



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

BERGAMO - 21 MAGGIO 2022

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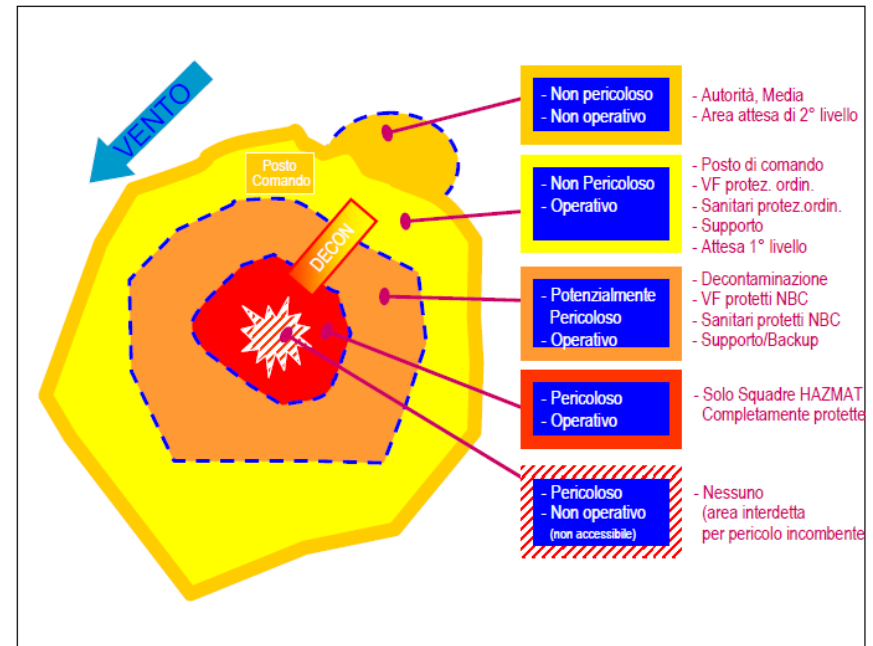


