Esposizione massiva a radiazioni ionizzanti in eventi NBCR: effetti clinici in acuto

BERGAMO - 19 NOVEMBRE 2022

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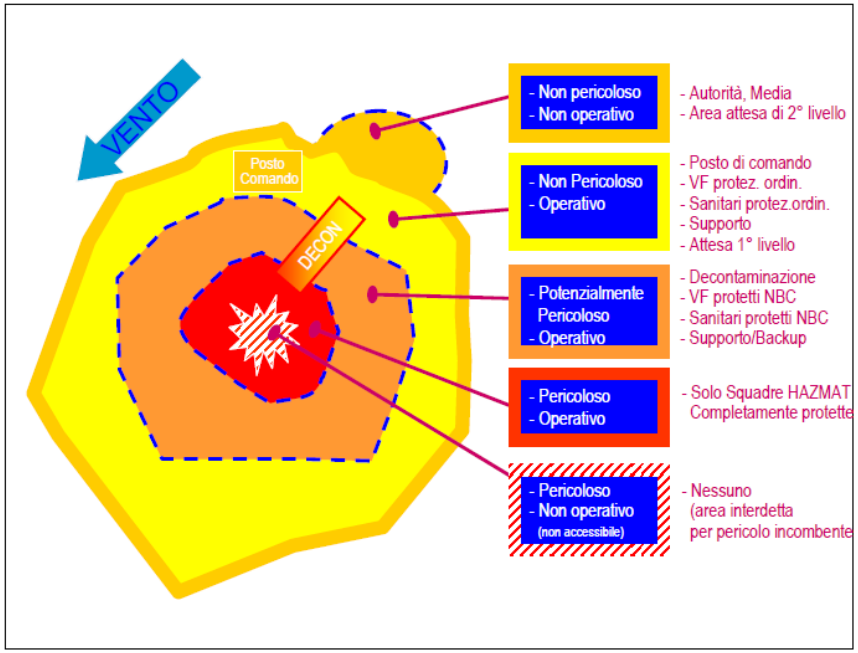
Photo Credit.: Mauro Dalla Torre MD

EVENTO NBCR (CBRN)

Evento (maxi-emergenza) caratterizzato dal rilascio/fuoriuscita di sostanze in grado di coinvolgere rapidamente più persone (sia quelle presenti nel luogo dell'evento che quelle che intervengono sul luogo dell'evento)



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Sistema Socio Sanitario
Regione Lombardia
ASST Papa Giovanni XXIII

Dr. Andrea Giampreti, MD
Bergamo Poison Control Center
ASST Papa Giovanni XXIII Hospital

EVENTO NBCR (CBRN)

'convenzionale'

- *incidente di laboratorio*
- *sversamento da mezzo di trasporto*
- *malfunzionamento*

'non convenzionale'

- *attacco terroristico*
- *attentato*

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EVENTO NBCR (CBRN)

N / R → Emissione di radiazioni ionizzanti

B →
Antrace
Botulismo
Vaiolo
Virus emorragici (es. Ebola, febbre gialla, etc.)
…

C →
Agenti Nervini
Asfissianti (CO, cianuro etc.)
Caustici / Solventi
…

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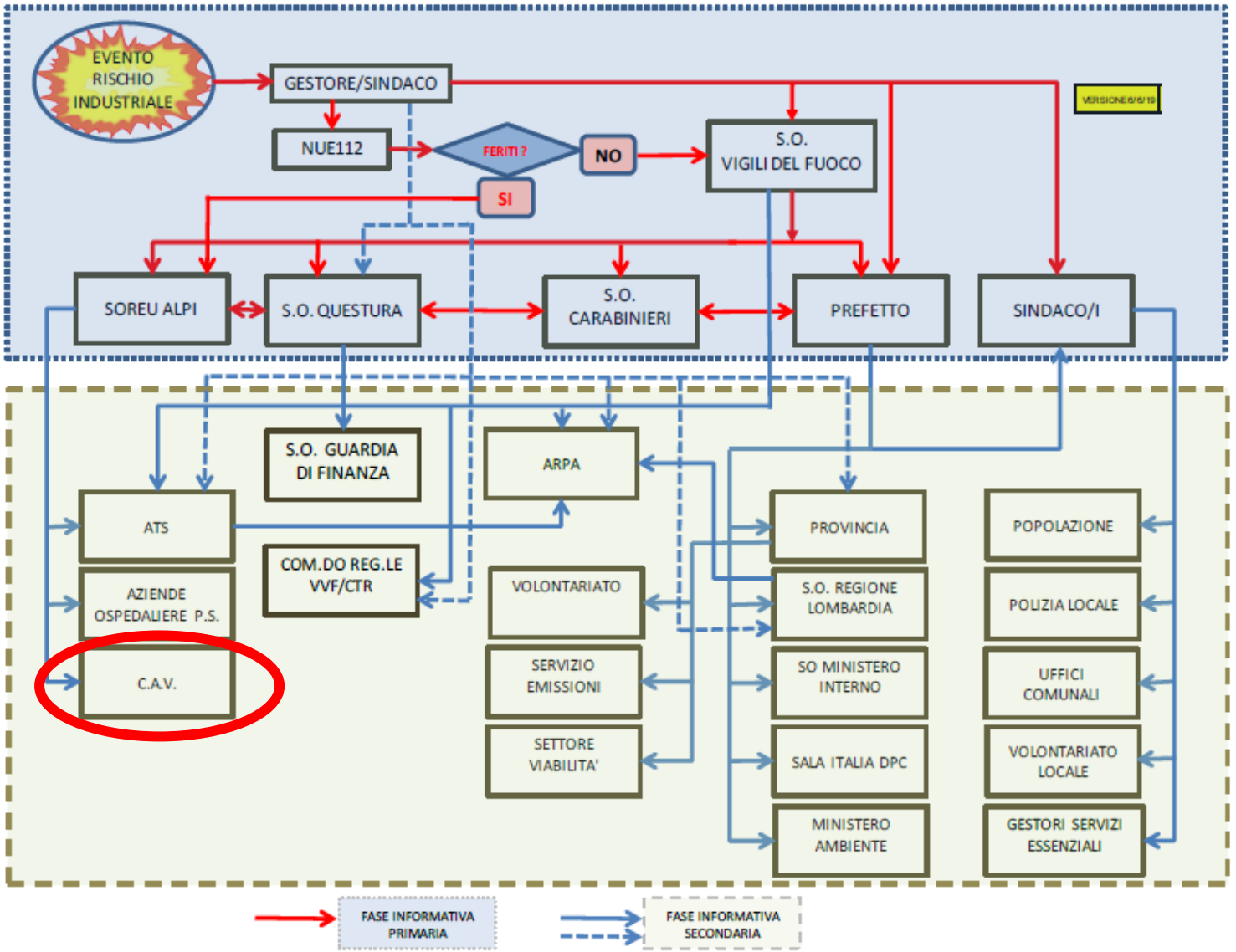
EVENTO NBCR

Figura 5: Quadro sinottico dei flussi di attivazione delle procedure di intervento

