Safety in Radiology

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RAD 366

Safety in Radiology

Lecture Objectives:

At the end of this lecture you should be able to:

- **Recognize, and evaluate essential information on the biologic effects of ionizing radiation and radiation safety to ensure the safe use of x-rays in diagnostic imaging.**
- **Know radiation quantities and units, regulatory and advisory limit for human exposure to radiation.**
- **Know equipment for radiation protection and measurement.**
- **Understand the fundamental principles of MRI safety**
- **Know about contrast agents reactions and safety.**
- **Understand how to prepare patients for radiology studies.**

Safety in Radiology

Major Sources of Risk in Radiology:

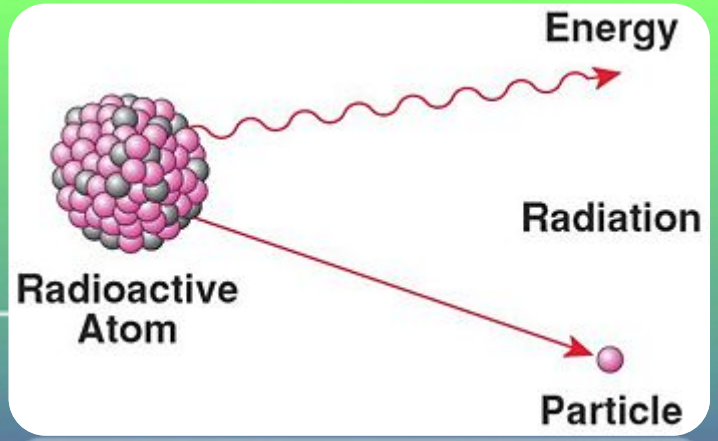
- **Radiation hazard.**
- **Radioactive materials hazard.**
- **Magnetic field hazard.**
- **Contrast agents hazard.**

What is Radiation?

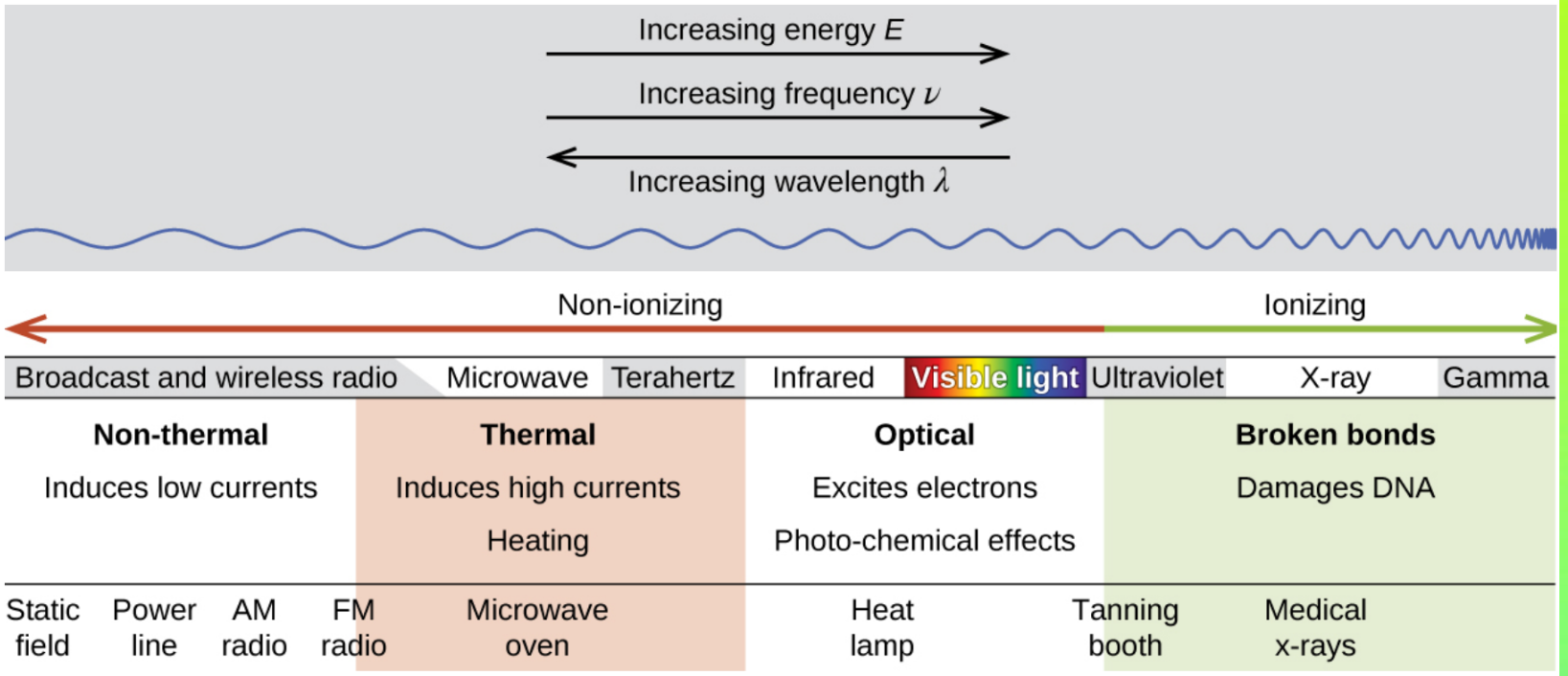
Radiation is energy emitted from a substance:

- **Non-ionizing:** **Microwave oven, Television, Radiowaves and Ultrasound.**

- **Ionizing:** **means alpha particles (α), beta (β), gamma (γ) and X-rays (among others) that are have enough energy to knock electrons out of molecules and produce ions.**

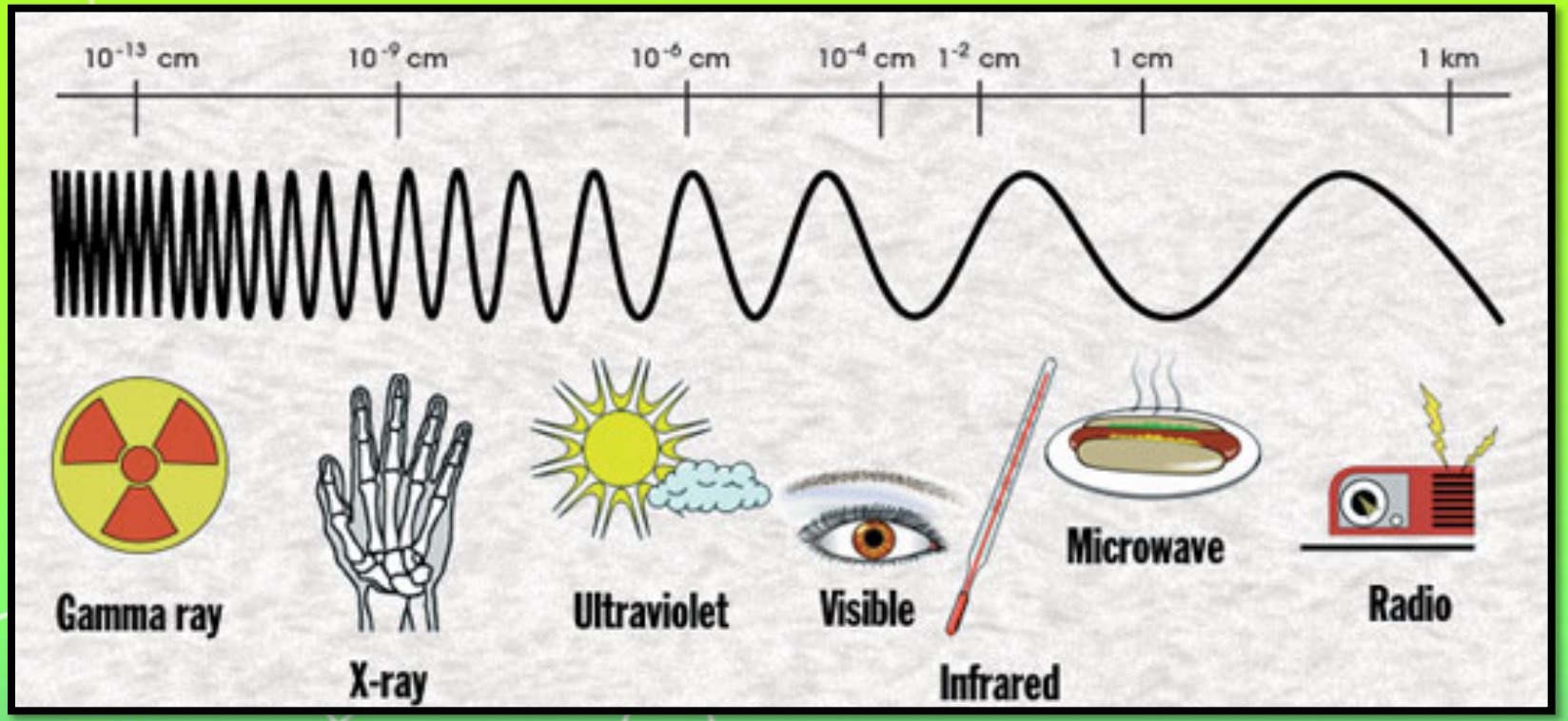


What is Radiation?