Photo Credit.: Mauro Dalla Torre MD



# 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)*





# EVENTO NBCR (CBRN)

## *'convenzionale'*

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

## *'non convenzionale'*

- *attacco terroristico*
- *attentato*



# EVENTO NBCR (CBRN)

**N / R**

Emissione di radiazioni ionizzanti

**B**

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

**C**

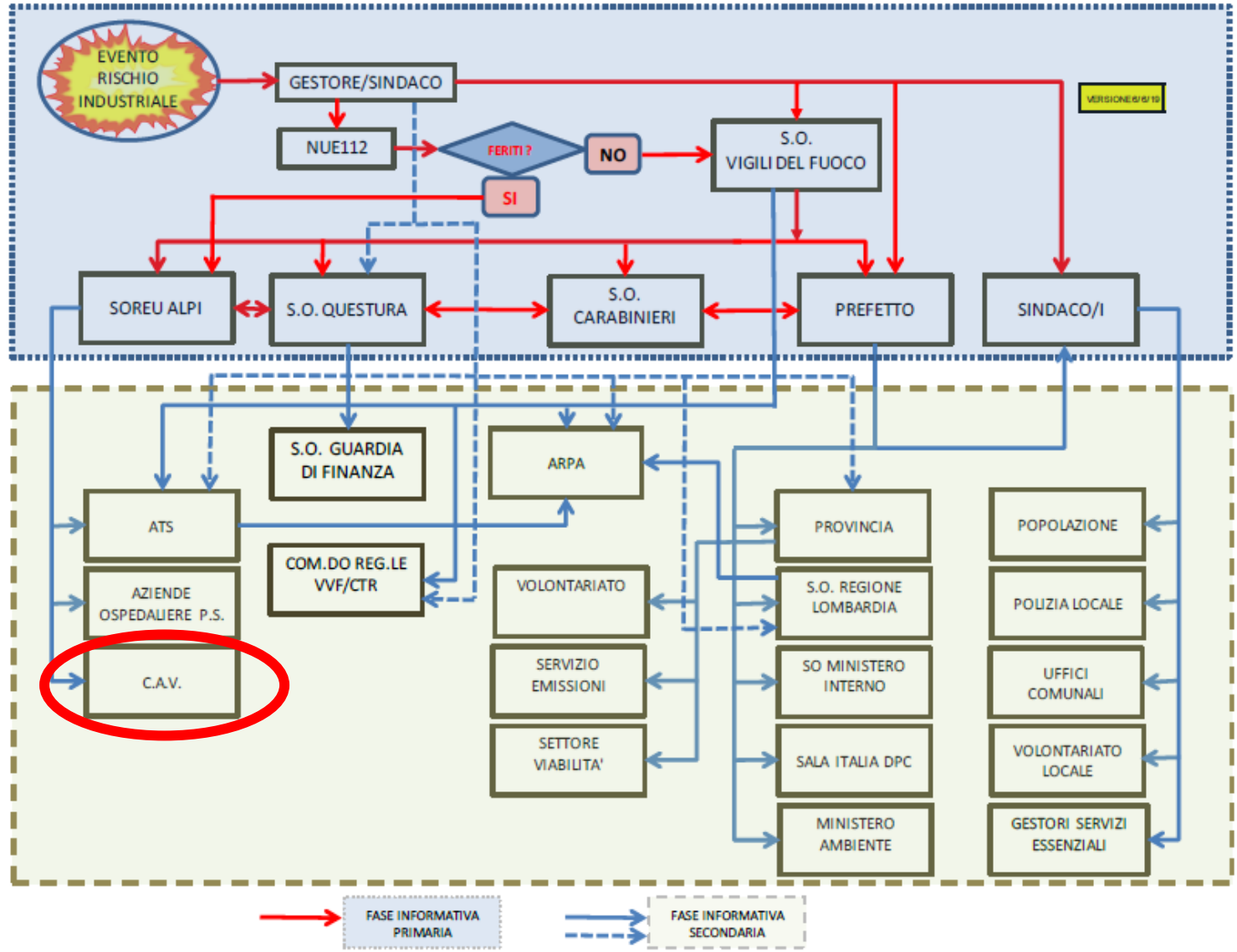
Agenti Nervini  
Asfissianti (CO, cianuro etc.)  
Caustici / Solventi  
...