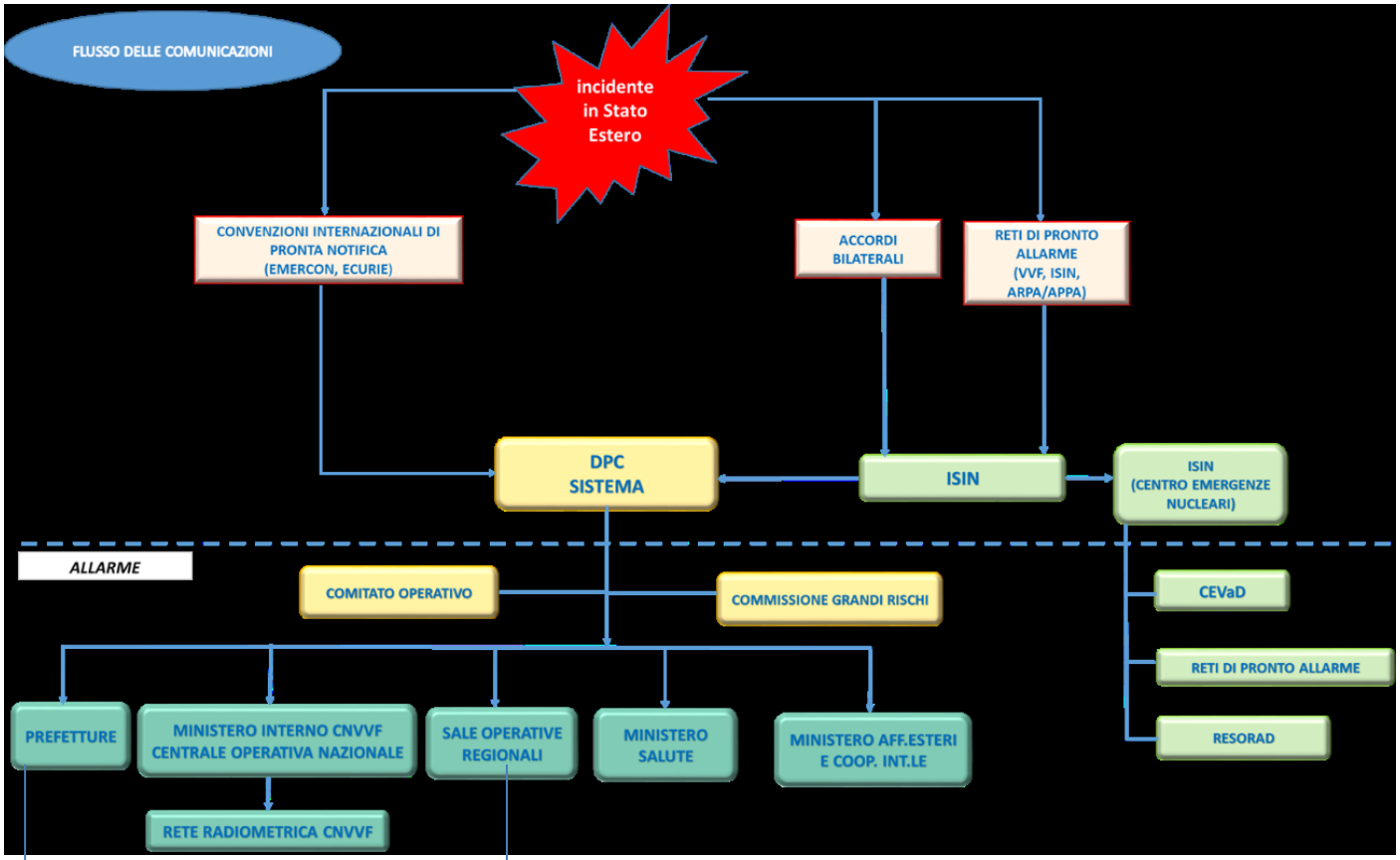


PIANO NAZIONALE PER LA GESTIONE DELLE EMERGENZE RADIOLOGICHE E NUCLEARI

previsto dall'art. 182, c. 2, del D.Lgs. 101/2020

9 marzo 2022

EVENTO NBCR



Radiation

Bad news

- The body cannot sense it
- No distinctive smell
- It cannot be seen or felt

People can receive a lethal dose without realizing it

Good news

- Detectable
- Rapidly detectable (more than bio or chem agents) with appropriate equipment

Radiation

The radiation we are concerned about is **ionizing radiation**
Ionizing radiation is energy that is given off from a radioactive source.

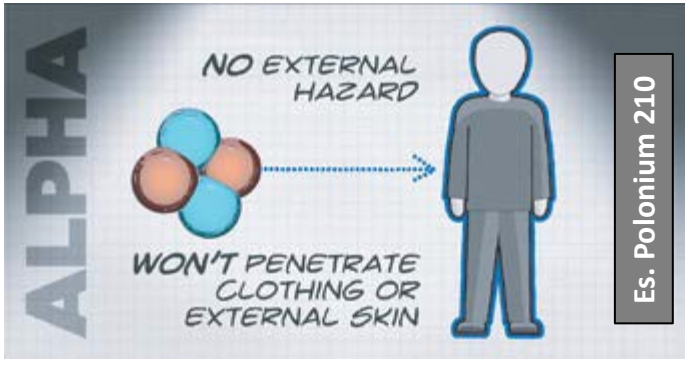
This energy may consists of:

- Energetic particles
  - Alpha particles
  - Beta particles
  - (Neutrons)
- Electromagnetic energy
  - Gamma rays
  - X rays

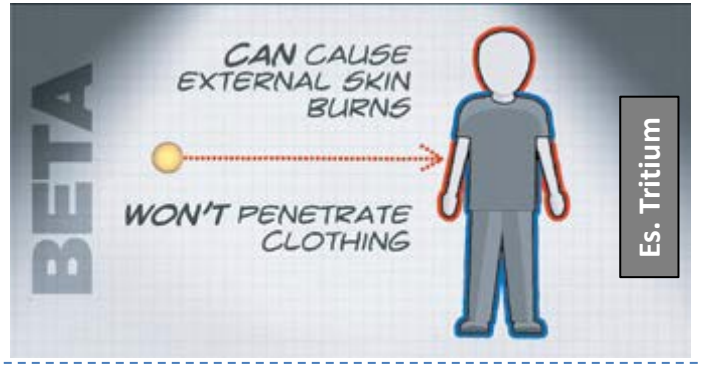
Strips electrons from molecules > Produces ions and free radicals
Breaks chemical bonds > Damaged molecules damage cells

Radiation

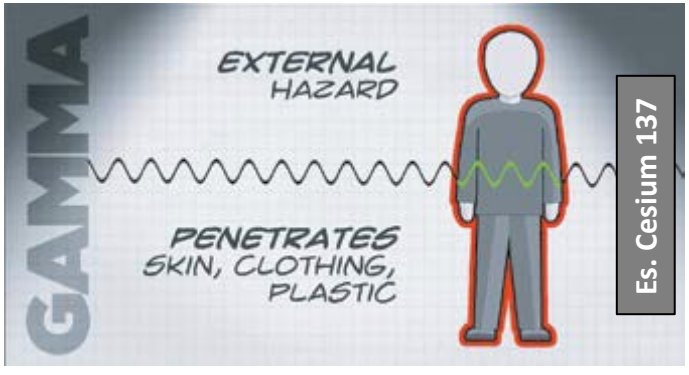
AMÉRICIUM	α / γ
CÉSIUM	β / γ
COBALT	β / γ
IODE	β / γ
MÉLANGE DE PRODUITS DE FISSION	
PLUTONIUM	α / γ
TRITIUM	β
URANIUM	α / γ



Alpha particles can't penetrate the skin, so alpha emitters are only a hazard if you internalize them by ingesting them, inhaling them, or getting them in a wound



Beta particles can damage the skin and can also damage cells from inside the body. Beta emitters are a hazard if they get on your skin or inside your body.