Lower frequency, lower-energy electromagnetic radiation is nonionizing, and higher frequency, higher-energy electromagnetic radiation is ionizing.

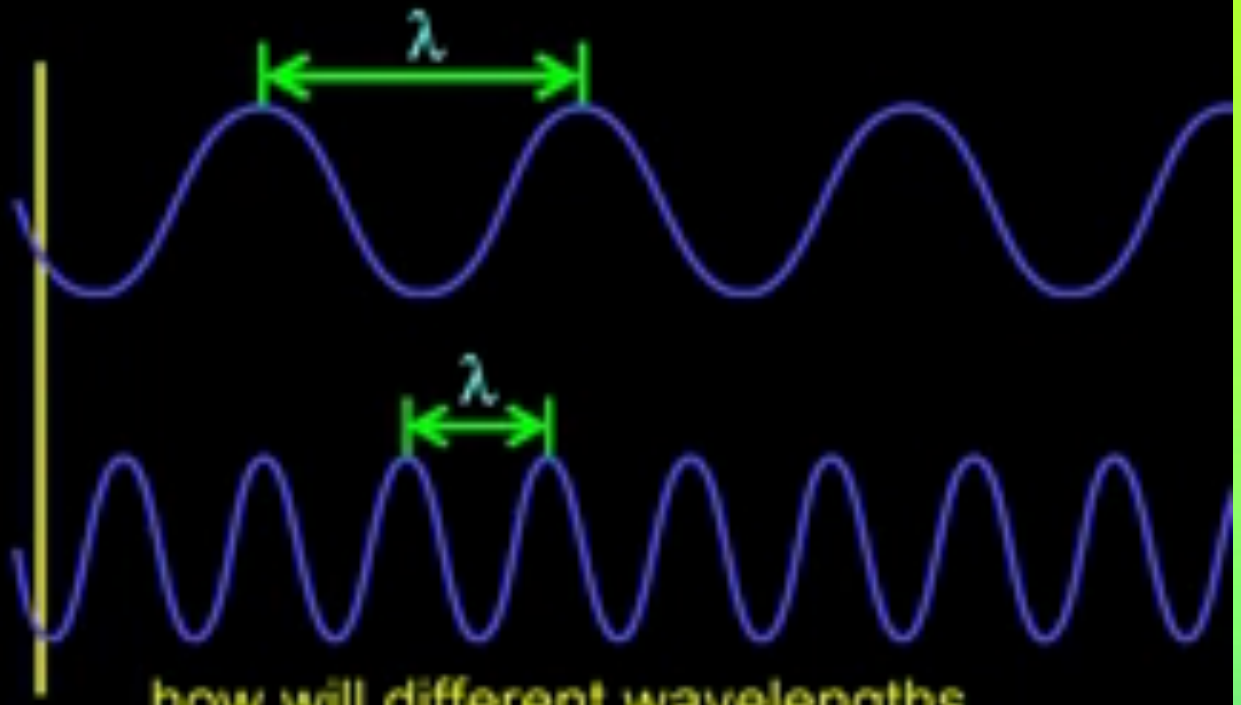
Radiation Spectrum



What is an X-ray?

- **X-rays are very short wavelength electromagnetic radiation.**
- **The shorter the wavelength, the greater the energy and the greater the ability to penetrate matter.**

WAVELENGTH:
The distance from one wave cycle to the next



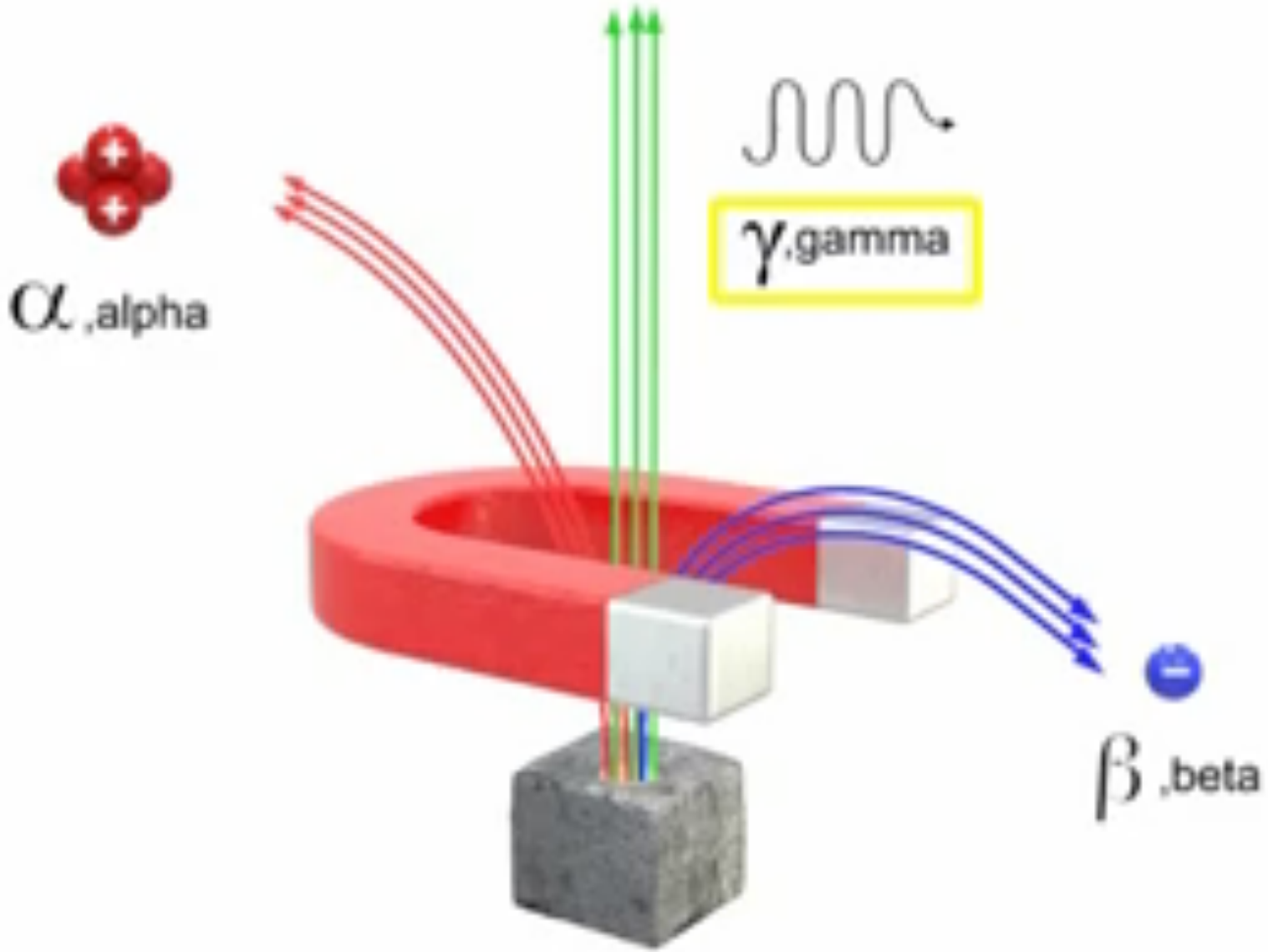
how will different wavelengths affect their frequency?

2. What is the relationship between frequency (ν) and wavelength (λ)?

What is an X-ray?

- **Ionizing radiation such x-ray can be carcinogenic and, to the fetus, mutagenic or even lethal.**
- **Different types of radiation have differing abilities to pass through material.**
- **A very thin barrier, such as a sheet or two of paper, or the top layer of skin cells, usually stops alpha particles.**

Radiation Rays



What is an X-ray?

- alpha particle sources are usually not dangerous if outside the body, but are quite hazardous if ingested or inhaled.
- Beta particles will pass through a hand, or a thin layer of material like paper or wood, but are stopped by a thin layer of metal.
- Gamma radiation is very penetrating and can pass through a thick layer of most materials.
- Some high-energy gamma radiation is able to pass through a few feet of concrete.

What is an X-ray?