## Piano di Emergenza Provinciale Rischio Industriale

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

EVENTO  
NBCR

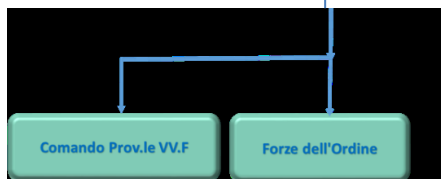
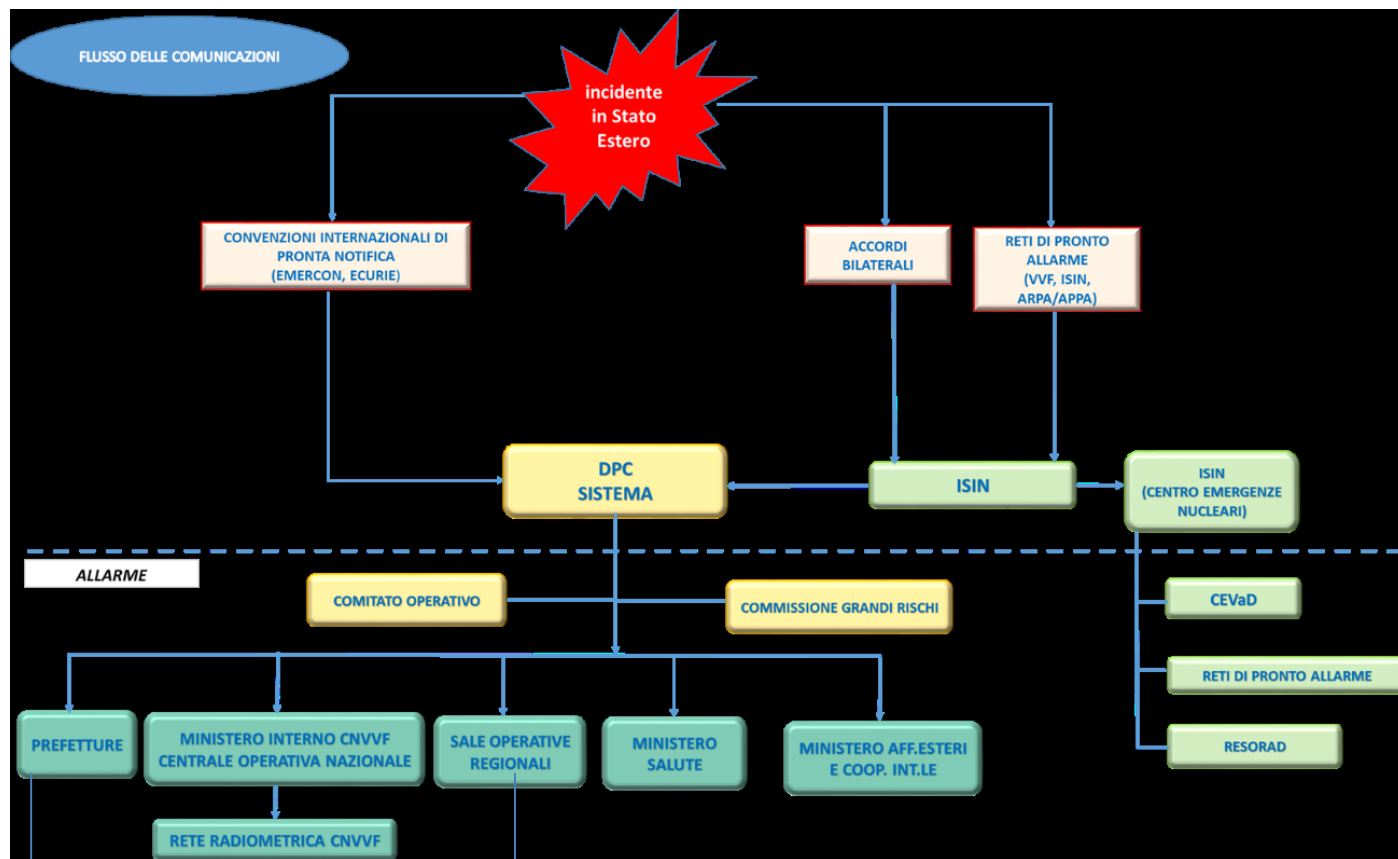