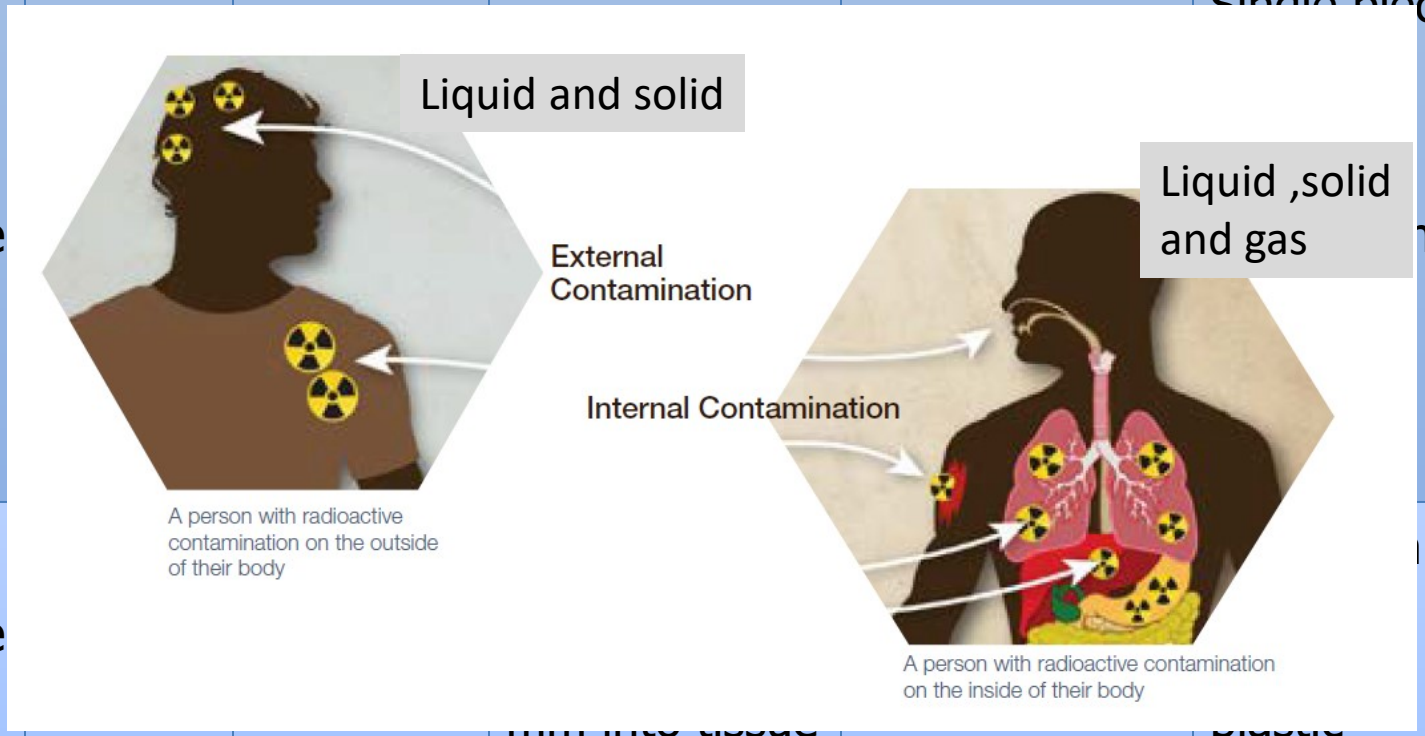
Gamma rays can travel directly through the body, damaging cells in the skin and other organs along the way

Radiation Shielding

Name	Type	Mass (u)	Charge	Penetration	Main Problems	Adequate Shielding
Alpha	Particle	4	+2	< 8 cm thru air Stratum corneum (dead outer skin layer)	Contamination	Single piece of paper Universal precautions PPE Regular clothing
Beta	Particle	1/1823	-1 (electron)	< 4 m thru air mm into tissue	Contamination	Aluminum foil Thick plastic

Radiation Shielding

Name	Type	Mass (u)	Charge	Penetration	Main Problems	Adequate Shielding
Alpha	Particle					Single piece ns
Beta	Particle					plastic



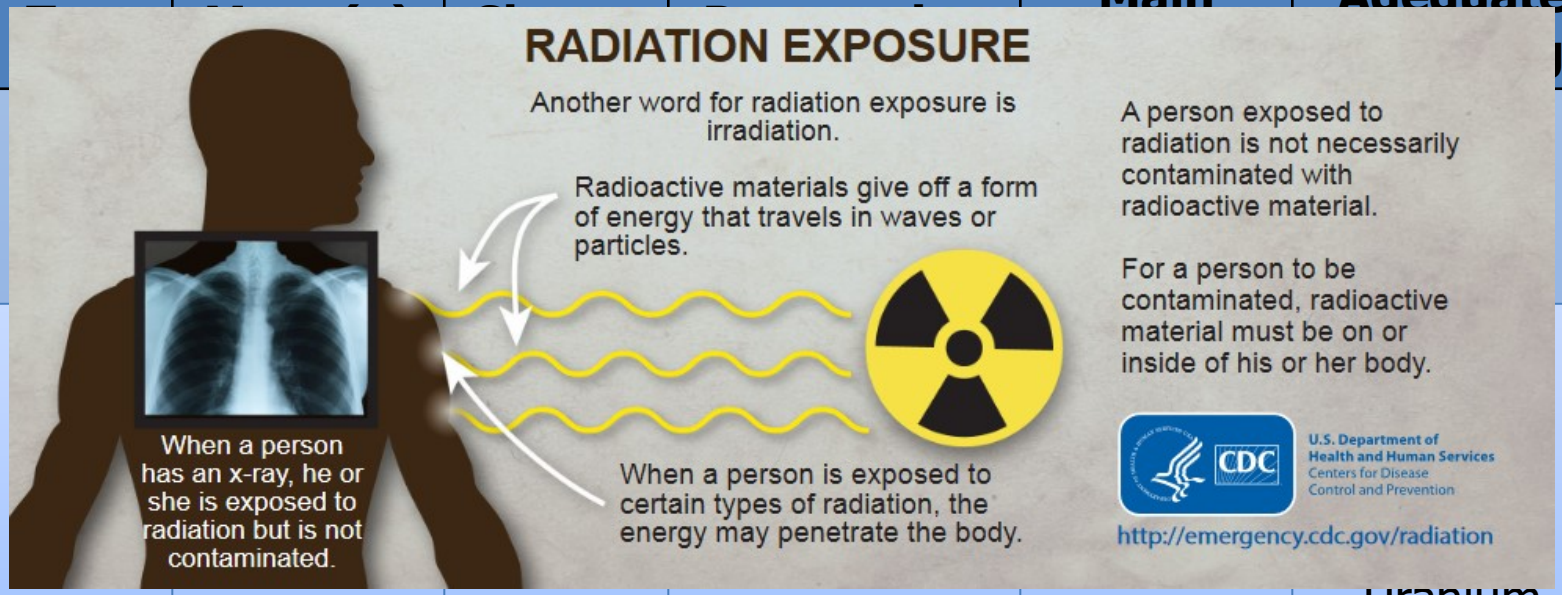
Patient decontamination necessary !
Risk of secondary contamination !

