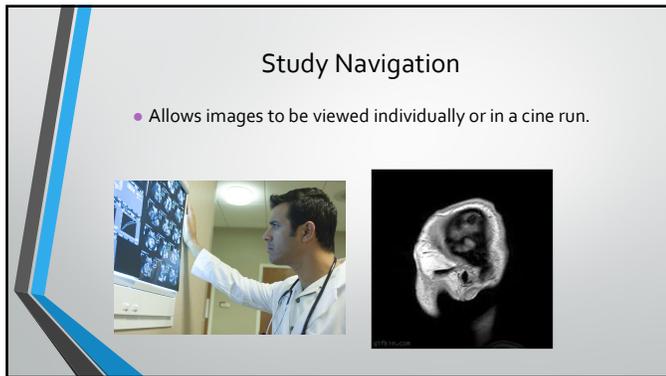
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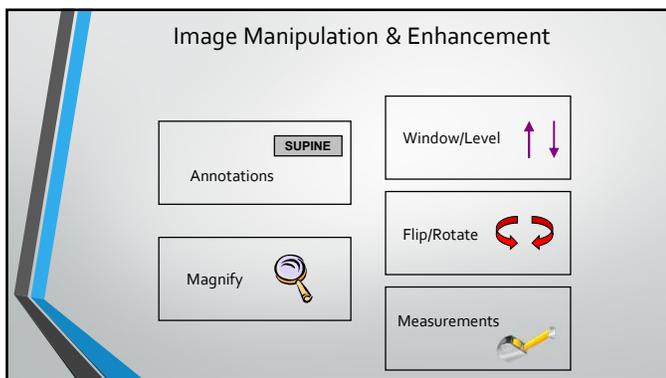
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89



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91



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Image Management Functions

- Patient demographics
 - Edit patient information for proper correlation with previous studies, billing, etc.
- Query / Retrieve
 - Locate images based on patient demographics
- Hardcopy images
 - Either CD or plain film
 - Usually only image library has this function

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3. Archive Servers

- File room of PACS
- Contains all historic and current data



94

PACS Archiving

- Consist of:
 - Image manager/controller
 - Image storage/server



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Image Manager

- Contains master database of everything in the archive
- Controls the receipt, retrieval and distribution of the images it stores
- Controls all the DICOM processes running within the archive
- Communicates with RIS and HIS
- Can populate image information into the EMR

MANAGER

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97

Image Storage/Archive Server

- Physical storage device for archive system
- Network of servers
- Setup in tiers
 - Short-term
 - Long-term

In the United States, storage requirement of a patient's images is from five to seven years.

98

Short Term Storage

- RAID
 - several magnetic disks or hard drives that are linked together in an array

RAID 5 is the most common level used for a PACS archive because it provides adequate redundancy and fault tolerance

99

Reading Hospital

- Short-term storage is done on servers located in IMS but maintained by Philips
 - Philips monitors the system through remote access
 - All backups and drive redundancy are handled by Philips

100

Long Term Storage

- RAID
- Optical disk
- Tape
- Magnetic disk

101

Cloud-Based Storage

- Offsite storage and servers supported by a secure network
- 3rd party vendor
- Shifts disaster recovery process to the vendor along with maintenance and storage equipment purchase
- You pay for the service and storage space

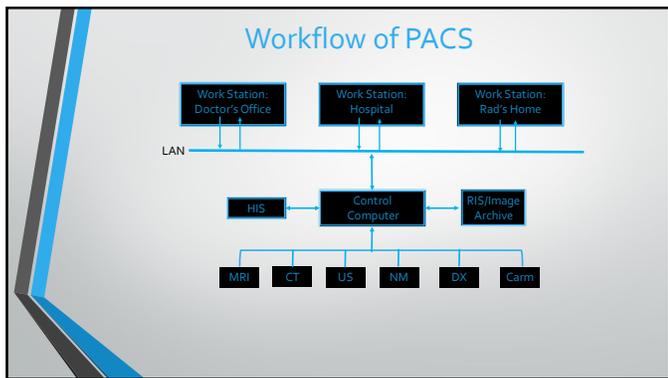
102

Reading Hospital:

- Prior to EPIC - \$1 million budget for record storage
- Legally obligated to retain films:
 - Pediatrics
 - Mammo
 - All other films



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Summary of PACS Functions

- Main function: Act as a *database*
 - Generate and sort according to status (i.e. pending, completed)
 - Various queries – users can search for specific information
- Manipulation – at any workstation
- Storage

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Vendor Neutral Archives (VNA)

- Allows for images and data from different systems and in different formats to be stored using a singular system on a common infrastructure
- May be used as replacements to existing PACS to avoid very expensive transition costs
- Used to consolidate a number of systems that exist within a single facility or across a system of facilities