# PIANO NAZIONALE PER LA GESTIONE DELLE EMERGENZE RADIOLOGICHE E NUCLEARI

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

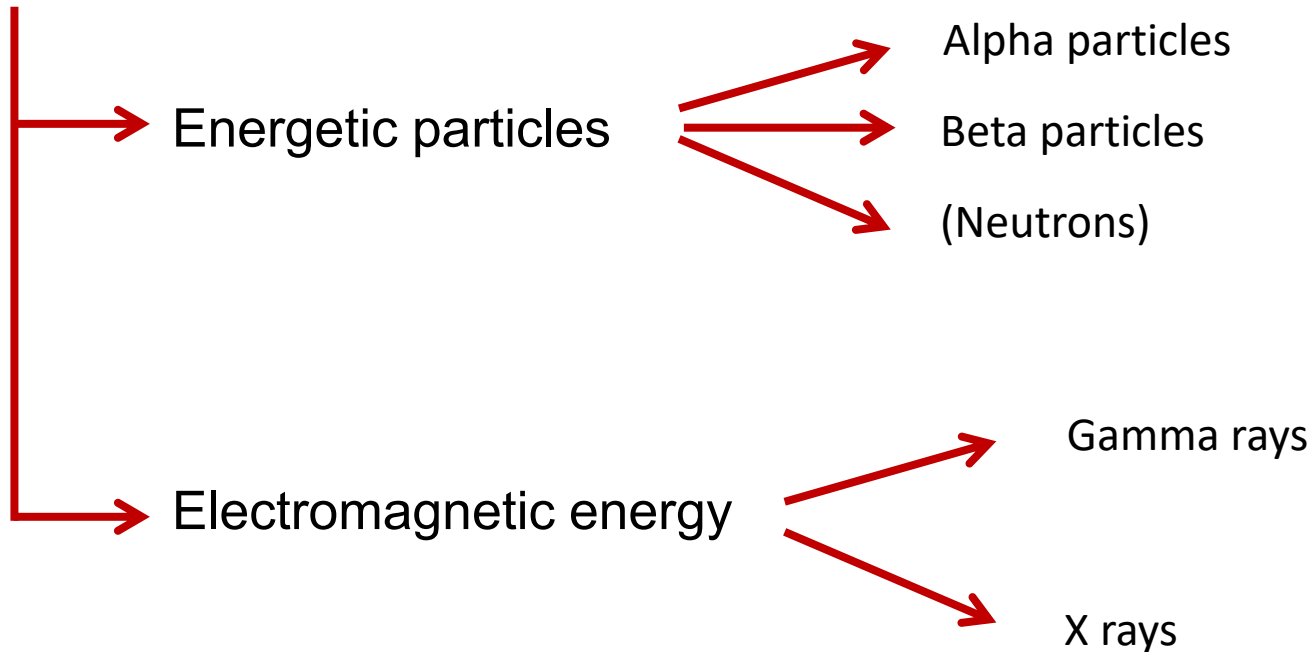




# Radiation

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

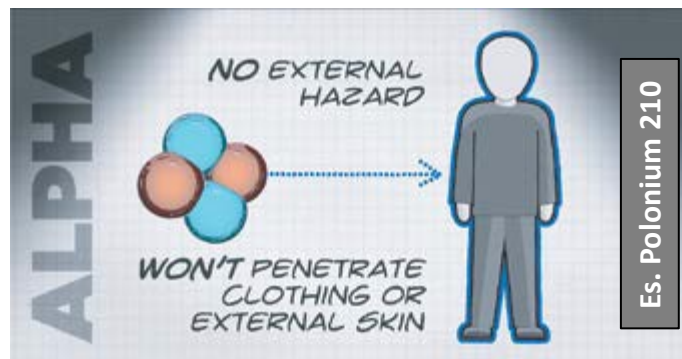
This energy may consists of:



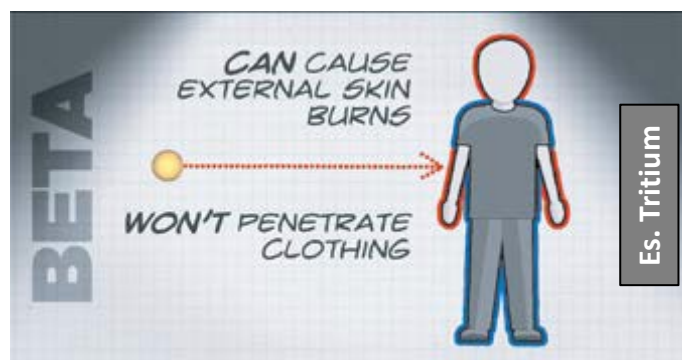
**Strips electrons from molecules** > Produces ions and free radicals  
**Breaks chemical bonds** > Damaged molecules damage cells

AMÉRICIUM	$\alpha / \gamma$
CÉSIIUM	$\beta / \gamma$
COBALT	$\beta / \gamma$
IODE	$\beta / \gamma$
MÉLANGE DE PRODUITS DE FISSION	
PLUTONIUM	$\alpha / \gamma$
TRITIUM	$\beta$
URANIUM	$\alpha / \gamma$