Radiation Shielding

Name	Type	Mass (u)	Charge	Penetration	Main Problems	Adequate Shielding
X-ray	Ray	0	0	91 m thru air Thru body	Irradiation	Lead Concrete
Gamma	Ray	0	0	800 m thru air Thru body	Irradiation	Thick concrete Depleted Uranium

Radiation Shielding

Name					Main	Adequate
X-ray						
Gamma						Uranium

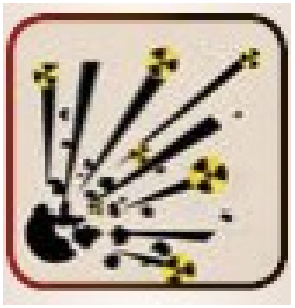


Patient exposure usually through irradiation !
Patient may be contaminated or not (only irradiated) !

Radiation Threat Scenarios

conventional

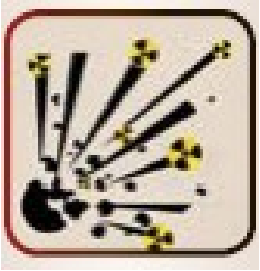
non conventional



Radiation Threat Scenarios

(some examples)

Nuclear reactor malfunction	Disabling nuclear reactor's cooling system
Radiological exposure device (RED)	Placing sealed, unshielded gamma source (Cs-137, Co-60, Ir-192) in public place
Radiological dispersal device (RDD)	Spreading unsealed radioactive material with sprayer or conventional explosives ("dirty bomb")
Improvised nuclear device (IND)	Detonating nuclear device
Nuclear weapon	Detonating conventional nuclear weapon

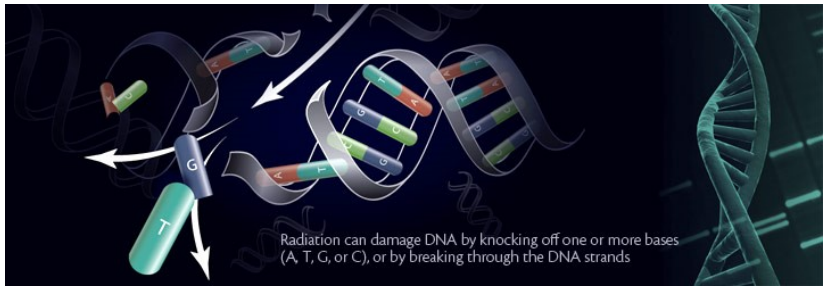


Radiation Damage

how radiation cause body damage

Direct damage

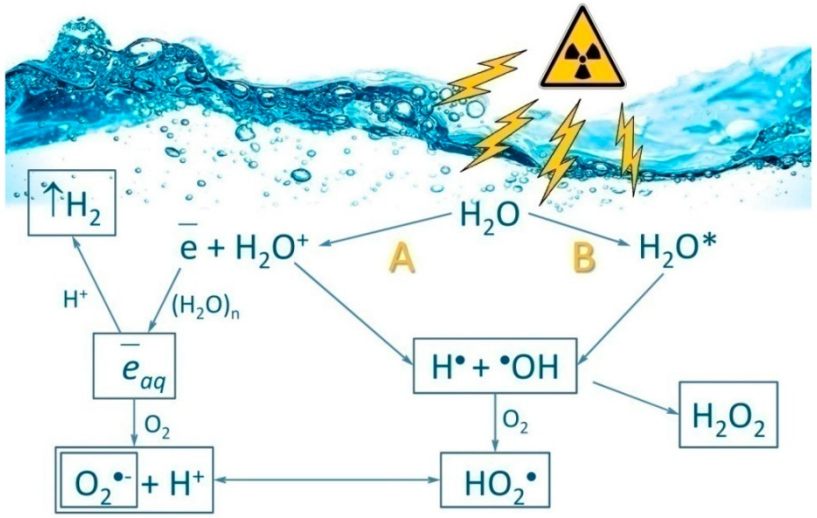
Direct "hit" on chromosome and/or other biochemicals



Indirect damage

Chemical radiolysis of water in cell

Hydroxyl radicals damage DNA & other biochemicals
Producing inflammation with elevated CRP



Radiation Damage

how radiation dose may impact on body damage

Deterministic effects

a threshold dose
need to be exceeded

Threshold dose > 1 Gray

ACUTE RADIATION SYNDROME (ARS)
CUTANEOUS RADIATION SYNDROME (CRI)

Stochastic effects

a threshold dose
does not exist

also very low doses not capable of producing deterministic effects may still contribute to late occurence of

CANCER
TERATOGENITY

Deterministic effect
THRESHOLD DOSE

- Dose determines effect
  - Must exceed threshold dose
    - **> 100 rad = 100 cGy = 1Gy**
    - Higher doses produce more effects
    - Lower doses produce less effects
    - Doses below threshold produce no effect

Ionizing Radiation ABSORBED Dose

Unit	Meaning	Symbol	Value	System
RAD	**R**adiation **A**bsorbed **D**ose	rad	1 cGy = 0.01 J/kg	USA
Gray	Eponym	Gy	100 rad = 100 cGy = 1 J/kg	SI

Ionizing Radiation ABSORBED Dose

Unit	Meaning	Symbol	Value	System
REM	**R**oentgen **E**quivalent **M**an	rem	1 cSv	USA
Sievert	Eponym	Sv	100 rem = 100 cSv	SI

Equivalent dose in Sv = Absorbed dose in Gy x W_R

W_R = radiation weighting factor:

Gamma = 1
Beta = 1
Alpha = 20
(Alpha particles weigh more,
so are worth more in this equation.)