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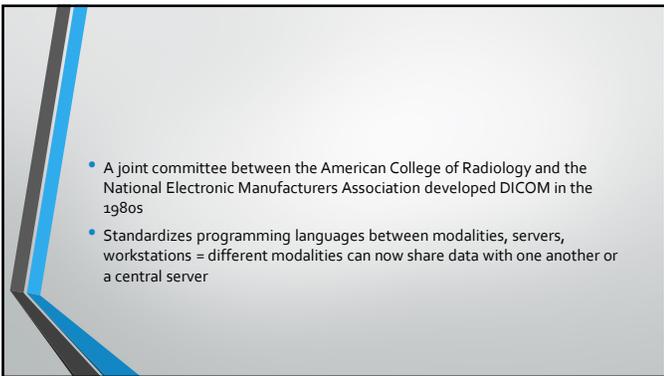
PACS Emergency Contingency Plan

- A backup copy of ALL archived records should be maintained either by the hospital or an Application Service Provider
- RH PACS Downtime Procedure Policy - <https://trh.elucid.com/documents/view/12114/33066/3>

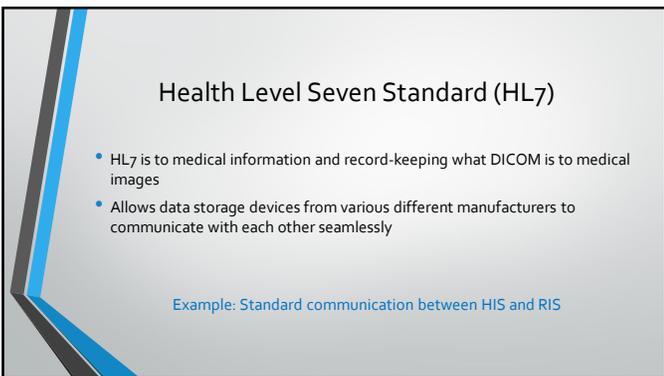
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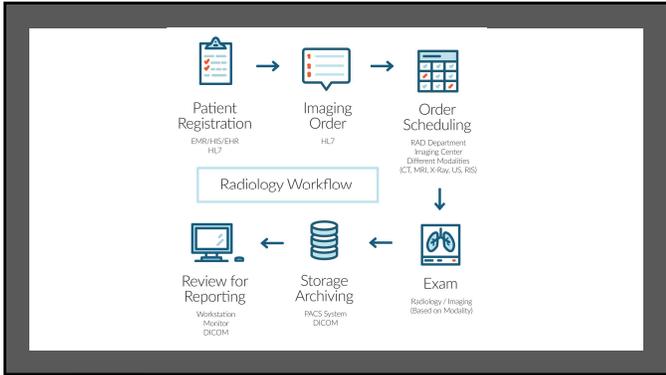
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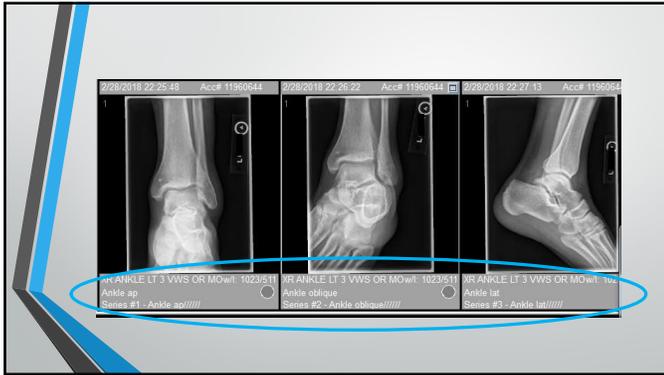
DICOM Header

- A summary of critical identification and study information such as:
 - Date and time of procedure
 - Number of images taken
 - Body part, position
 - Technique used
 - Image format and receptor size
 - Parameters used to digitally process the image
- All this information is stored as **metadata**
 - Should appear in a bar at the top of the screen for each image
 - Shows summary of essential metadata for the image