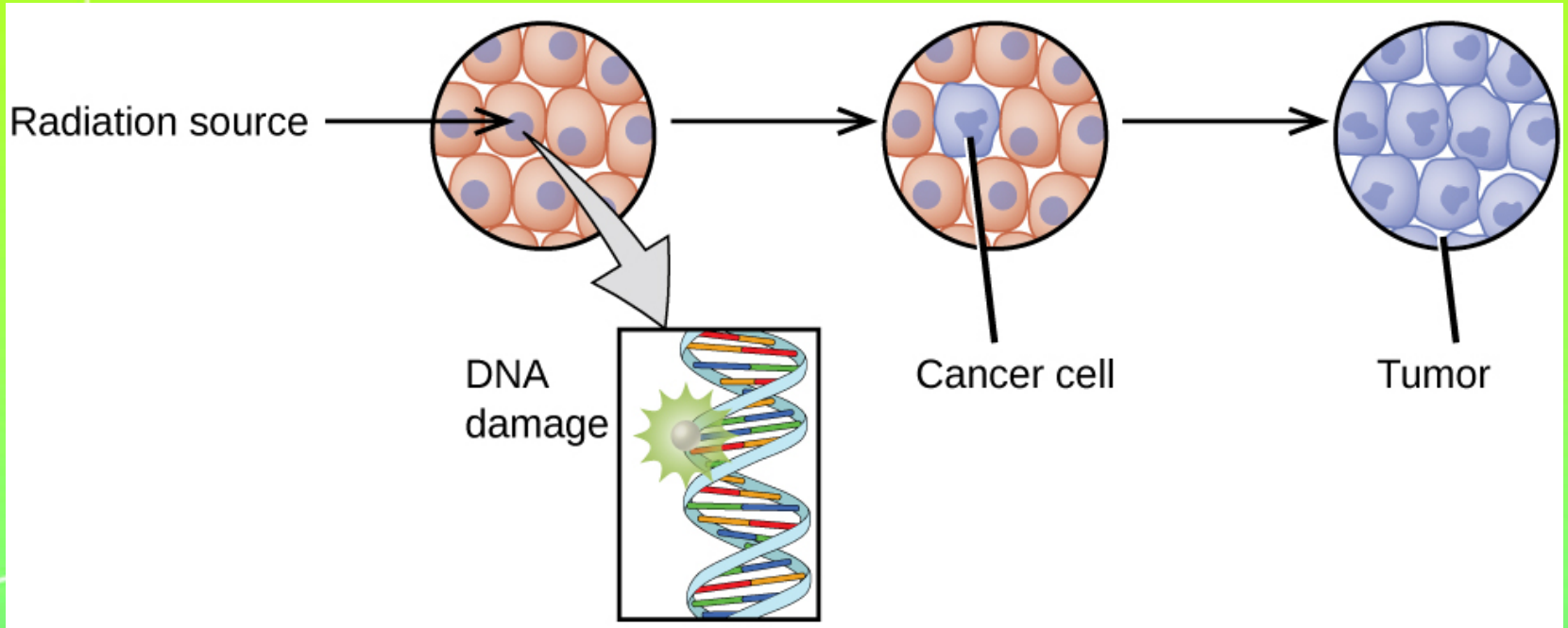
- **The ability of various kinds of emissions to cause ionization varies greatly, and some particles have almost no tendency to produce ionization.**
- **Alpha particles have about twice the ionizing power of fast-moving neutrons, about 10 times that of β particles, and about 20 times that of γ rays and X-rays.**

The three types of radiation

Use this table to find information about and to compare α, β and γ radiation

	Alpha (α)	Beta (β)	Gamma (γ)
Nature	It's a nucleus of helium $^{4}_{2}He$. Two protons and two neutrons	It's an electron e^{-}	It's an electromagnetic wave
Charge	+2	-1	0
Mass	Relatively large	Very small	No mass
Speed	Slow	Fast	Speed of light
Ionizing effect	Strong	Weak	Very weak
Most dangerous	When source is inside the body	When source is outside the body	When source is outside the body

What is an X-ray?



Radiation can harm biological systems by damaging the DNA of cells. If this damage is not properly repaired, the cells may divide in an uncontrolled manner and cause cancer.

Goals of Radiation Safety

- **Eliminate deterministic (acute) effects.**
- **Reduce incidence of stochastic (Chronic or random) effects.**


Damaged cell

Deterministic Effects

- **Acute radiation symptoms are caused by high levels of radiation usually over a short period of time.**
- **They cannot be predicted with certainty.**
- **severity of damage increases with increasing dose above that threshold.**

Deterministic (acute) Effects

Examples of deterministic effects:

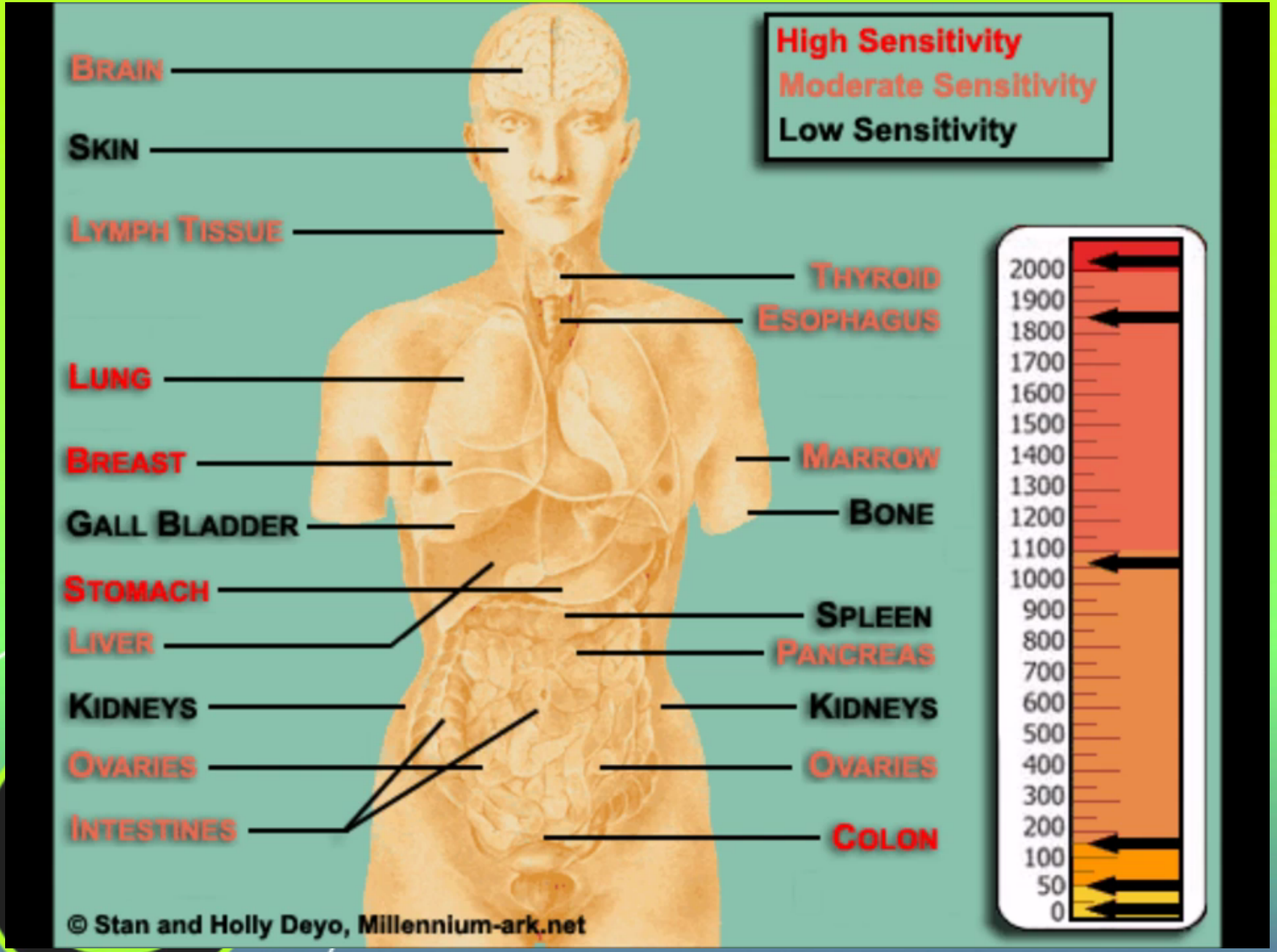
- **Cataract formation.**
- **Skin reddening (erythema).**
- **lowering of the white blood cell count.**
- **hair loss.**
- **Bone marrow failure.**
- **Lung Fibrosis.**
- **Infertility.**

Deterministic Effects

Deterministic Effects

Major organs annual dose limits for preventing deterministic effects are as follows:

Threshold for deterministic effects (Gy)			
Organ	Effects	One single absorption (Gy)	Prolong absorption (Gy-year)
testis	permanent infertility	3.5 - 6.0	2
ovary	permanent infertility	2.5 - 6.0	> 0.2
Lens of eyes	milky of lens cataract	0.5 - 2.0 5.0	> 0.1 > 0.15
Bone marrow	Blood forming deficiency	0.5	> 0.4


High Sensitivity
Moderate Sensitivity
Low Sensitivity
Brain
Skin
Lymph Tissue
Thyroid
Esophagus
Lung
Breast
Marrow
Gall Bladder
Bone
Stomach
Spleen
Liver
Pancreas
Kidneys
Kidneys
Ovaries
Ovaries
Intestines
Colon
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
50
0
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Radiation UNITS

- Gray, Rem, rad, Curie, Becquerel and Sievert are units of radiation.
- One chest x-ray 0.15 mGray.
- To reach the hazardous level of 2 Gray you need 10000 chest x ray or 100 CT abdomen or 30 mins to 1 hr fluoroscopy exposure.