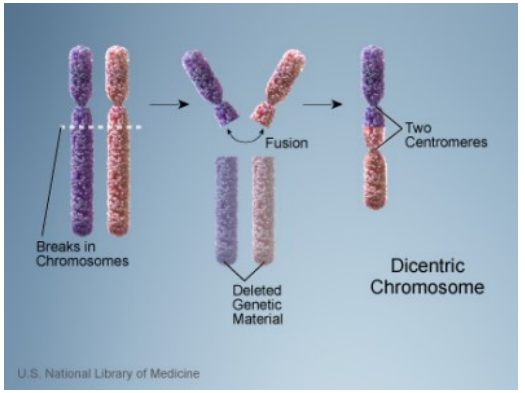
Deterministic effects of radiation

- **Acute Radiation Syndrome (ARS)**
  - systemic toxicity
  - sub-syndromes
    - hematopoietic
    - gastrointestinal
    - cardiovascular/CNS
- **Cutaneous Radiation Injury (CRI)**
  - local toxicity

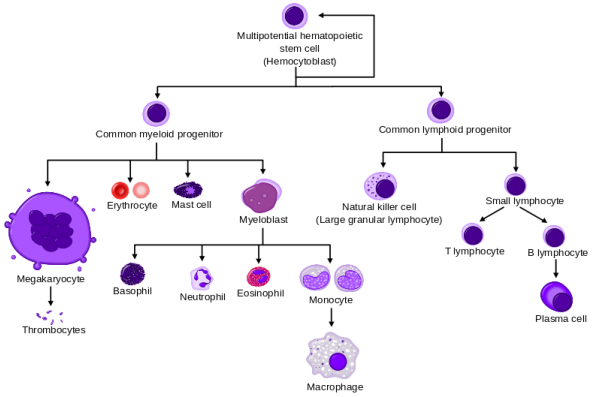
Dose absorption evaluation

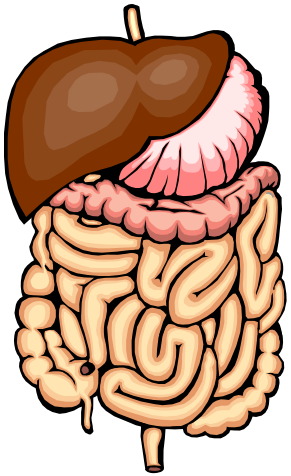
- **Directly measured**
  - Dosimeter
    - Occupational
- **Calculated (Reconstructed)**
  - Health physicist or radiation safety officer
    - Radiation source output
    - Duration of exposure
    - Distance from source
    - Shielding

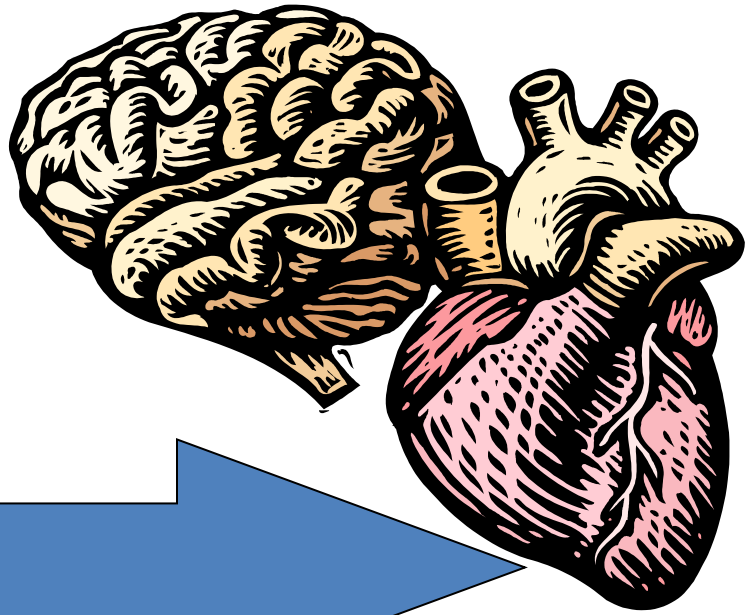
- **Biodosimetry**
  - **Clinical**
    - Signs & symptoms
    - Conventional labs
  - **Cytogenetics**
    - REAC/TS
    - AFRRI