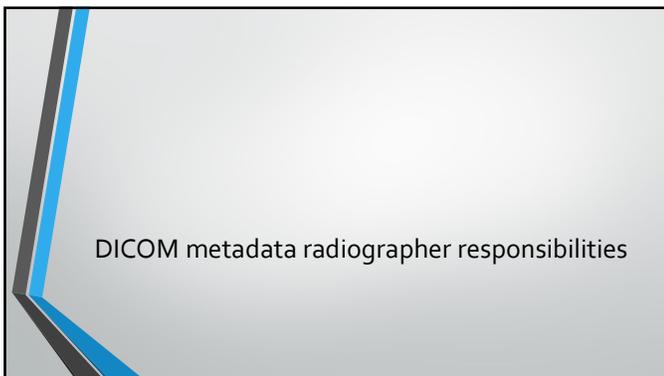
115

Group Tag	Element Tag	Tag Description	Value
0010	0011	Private Tag	MURKIN
0010	0020	Patient ID	12345
0010	0030	Patient's Birth Date	00000000
0010	0040	Patient's Sex	M
0010	1030	Patient's Weight	0
0010	2165	Private Tag	None
0010	2166	Private Tag	None
0010	4000	Patient Comments	
0018	0015	Body Part Examined	THORAX
0018	1000	Device Serial Number	00000000
0018	1020	Software Version(s)	1.0.1.120
0018	1164	Image Field Sequence	0.16
0018	1508	Positioner Type	COLLIMIN
0018	5100	Patient Position	ANTERIOR - POSTERIOR
0018	7004	Detector Type	DIRECT
0018	7006	Detector Description	
0018	7014	Detector Serial	1.1.1
0020	0020	Study Instance UID	1.2.825.0.1.3680043.2.1330.1000001.1.2213256752.2712337879
0020	000E	Series Instance UID	1.2.825.0.1.3680043.2.1330.1000001.4.2213256752.27123318877
0020	0010	Study ID	None
0020	0011	Series Number	1
0020	0019	Instance Number	29
0020	0020	Patient Orientation	N
0020	0060	Laterality	L
0020	0062	Private Tag	U
0020	4000	Image Comments	
0028	0002	Samples per Pixel	1

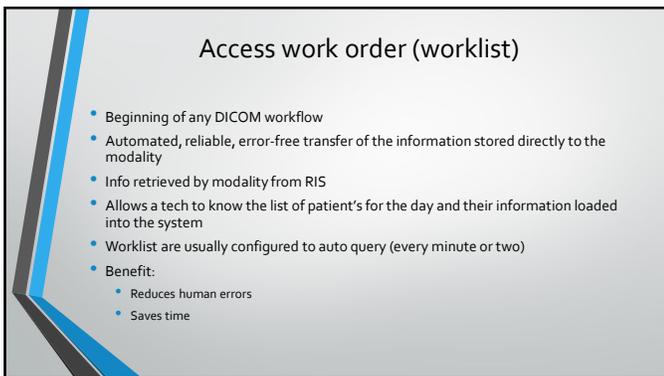
116



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118



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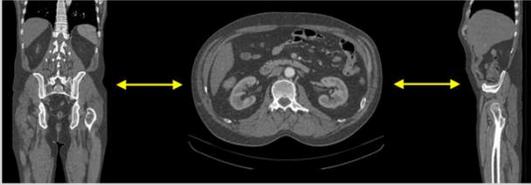
Post Processing – Image operation and manipulation

- Image operation activities
- Multiplanar Reconstruction
- Maximum and Minimum Intensity Projection
- Volume Rendering Technique (VRT)
- Shaded Surface Display (3D technology)
- CAD

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Multiplanar Reconstruction

- Creates multiple planes of view from a single scan



<https://www.youtube.com/watch?v=H1nPMSVijag>

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Maximum & Minimum Intensity Projections

- Enhancement of small vessels (MIP) and air-filled structures (MinIP)

MinIP – Minimum Intensity Projections

MIP – Maximum Intensity Projections



MinIP AIP MIP

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Volume Rendering Technique (VRT)

- Assists in differentiating between anatomical structures by adding color shades based on pixel intensity



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Shaded Surface Display (SSD)

- Creates a 3D, moveable image based on the pixel intensity of choice



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CAD (Computer Aided Diagnosis/Detection)

- used as a "second opinion" in assisting radiologists' image interpretations
 - complementary tools that draw the radiologists' attention to certain image areas that need further evaluation
- Uses algorithms
- Used in Mammography at RH



Source: Appl Radiol © 2004 Anderson Publishing, Ltd

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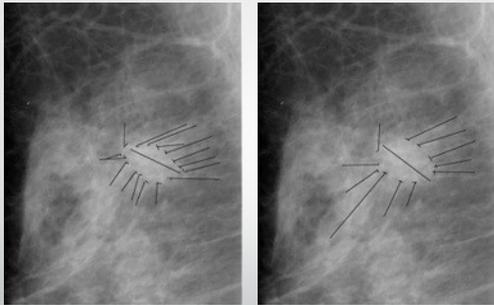
Annotation Issues: Annotations and Mark Ups

- *Image annotation* – describes the meaning in images
- *Image markup* – visual presentation of the annotation
- AIM Project (Annotation and Image Mark up project)
 - The model contains information about who created the annotation, the equipment with which the annotation was created, when the annotation was created, and the image(s) to which the annotation refers.
 - Once the annotation is defined in the AIM, sophisticated queries are now easily found
 - "Find all studies that contain enhancing right middle lobe lung masses that measure between 5 and 6 cm"