Radiation UNITS

- **RAD**: Radiation Absorbed Dose. Original measuring unit for expressing the absorption of all types of ionizing radiation (alpha, beta, gamma, neutrons, etc) into any medium.
- **REM**: Roentgen Equivalent Man is a measurement that correlates the dose of any radiation to the biological effect of that radiation. Since not all radiation has the same biological effect, the dosage is multiplied by a "quality factor" (Q). For example, a person receiving a dosage of gamma radiation will suffer much less damage than a person receiving the same dosage from alpha particles, by a factor of three.

Radiation UNITS

Measurement Purpose	Unit	Quantity Measured	Description
activity of source	becquerel (Bq)	radioactive decays or emissions	amount of sample that undergoes 1 decay/second
	curie (Ci)		amount of sample that undergoes 3.7×10^{10} decays/second
absorbed dose	gray (Gy)	energy absorbed per kg of tissue	1 Gy = 1 J/kg tissue
	radiation absorbed dose (rad)		1 rad = 0.01 J/kg tissue
biologically effective dose	sievert (Sv)	tissue damage	Sv = RBE × Gy
	roentgen equivalent for man (rem)		Rem = RBE × rad

Radiation UNITS

QUANTITY	UNIT	SI UNIT	RELATIONSHIP BETWEEN UNITS
Absorbed dose	Rad	Gray (Gy)	1 Gy = 100 rad 100 mGy = 10 rad 10 mGy = 1 rad 1 mGy = 100 mrad
Equivalent dose	Rem	Sievert (Sv)	1 Sv = 100 rem 100 mSv = 10 rem 10 mSv = 1 rem 1 mSv = 100 mrem

The Effects of Nuclear Exposure

DOSE (Gy)	PHYSICAL CONDITION	CHANCE OF SURVIVAL
20 +	Neurovascular Syndrome onset	**Death almost certain** Multiple organ failure sets in
11		
10		**Death likely** Stem cell transplants required to survive
9		
8		
7	Gastrointestinal Syndrome onset	**Death possible** 50 percent of the population will survive for 60 days with supportive medical care
6		
5		**Death not likely** 50 percent of the population will survive for 60 days without medical care
4		
3		
2		**Death not happening** Medical treatment not necessary
1	Hematopoietic Syndrome onset	
0		

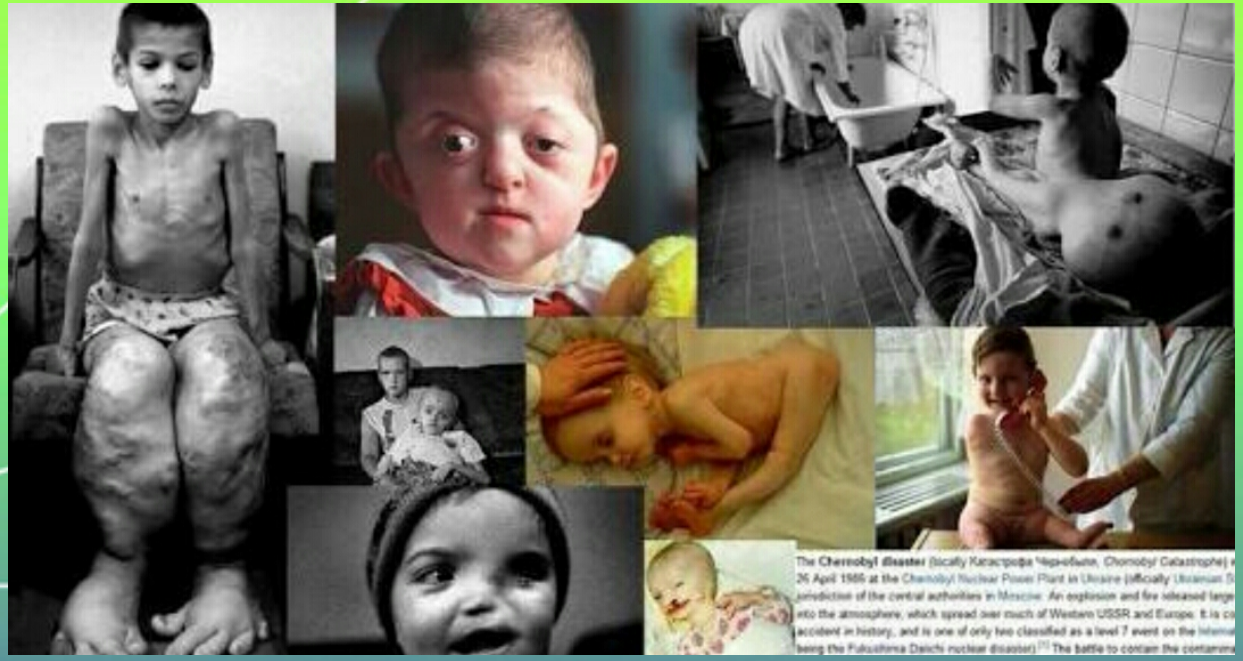
Stochastic (chronic) Effects

- **Also referred to as Probabilistic, probability of occurrence depends on absorbed dose.**
- **Chronic radiation symptoms are caused by low-level radiation over a long period of time.**
- **The effect may (potentially) occur following any amount of exposure, there is no threshold.**
- **Even the smallest quantity of Ionizing Radiation exposure can be said to have a finite probability of causing an effect.**
- **Severity of the effect is not dose related.**

Stochastic Effects

Examples of stochastic effects:

- **Carcinogenic effect.**
- **Genetic effect.**



Radiation Exposure Levels & Effects

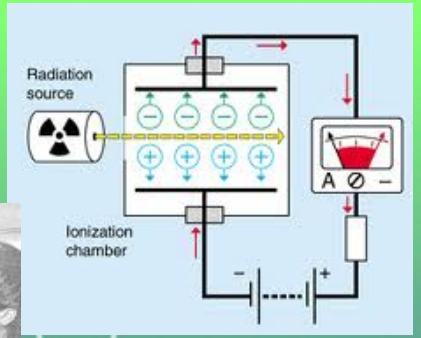
- **0.62 rem/y – average annual radiation exposure.**
- **2 rem/y – international radiation exposure limit.**
- **25 rem – measureable blood changes.**
- **100 rem – onset of radiation sickness.**

Radiation Exposure Levels & Effects

- **200 rem – radiation sickness with worse symptoms in less time**
- **400 rem – approximately the lethal dose for 50% of the population in 30 days**
- **1,000 rem – death probable within about 2weeks, effects on the gastrointestinal tract**
- **5,000 rem – death probable within 1-2 days, effects on the central nervous system.**
- .