Radiation Subsyndromes



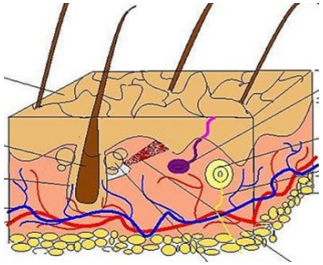




Hematopoietic
1 to 8 Gy

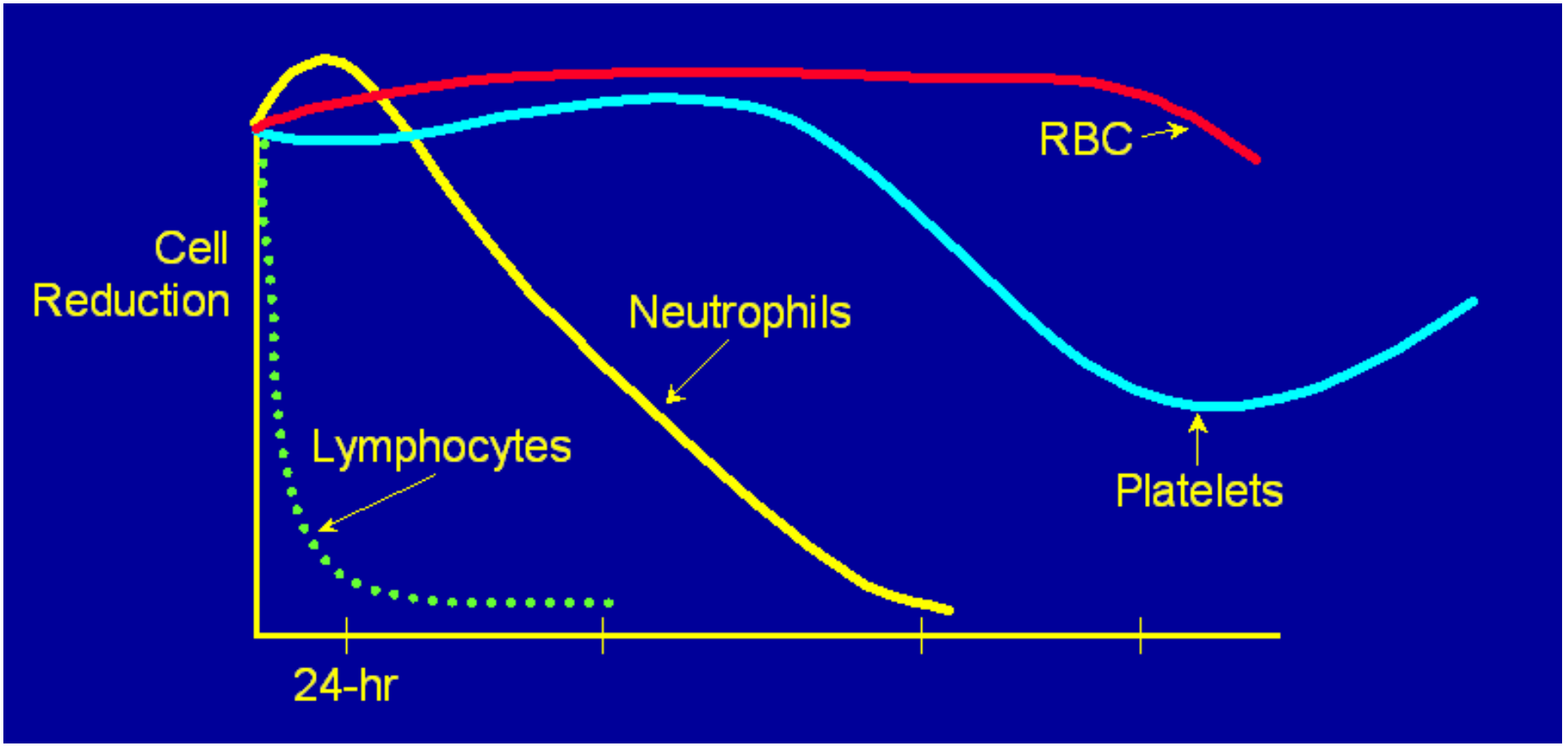
Gastrointestinal
6-8 to 20 Gy

Neurovascular
>20 Gy



Cutaneous (blistering)
>1 Gy

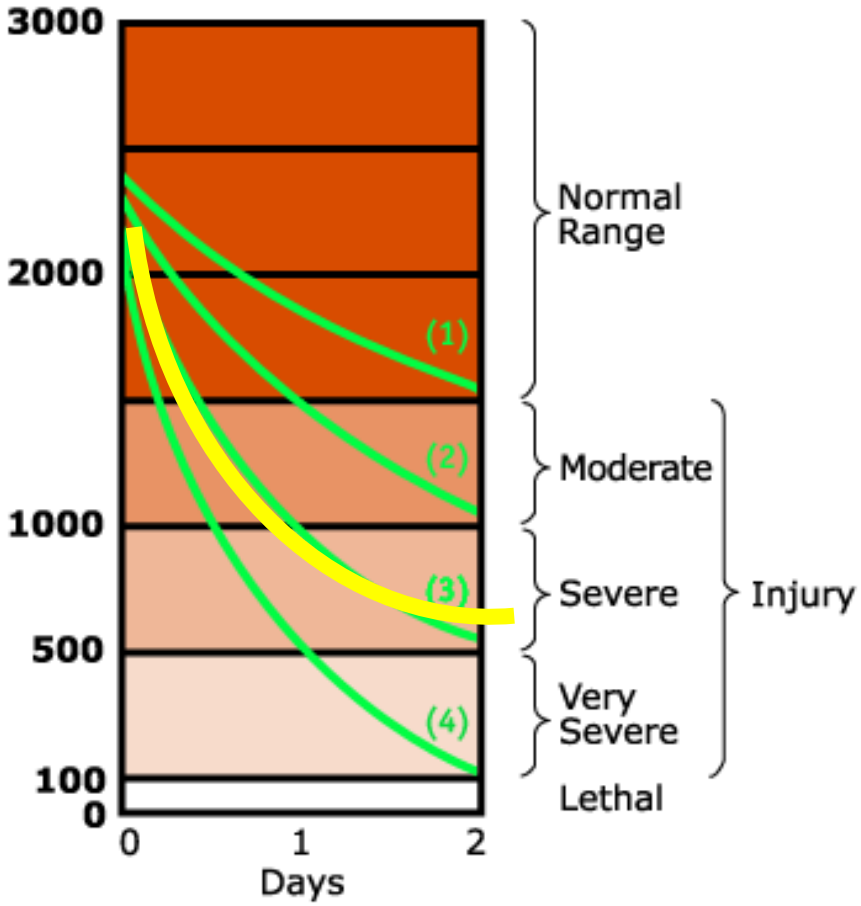
Hematopoietic Subsyndrome



Courtesy of Dr. Keith Edsall, MBBS, MRCS, LRCP, MSc

Hematopoietic Subsyndrome

1= 3.1 Gy
2= 4.4 Gy
3= 5.6 Gy
4= 7.1 Gy



Gastrointestinal Subsyndrome

- **Whole-body dose > 6 - 8 Gy = 600 - 800 cGy = 600 - 800 rad**
- GI epithelial cell populations decline
  - Nausea
  - Vomiting
  - Diarrhea
  - Hypovolemia and electrolyte abnormalities

  - **Sepsis**
    - Loss of barrier between gut bacteria & bloodstream
  - **GI bleed**
    - Lower
      - More common
      - Bloody diarrhea
    - Upper
      - Less common

Neurovascular Subsyndrome

- **Whole body dose > 8-20 Gy = 2000 cGy = 2000 rad**
  - Criticality incident
  - Industrial irradiator incident
  - Nuclear weapon detonation
- Blood vessel (endothelial) leak
  - **Cerebral edema**
  - Coma
  - Death
    - Inevitable by 2 to 3 days
      - Exclude reversible other causes of patient's signs & symptoms, then
        - » Provide comfort care
        - » Palliative therapy

Prodromal Phase:
ARS Degree & Dose vs. Symptom Onset

Signs & Symptoms	Mild (1-2 Gy)	Moderate (2-4 Gy)	Severe (4-6 Gy)	Lethal (>8 Gy) [Pass away]
Emesis (Puke)	≥2h	1 to 2h	**<1h**	<10min
Diarrhea (Poop)	None	None	Mild 3-8h	Heavy **<1h**
Level of Consciousness (Pass out)	Normal	Normal	Normal	**Unconscious (Pass out)** In sec to min

Manifest Illness (Critical) Phase

Signs, Symptoms, & Lab	Mild (1-2 Gy)	Moderate (2-4 Gy)	Severe (4-6 Gy)	Lethal (>8 Gy) [Pass away]
Onset (days)	> 30	**18-28**	**8-18**	**immediate**
Infections	No	**Yes**	**Yes**	**Yes**
Bleeding	No	**Yes**	**Yes**	**Yes**
Platelet Count (10^9/L)	60 to 100	30 to 60	25 to 35	<20
Death (%)	0%	0 to 50%	20 to 70%	100 %
Onset (days - weeks)	N/A	6 to 8 weeks	4 to 8 weeks	1st day

Medical Management Based on Phase & Degree of ARS

ARS Phase	1 to 2 Gy	2 to 4 Gy	4 to 6 Gy	6 to 8 Gy	Lethal >8 Gy
Prodromal	Decon only if contaminated with particles (matter).				
	Outpatient labs & observation	Inpatient treatment in general hospital for labs & observation. Transfer to specialty hospital, if necessary.	Inpatient treatment in specialty hospital	Inpatient treatment in specialty hospital	Palliative symptom therapy

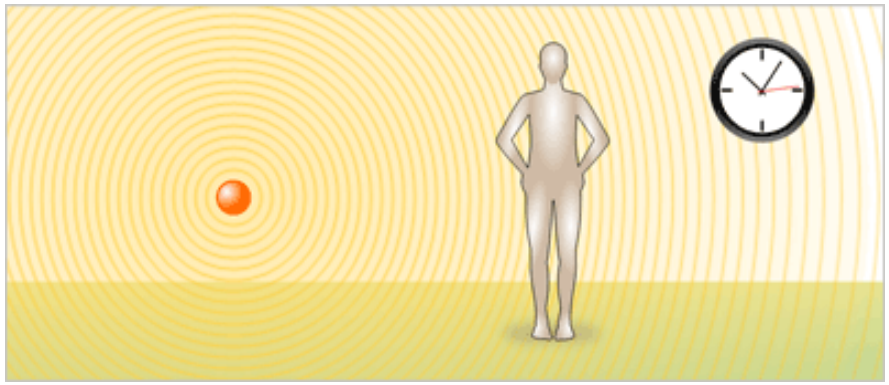
Medical Management Based on Phase & Degree of ARS