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- Other concerns are
 - What is more accurate tool to use --- stylus or mouse for marking or measurements?
 - Human error
 - Legal issues

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Mouse Stylus

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Case number	Annotation time for mouse (s)	Annotation time for stylus (s)
1	109	86
2	121	71
3	108	70
4	78	74
5	109	91
6	55	57
7	78	77
8	90	54
9	113	60
10	89	85
11	101	98
12	81	41

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Image Transmission

- Concerns of medical data overload
 - CT may produce 300 to 500 images and a CT angiography runoff study may include 1,500 to 2,000 images
- In teleradiology, the header of the DICOM image is first transmitted followed by the compressed image data and then at the receiving end, images are reconstructed from low quality to high (or perfect) quality
- Facilities will compress images to send, this allow it to be sent more efficiently
 - Lossless compression have been defined as "visually acceptable" images by the medical imaging community

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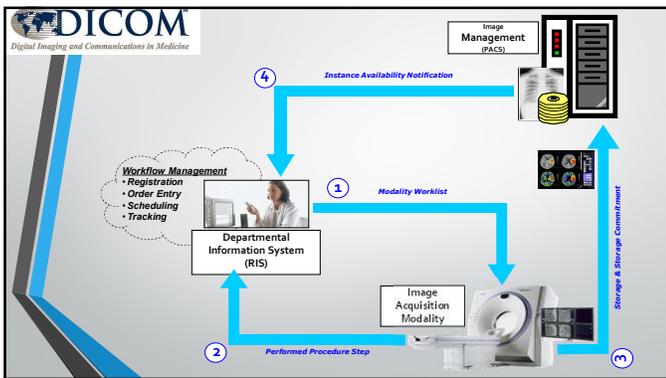
HIPAA

- Health Insurance Portability and Accountability Act of 1996 (HIPAA) Privacy Rule is to ensure you have rights over your own health information, no matter what form it is in.
- The government also created the HIPAA Security Rule to require specific protections to safeguard your electronic health information.
- Federal law requires doctors, hospitals, and other health care providers to notify you of a "breach."
- Facilities should implement high-grade security and encryption in their systems in order to protect records from hackers or theft
- Adhering to HIPAA guidelines often means subjecting software developments to a legal team who can determine whether or not the software falls within HIPAA regulations for security and confidentiality

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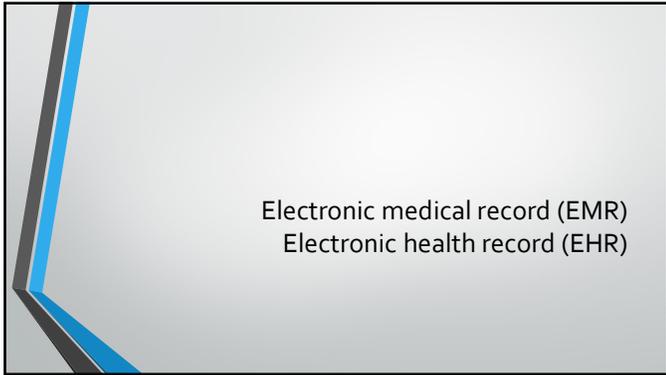
133

DICOM Services for Acquisition Workflow Management

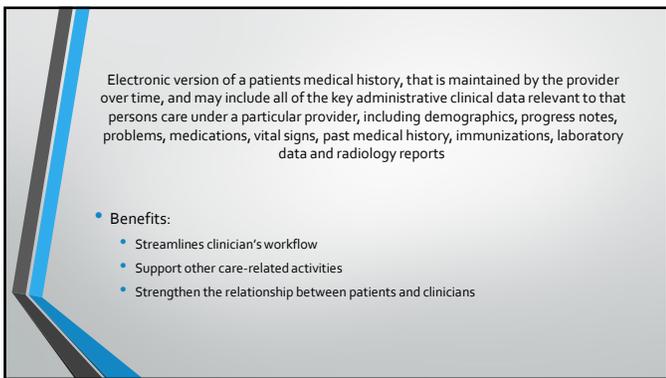
- Improve Interoperability of Imaging Equipment
- Ensure Data Consistency
- Facilitate Reliable Data Management
- Improve Process Efficiency
- Better Quality of Imaging Services

DICOM
Digital Imaging and Communications in Medicine

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- Any system which allows remote transmission and viewing of radiographic images via modems over phone or cable lines
- Makes it possible for images to be sent great distances for a specialist to collaborate with a radiologist, and for images stored at a hospital to be accessed almost instantly by doctors at their individual clinics
 - Example: transmit images to radiologist's home during off hours