Typical Radiation Detectors

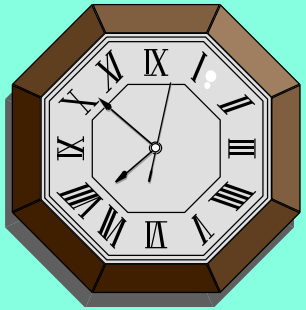
- Film packet
- Thermoluminescent Dosimeter (TLD)
- Ionization chamber
- Geiger-Müller (GM) Detector
- Scintillation Detector



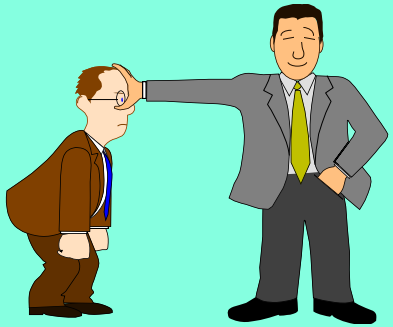
LIMITING YOUR EXPOSURE

- **Three basic methods for reducing exposure of workers to X-rays:**
  - **Minimize exposure time.**
  - **Maximize distance from the X-ray source.**
  - **Use shielding.**

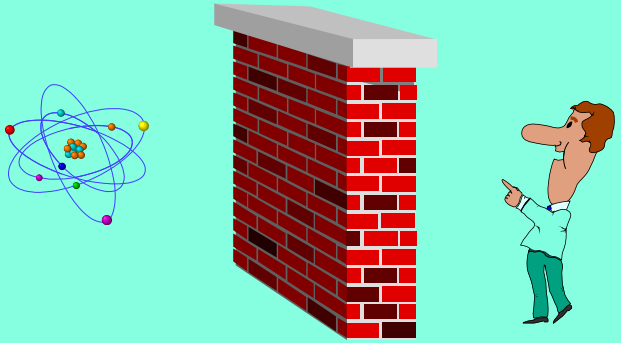
General Methods of Protection



- **Time (Minimize)**



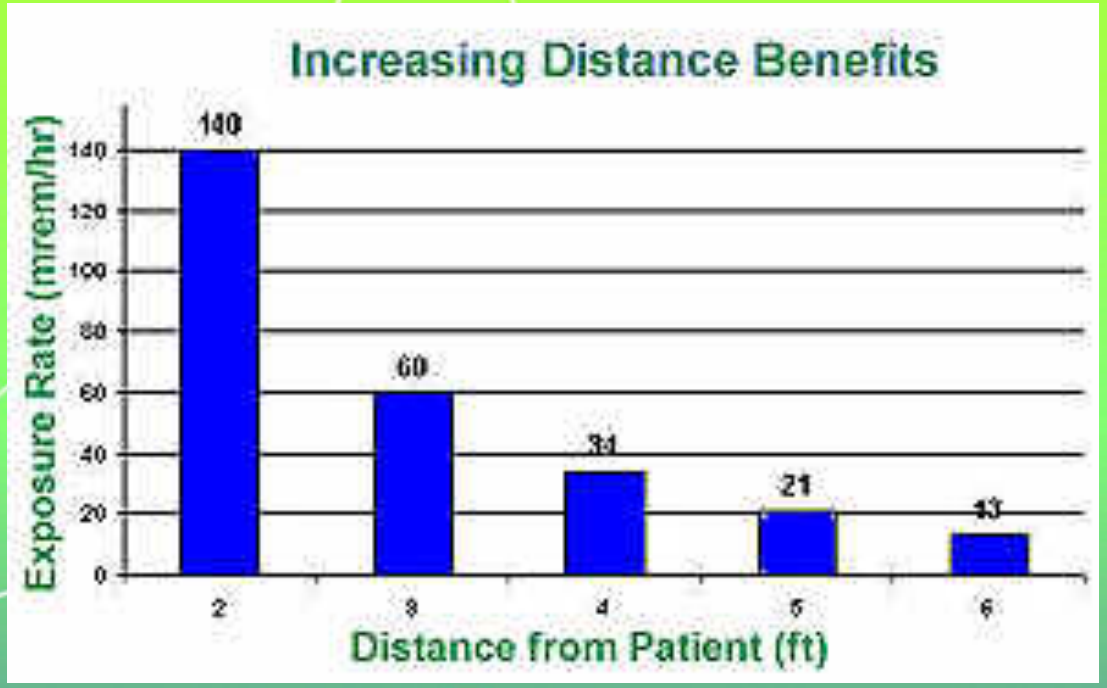
- **Distance (Maximize)**



- **Shielding (stand behind lead protection.**

LIMITING YOUR EXPOSURE

- **Exposure varies inversely with the square of the distance from the X-ray tube:**



www.e-radiography.net/radsafety/reducing_exposure.htm

LIMITING YOUR EXPOSURE

- **Shielding:**
  - **Operators view the target through a leaded glass screen.**
  - **Wear lead aprons. Almost any material can act as a shield from gamma or x-rays if used in sufficient amounts.**

LIMITING YOUR EXPOSURE

- **Shielding:**
  - **Standard 0.5mm lead apron Protect you from 95% from radiation exposure.**

ALARA Rule

- **As low as reasonably achievable:**
  - **Reduce number of exams.**
  - **Reduce time of exams.**
  - **Radiation Hazard symbol displayed at places where radioactive materials are used and stored.**
  - **Use alternative (US or MRI).**

Radioactive Materials Hazard

What do we mean by Radioactivity?

- **Radioactive decay is the process in which an unstable atomic nucleus loses energy by emitting radiation in the form of particles or electromagnetic waves.**
- **An unstable nucleus releases energy to become more stable.**

Where are the Sources of Radioactivity?

➢ Naturally Occurring Sources:

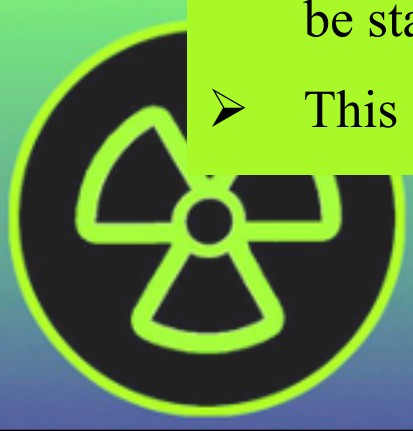
- **Radon from the decay of Uranium and Thorium.**
- **Potassium 40 found in minerals and in plants.**
- **Carbon 14 found in plants and animal tissue.**

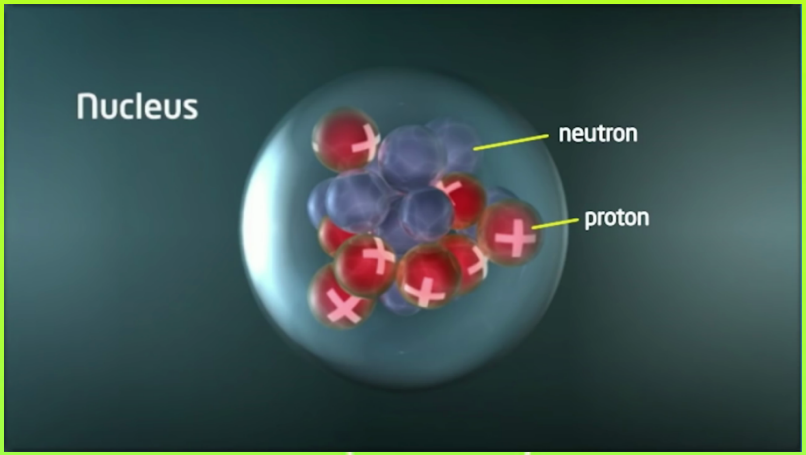
➢ Manmade Sources:

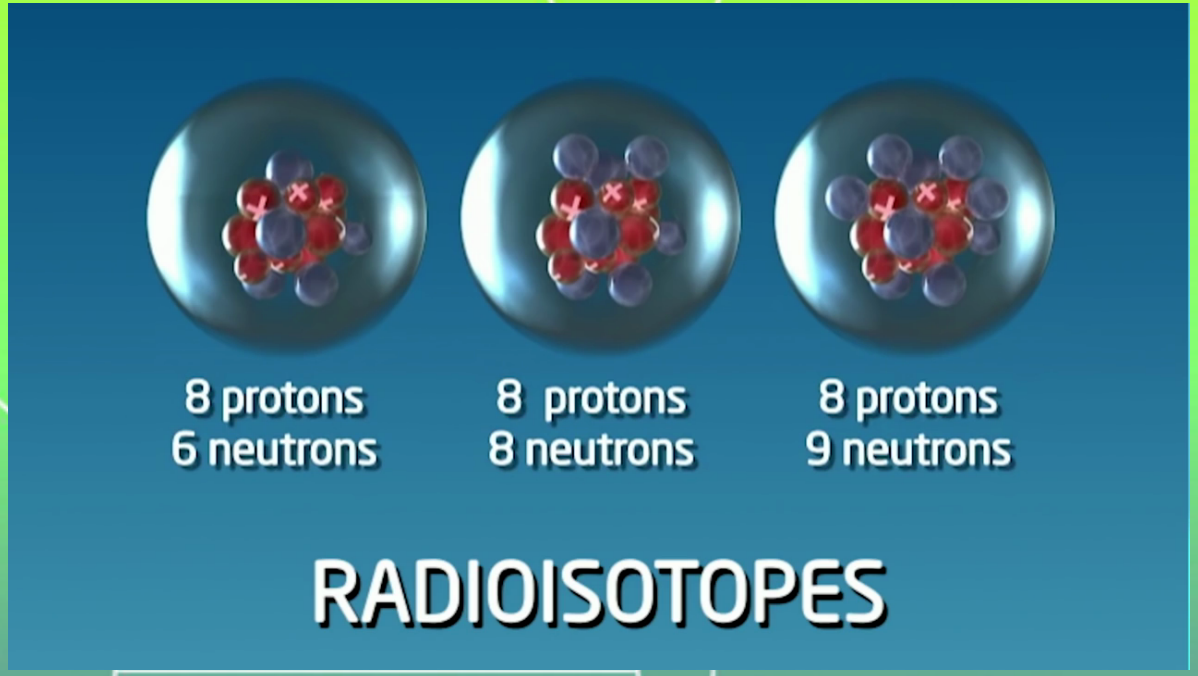
- **Medical use of Radioactive Isotopes.**
- **Certain consumer products –(eg smoke detectors).**
- **Fallout from nuclear testing.**
- **Emissions from Nuclear Power plants.**

Radioisotopes.