ARS Phase	1 to 2 Gy	2 to 4 Gy	4 to 6 Gy	6 to 8 Gy	>8 Gy
Manifest Illness (Critical)	No specific treatment	Antibiotics as needed. Platelets as needed. Blood as needed. Colony stimulating factors (CSF). Reverse isolation from days 10 to 20.	Reverse isolation from first day. Antibiotics, IV fluids, platelets, & blood, as needed. Colony stimulating factors (CSF). Gut bacterial prophylaxis.	Same as 4 to 6 Gy. Consider stem cell transplant (BMT or cord blood).	Palliative symptom therapy

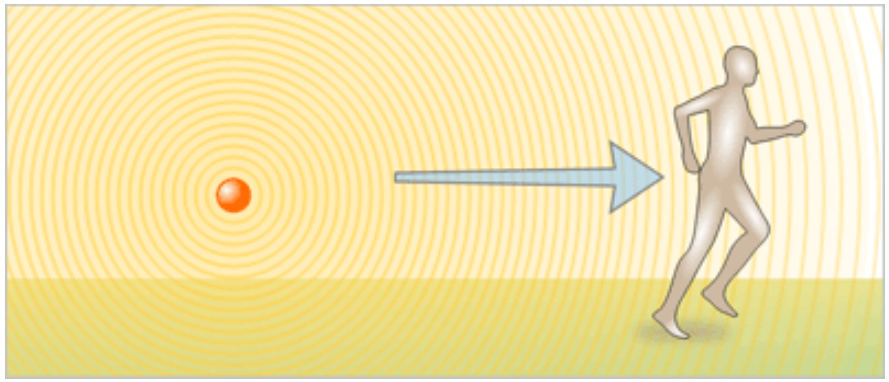
Cutaneous Radiation Injury

5 Skin Lesions	**Dose (Gy)**
• **Epilation** (hair loss) – 17 – 21 days	> 0.3
• **Erythema** (redness) – Early (initial) • Within hours, not minutes – Within minutes implies chemical burn • ≤ 24-48h – Examine hourly for 24h • Take photos & note time	> 0.6
• **Blistering (wks)**	**> 1**
• **Ulceration (2-3 wks)**	**> 2**
• **Necrosis (wks/months)**	**> 5**

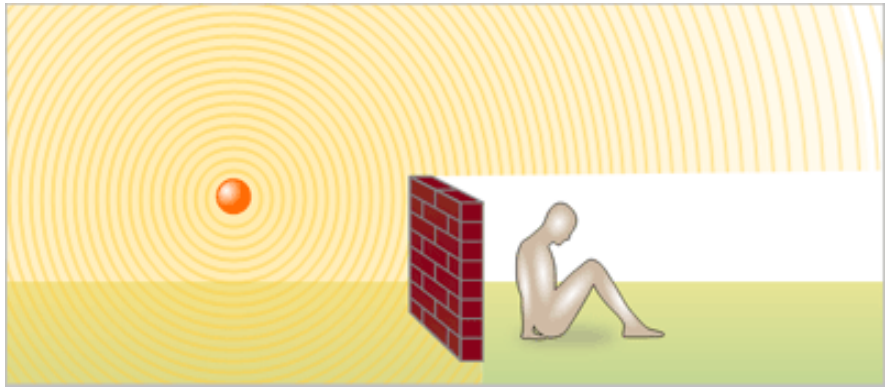
Radiation Protection



Decrease time of exposure



Increase distance from source



Use shielding

Radiological Protection:
Decrease Time

- Dose directly proportional to exposure time
  - Halving exposure time halves dose
- Limit exposure time to limit dose
  - Rotate rescue & medical teams
    - Shift work limits individual rescuer's dose
      - Short shifts
      - Dosimetry

Radiological Protection:
Increase Distance

Distance from source (m)	Dose rate (Gy/h)
2	16
4	4
8	1

Radiological Protection: Decrease Quantity

- Remove & store victims' contaminated clothes away from first responders & first receivers
  - Do not store contaminated clothes in decon room or emergency dept.

Radiation Treatment:

- Decrease time
- Increase distance
- (Use shielding)

- Decontamination

- Antidotes
  - Internal contamination
    - DTPA
      - **Plutonium**
      - **Americium**
      - **Curium**
    - Potassium iodide
      - **Iodine 125 and 131**
    - Prussian blue
      - **Cesium 137**
      - **Tl 201**

Radiation Treatment:

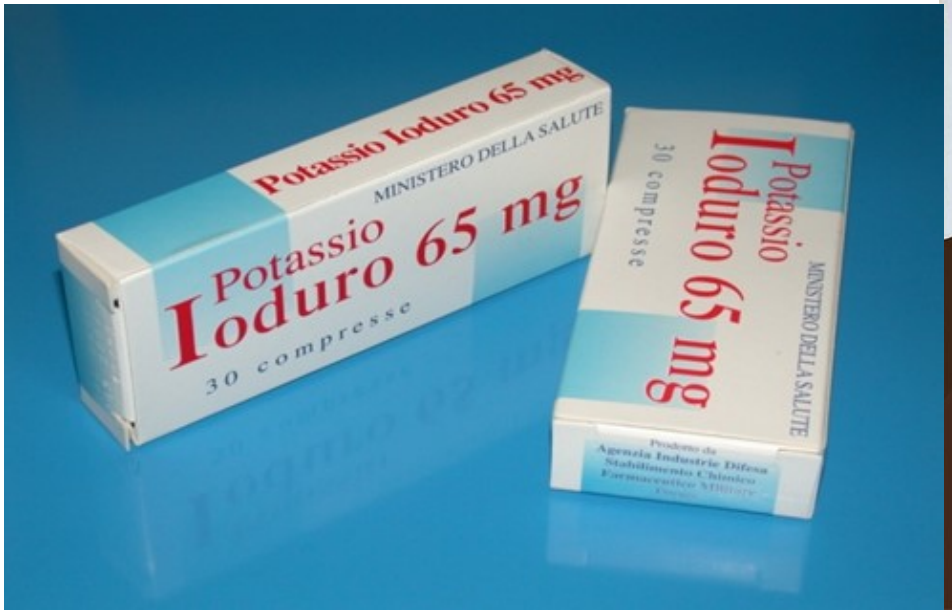
Enhance Elimination

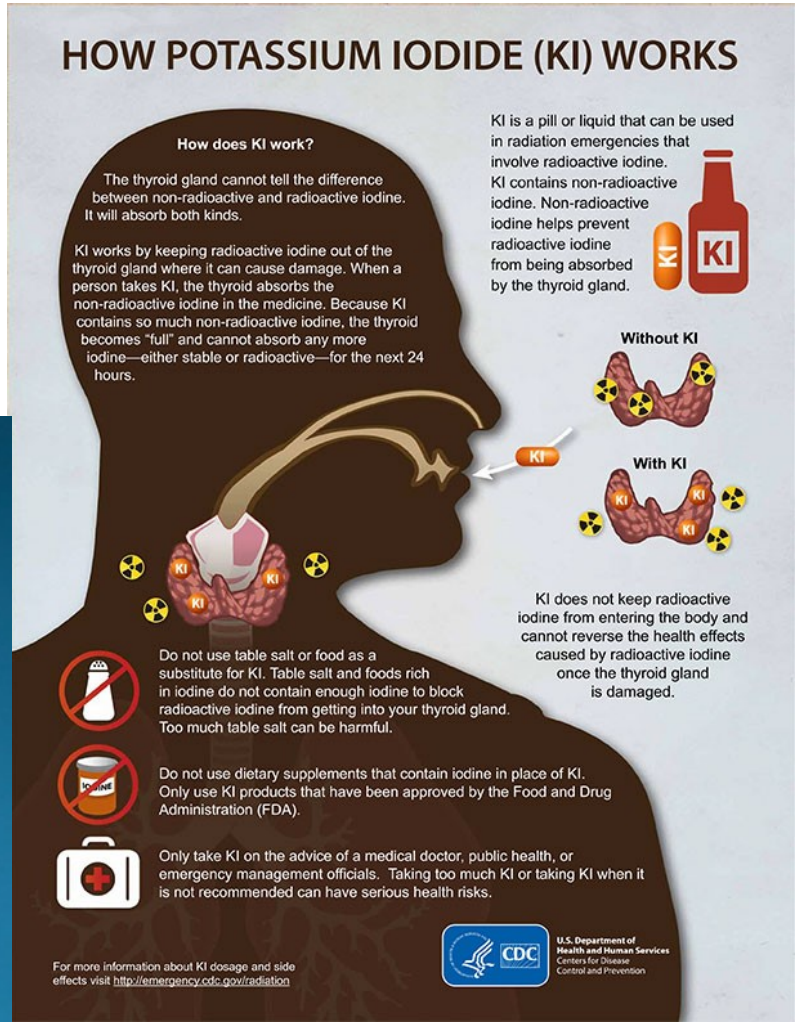
- DTPA
- Potassium iodide
- Prussian blue
- Forced water intake & diuresis for
  - Tritium (H3) internal contamination
- Bicarbonate diuresis for
  - Uranium internal contamination

Radiation Treatment:

Enhance Elimination

- DTPA
- **Potassium iodide** →

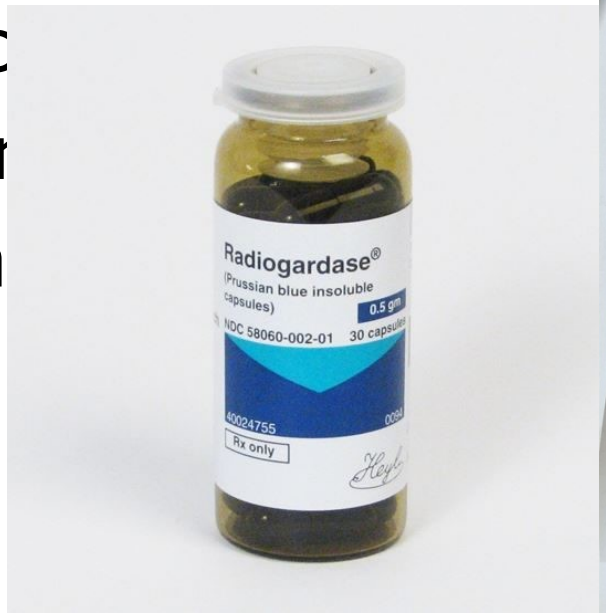


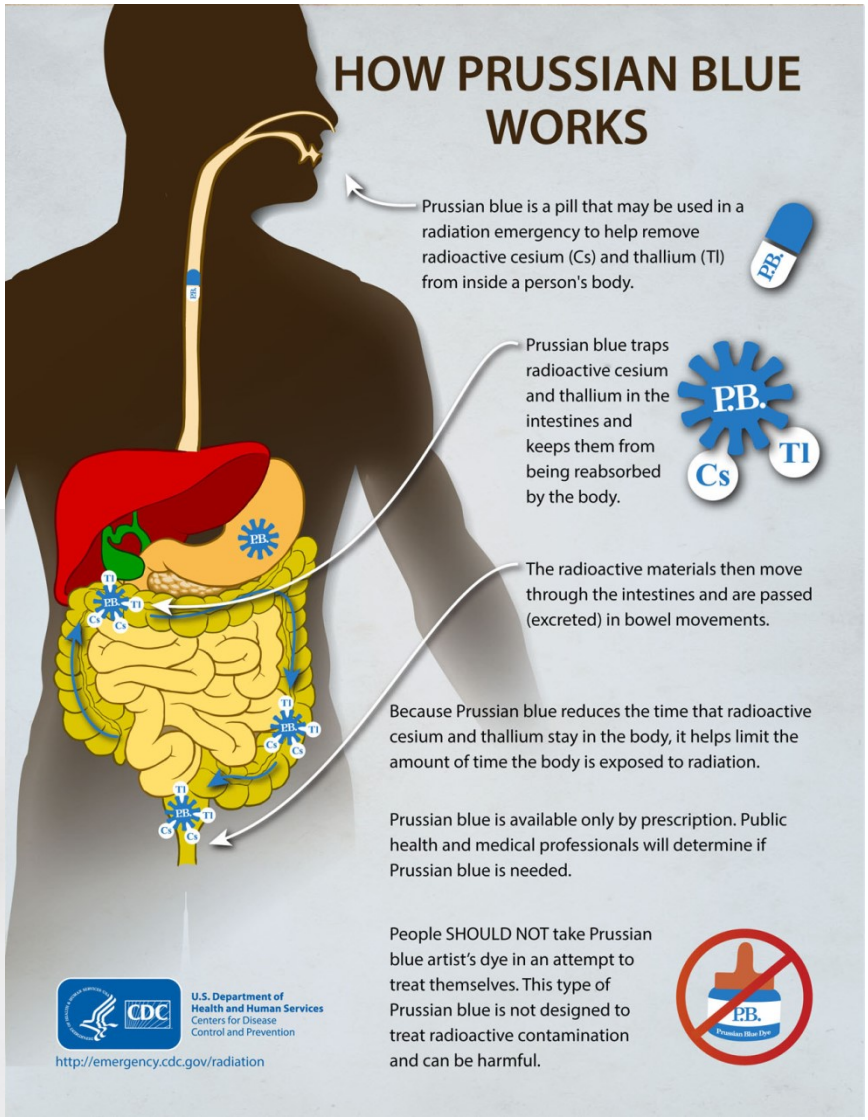


Radiation Treatment:

Enhance Elimination

- DTPA
- Potassium iodide
- **Prussian blue** →
- Forc
  - Tr
- Bica
  - U





Radiation Detection & Monitoring

It is true that…

- Body senses cannot detect ionizing radiation
- and ionizing radiation **cannot** be
  seen, heard, smelled, tasted or felt

BUT…

- ARS is well known syndrome
- Instruments can immediately detect ionizing radiation
- Personal dosimeters
- Survey meters
  - e.g., Geiger-Mueller meter

Thank you