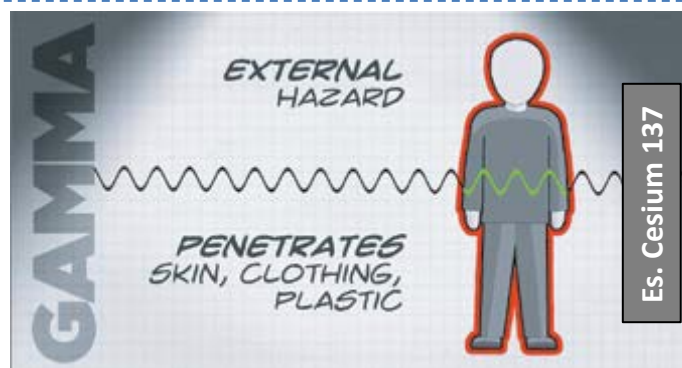
# Radiation



**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.



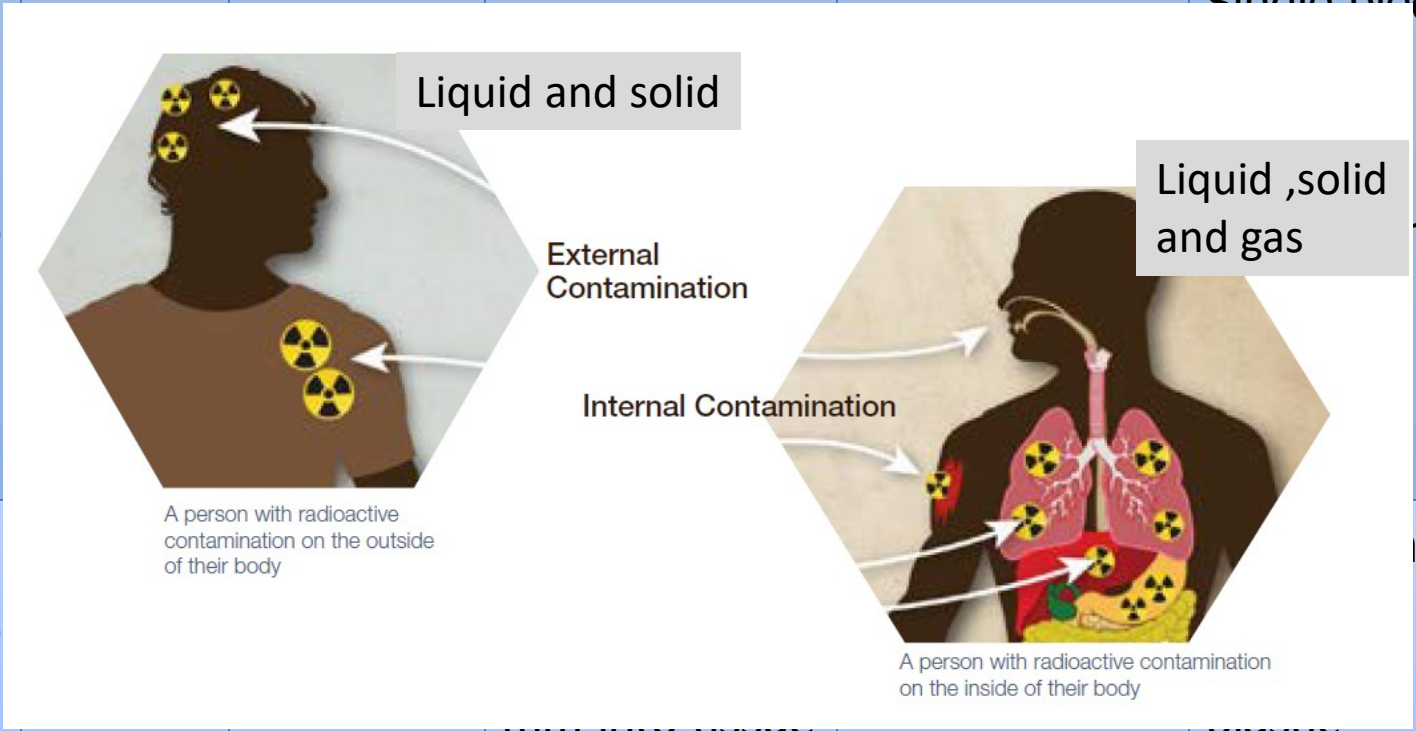
**Gamma rays** can travel directly through the body, damaging cells in the skin and other organs along the way

# Radiation Shielding

Name	Type	Mass (u)	Charge	Penetration	Main Problems	Adequate Shielding
<b>Alpha</b>	Particle	4	+2	< 8 cm thru air  Stratum corneum (dead outer skin layer)	Contamination	Single piece of paper  Universal precautions PPE  Regular clothing
<b>Beta</b>	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
<b>Alpha</b>	Particle					Single piece
<b>Beta</b>	Particle					