- Any two or more forms of a chemical element, having the same number of **protons** in the nucleus, or the same atomic number, but having different numbers of neutrons in the nucleus, or different atomic weights are called ***isotopes***.
- Isotopes of an atom that are radioactive are called ***radioisotopes***
- Examples of natural radioisotopes are 238 U (uranium), 40 K (potassium), 232 Th (thorium) and their child nuclei (obtained by radioactive decay of the previous ones) 226 Ra (radio), 222 Rn (radon) and 218 Po (polonium).
- These atoms are radioactive because they have too much energy to be stable; they will release energy until they become stable
- This is called ***radioactive decay***.

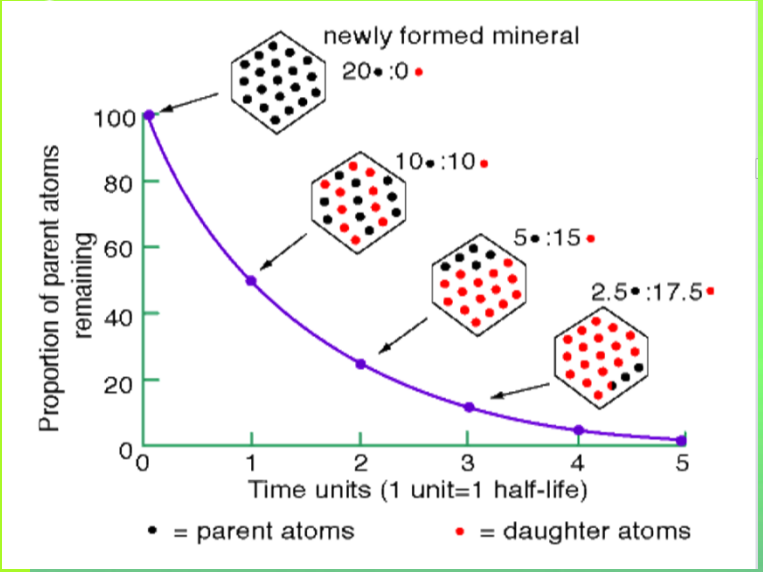



Nucleus
neutron
proton


8 protons
6 neutrons
8 protons
8 neutrons
8 protons
9 neutrons
RADIOISOTOPES

Radioactive Decay.

- In the process of radioactive decay, an atom actually changes from one element to another by changing its number of protons.
- The **half-life** of a radioactive substance is the amount of time required for it to lose *one half* of its radioactivity and transform into another element.



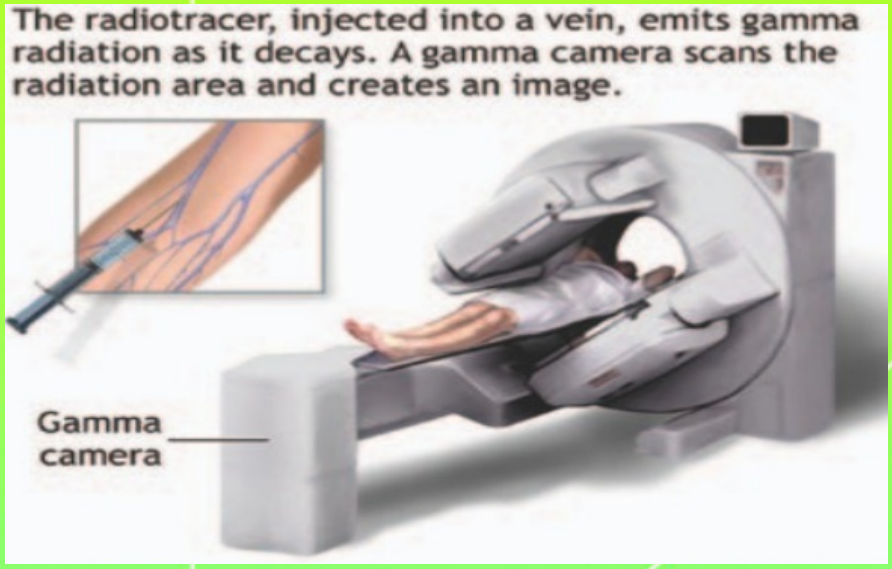
Medical use of Radioactive Isotopes.

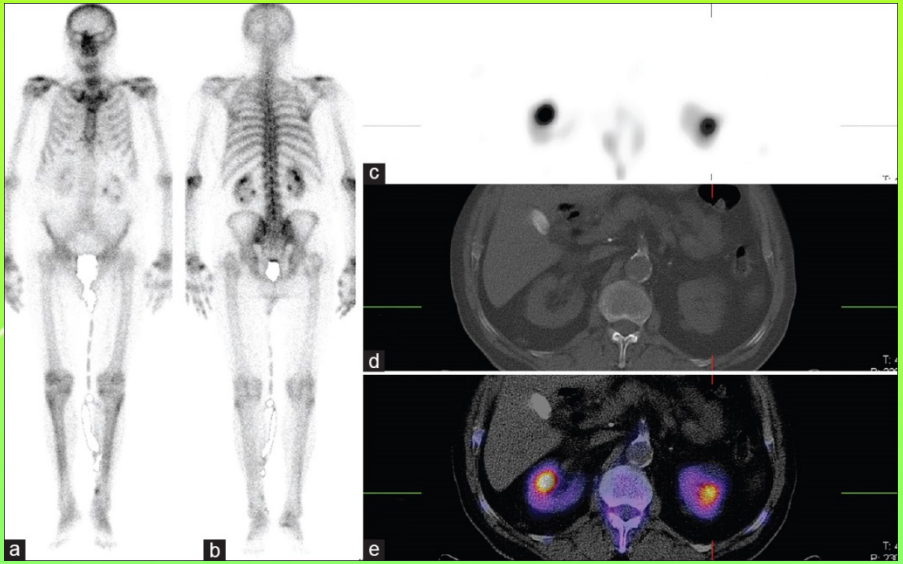
- Radioactive isotopes introduced into the body are distinguishable by their radiation from the atoms already present.
- This permits the relatively simple acquisition of information about the dynamics of processes of uptake, incorporation, exchange, secretion, etc.

Radiopharmaceuticals

- The most widely used radioisotope in medical imaging is Technetium (Tc), with a half-life of six hours.
- activity in the organ can then be studied either as a two dimensional picture or, with a special technique called tomography, as a three dimensional picture (SPECT, PET).

Radiopharmaceuticals





Handling Radiopharmaceuticals

- **No radioactive substance should be handled with bare hands. Alpha and beta emitters can be handled using thick gloves.**
- **Radioactive materials must be stored in thick lead containers.**
- **Reactor and laboratories dealing with radioactive materials must be surrounded with thick concrete lined with lead.**
- **People working with radioactive isotopes must wear protective clothing which is left in the laboratory.**
- **The workers must be checked regularly with dosimeters, and appropriate measures should be taken in cases of overdose.**
- **Radioactive waste must be sealed and buried deep in the ground.**


VAC


RADIOACTIVE


RADIOACTIVE
MATERIALS


CENTURY

Spill Response

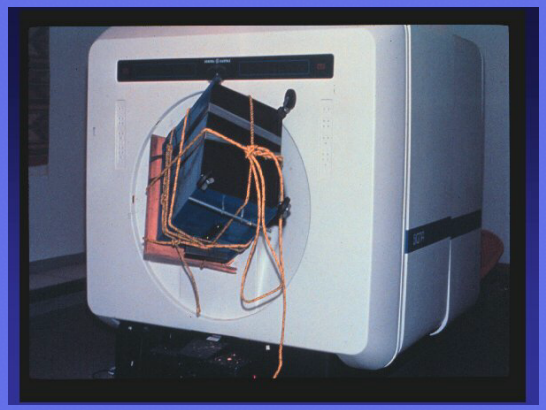
- **On Skin — flush completely**
- **On Clothing — remove**
- **If Injury — administer first aid**
- **Radioactive Gas Release — vacate area, shut off fans, post warning**
- **Monitor all persons and define the area of contamination.**

Magnetic Field Hazard

Magnetic Resonance Hazard

- **MRI is one of the imaging modality that is widely used in radiology.**
- **There is no dangerous radiation in MRI instead it uses very high magnetic field up to 3Tesla (1 Tesla = 20000 times earth gravity).**
- **This strong magnetic field produces powerful attractive force and torque which the magnet exerts on ferromagnetic objects, this is called missile effect. ***
- **The missile effect can pose a significant risk to anyone in the path of the projectile, and cause significant damage to the scanner.**
- **The effect is clearly greater for high field systems**

STRONG MAGNETIC FIELD



Magnetic Resonance Hazard

Magnetic Resonance Hazard

Magnetic Resonance Hazard

- **To guard against accidents from metallic projectiles, the "5 gauss line" should be clearly demarcated and the area with that line kept free of ferromagnetic objects.**

- **It is essential that patient with ferromagnetic surgical clips, implants containing ferromagnetic components, and persons who have suffered shrapnel or steel fragment injuries, especially to the eyes, be excluded from the imager.**

Magnetic Resonance Hazard

- **A number of general precautions must be taken to ensure the safety of patients and personal working in the imaging suite.**
- **Access to the imaging area should be limited, and signs should be displayed to warn persons with cardiac pacemaker or neuro-stimulators not to enter the area.**
- **Credit cards and watches with mechanical parts should be left outside the imaging area to prevent magnetic tape erasure and watch malfunction.**


WARNING
STRONG MAGNETIC FIELD
No Pacemaker
No Metallic Implants
No Neuro Stimulators
No Loose Metal Objects
تحذير
مجال مغنطيسي قوي
WARNING


WARNING
STRONG MAGNETIC FIELD
NO PACEMAKERS
NO METALLIC IMPLANTS
NO NEUROSTIMULATORS
Persons with pacemakers, neurostimulators, or metallic implants must not enter this area. Serious injury may result.
NO LOOSE METAL OBJECTS
Iron, steel and other ferrous materials must not be taken into this area. Serious injury or property damage may result.


MRI

Magnetic Resonance Hazard

- **Some implants are paramagnetic, or even ferromagnetic. These implants tend to move and align with the main magnetic field.**
- **This results in a force and torque on the implant and the implant may become dislodged, resulting in severe injury to the patient.**
- **Aneurysm clips are examples of implants that can result in death if displaced.**

Magnetic Resonance Hazard

- **Some implants are paramagnetic, or even ferromagnetic. These implants tend to move and align with the main magnetic field.**
- **This results in a force and torque on the implant and the implant may become dislodged, resulting in severe injury to the patient.**
- **Aneurysm clips are examples of implants that can result in death if displaced.**
- **Pacemaker and implanted cardiac defibrillator are typical examples of such devices.**

Please Check and Indicate the following:

Posible Hazards Present	Yes	No
1. A cardiac pacemaker		
2. Intracranial Vascular Clips		
3. Neurostimulators of any sort		
4. Intraocular metallic foreign bodies		
5. Ossicular implantations		
6. Any metallic implants : metal plates, pins, rods, etc.		
7. Hair pieces		
8. Any prosthetic devices		
9. Heart Failure		
10. Surgical clips on the arteries & wire sutures		
11. Heart valve		
12. Pregnancy		
13. Sharpnel		
14. Metallic/Silver eye liners		

N.B. This information must be completed by the referring consultant who is responsible for ensuring that the details are correct. Failure to comply may result in the patient's safety being compromised.
NO APPOINTMENT WILL BE MADE IF INSUFFICENT INFORMATION IS GIVEN.

Consultant's Name: _____

I.D. No. _____ **Bleep No.** _____

Name of Accepting Radiologist: _____

Contrast medium Hazard

Contrast Agents

- **Compounds used to improve the visibility of internal body structures in an image.**
- **Since their introduction in the 1950s, organic radiographic iodinated contrast media (ICM) have been among the most commonly prescribed drugs in the history of modern medicine.**
- **These contrast agents attenuate x-rays more than body soft tissues due to their high atomic weight.**
- **Millions of intravascular contrast media examinations are performed each year.**

Contrast Agents

- **Iodinated contrast media generally have a good safety record.**
- **Adverse effects from the intravascular administration of ICM are generally mild and self-limited;**
- **Reactions that occur from the extravascular use of ICM are rare.**
- **Nevertheless, severe or life-threatening reactions can occur with either route of administration.**

Types of Contrast Agents

Negative contrast

- **Organs become more radiolucent.**
- **X-rays penetrate more easily.**
- **Low atomic # material**
- **Black on film**
- **Example: air and CO_2.**
- **Commonly used to inflate a structures; distinguish colon from other structures**

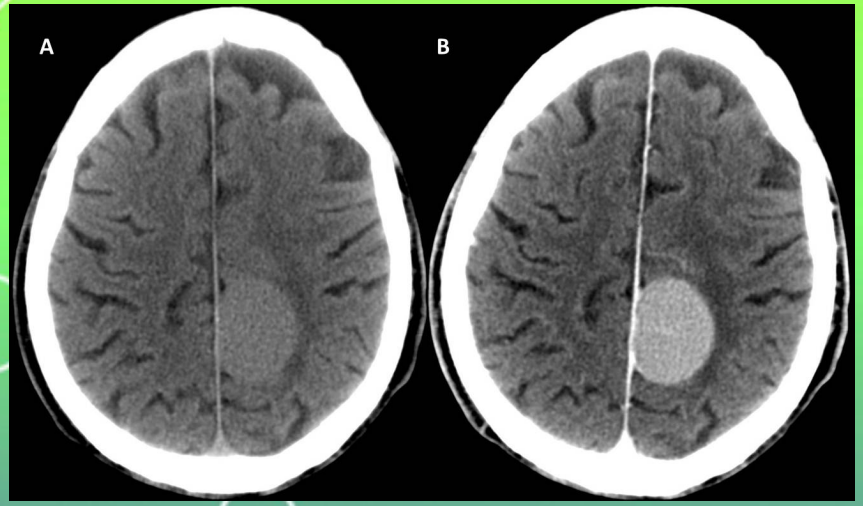
Types of Contrast Agents

Positive contrast

- **Substance absorbs x rays, organ become radiopaque.**
- **High atomic # material**
- **White on film**
- **Most common media:**
  - **Iodinated contrast agent.**
  - **Barium sulfate.**

WHY IODINE?

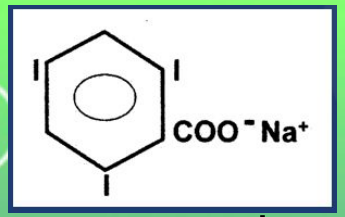
- **IODINE (atomic wt 127) provides excellent radio-opacity.**
- **Higher atomic number maximizing the photo-electric effect.**



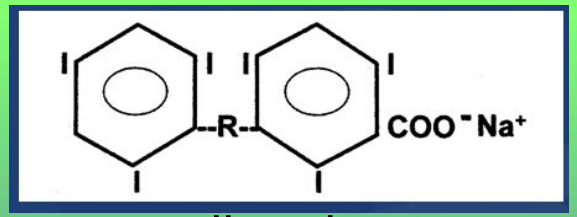
Classification of agents

Contrast agents are classified based on 3 properties:

- The charge of the iodinated molecule (ionic or nonionic)
- The molecular structure (monomeric or dimeric)
- The osmolality of the injected preparation (hyperosmolal, low osmolal, or iso-ismolal relative to normal serum osmolality [275 to 290 mosm/kg])

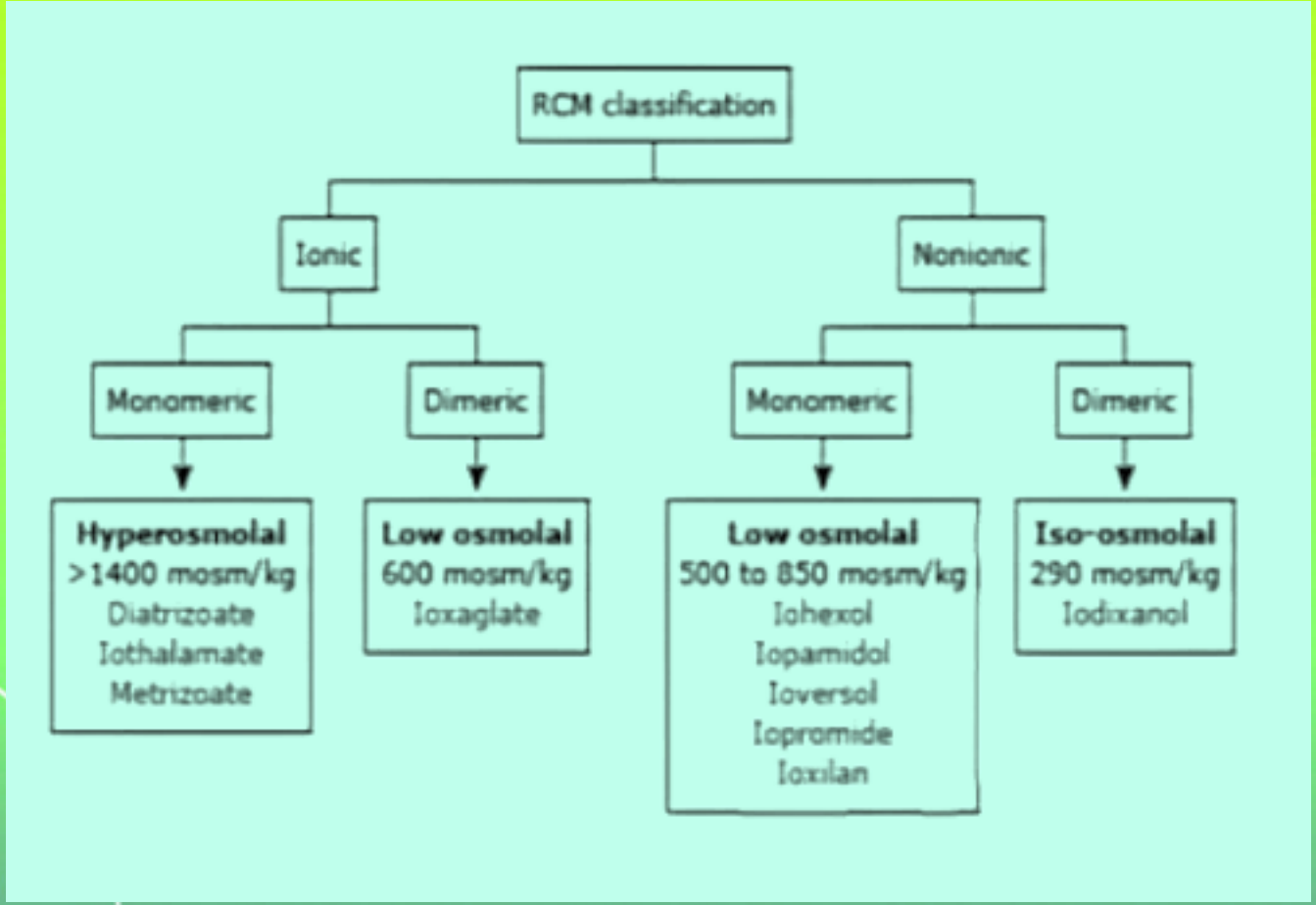


monomeric



dimeric

Iodinated Contrast Agents



Iodinated Contrast Agents

- **The toxicity of contrast agents decreases as osmolality approaches that of serum.**
- **This has been accomplished by developing nonionizing compounds and then combining two monomers to form a dimer.**

Iodinated Contrast Agents

- **Currently used iodinated agents are cleared almost completely by glomerular filtration.**
- **Circulatory half life is 1–2 hours, assuming normal renal function.**

Effects of Ionic vs. Nonionic Contrast Media

Ionic	Nonionic
1. Dissociates into separate ions when injected	Does not dissociate
2. Creates hypertonic condition	Remains near isotonic
3. Increase in blood osmolality	No significant increase in osmolality
4. Less money	More money
5. More reactions	Less reactions

Methods of administration of contrast material

- INGESTED
  - ORAL: Barium sulfate suspension
- RETROGRADE
  - AGAINST NORMAL FLOW: Barium Enema
- INTRATHECAL
  - Spinal canal
- INTRAVENOUS
  - Injecting into bloodstream
  - (anything other than oral)

Reaction classification

- **Immediate reactions:** were defined as those occurring within the department (within one hour).
- **Delayed:** as those occurring between the time the patients left the department and up to seven days later.

Reaction classification

- **The American College of Radiology has divided adverse reactions severity to contrast agents into the following categories:**
  - **Mild.**
  - **Moderate.**
  - **Severe.**

Mild Reaction (5%)

- Signs and symptoms appear self-limited without evidence of progression,
- Nausea, vomiting, warmth, headache, dizziness, shaking, altered taste, itching, flushing, chills, sweats, rash, nasal stuffiness, swelling: eyes, face and anxiety.
- Treatment: Observation and reassurance. Usually no intervention or medication is required; however, these reactions may progress into a more severe category.

Moderate Reaction (1%)

- Reactions which require treatment but are not immediately life-threatening,
- Tachycardia/ bradycardia, hypertension, pronounced cutaneous reaction, hypotension, dyspnea, pulmonary edema, bronchospasm, wheezing and laryngeal edema.
- Treatment: Prompt treatment with close observation.

Severe Reaction (0.05%)

- Life-threatening with more severe signs or symptoms including,
- Laryngeal edema (severe), profound hypotension, convulsion, unresponsiveness and cardiopulmonary arrest.
- Treatment: Immediate treatment, antiemetic drugs. Usually requires hospitalization.

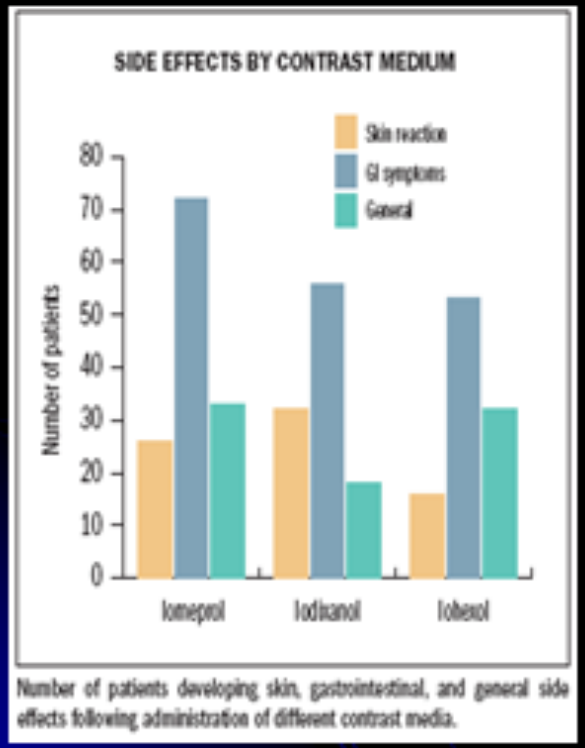
Some Reaction Medications

- **Aggressive fluids.**
- **Lasix**
- **Dopamine**
- **Mannitol**

Delayed Contrast Reactions

- **Delayed contrast reactions can occur anywhere from 3 hours to 7 days following the administration of contrast.**
- **It is important for anyone administering intravenous contrast media to be aware of delayed reactions.**
- **The more common reactions include a cutaneous exanthema, pruritus without urticaria, nausea, vomiting, drowsiness, and headache.**

Delayed Contrast Reactions



Number of patients developing skin, gastrointestinal, and general side effects following administration of different contrast media.

- Skin effects included itching, rash, and hives.
- Nausea, vomiting, and diarrhea were the gastrointestinal side effects
- General side effects included headache, dizziness, and fever.
- Infants and patients older than 60 years are at increased risk of developing a side effect.

Delayed Reactions

- flu like symptoms
- delayed arm pain
- rash/ pruritus
- salivary gland swelling
- Steven Johnson syndrome

Contraindications for Contrast

- **Renal Failure (Check BUN & Creatinine)**

  Elevated levels could cause renal shutdown
- **Anuria (no urine production)**
- **Asthma (possible allergies)**
- **Hx of Contrast Allergy / Reactions**
- **Diabetes - get a hx of medications taken**

  glucophage must be stopped 48 hrs before contrast injection
- **Multiple Myeloma**

Contraindications for Contrast

- **Pregnancy (risk of fetal Thyroid toxicity).**
- **Allergic Reaction, Pre – medication is available.**

EXTRAVASATION

- **Contrast material has seeped outside of vessel.**
- **Apply WARM Compress 1st 24 hours.**
- **Cool compress for swelling.**

Extravasation of Contrast into soft tissue of arm

MRI Contrast Agents

- The Contrast used in MRI is based on paramagnetic ions eg. Gadolinium.
- By themselves these ions are highly toxic so bound up in large molecules eg. DTPA.
- Provides a greater contrast between normal and abnormal tissues.

MRI Contrast

Gadolinium Side Effects

- **With impaired kidney function, gadolinium could lead to a serious and potentially fatal disorder called Nephorgenic Systemic Fibrosis. (NSF)**