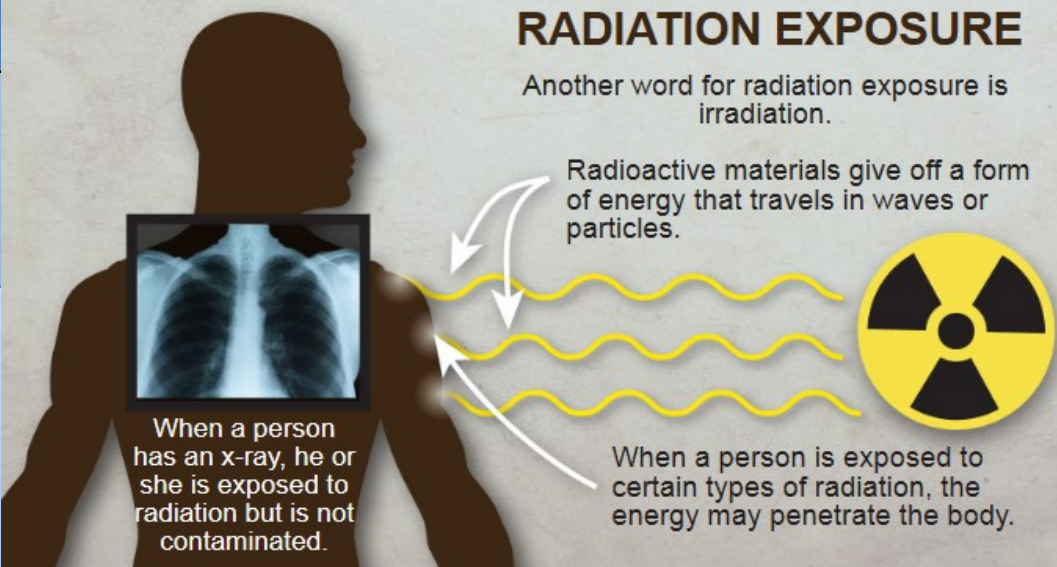



**Patient decontamination necessary !  
Risk of secondary contamination !**

# Radiation Shielding

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

# Radiation Shielding

Name		Main	Adequate
X-ray	<div style="text-align: center;"> <h2 style="margin: 0;">RADIATION EXPOSURE</h2> <p style="margin: 0;">Another word for radiation exposure is irradiation.</p> <p style="margin: 0;">Radioactive materials give off a form of energy that travels in waves or particles.</p>  <p style="margin: 0;">When a person has an x-ray, he or she is exposed to radiation but is not contaminated.</p> <p style="margin: 0;">When a person is exposed to certain types of radiation, the energy may penetrate the body.</p> </div>		
Gamma	<p style="margin: 0;">A person exposed to radiation is not necessarily contaminated with radioactive material.</p> <p style="margin: 0;">For a person to be contaminated, radioactive material must be on or inside of his or her body.</p> <div style="text-align: right; margin-top: 10px;">  <p style="margin: 0; font-size: small;">U.S. Department of Health and Human Services Centers for Disease Control and Prevention</p> <p style="margin: 0; font-size: small;"><a href="http://emergency.cdc.gov/radiation">http://emergency.cdc.gov/radiation</a></p> </div>		

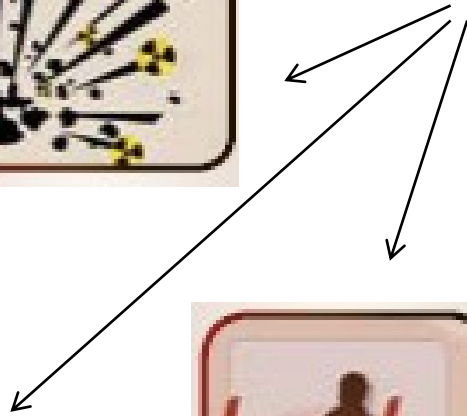
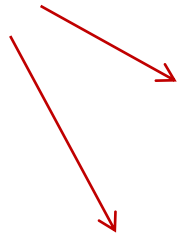
Uranium

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



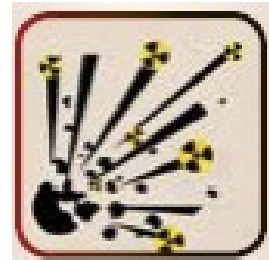
**Radiological exposure device (RED)**

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**

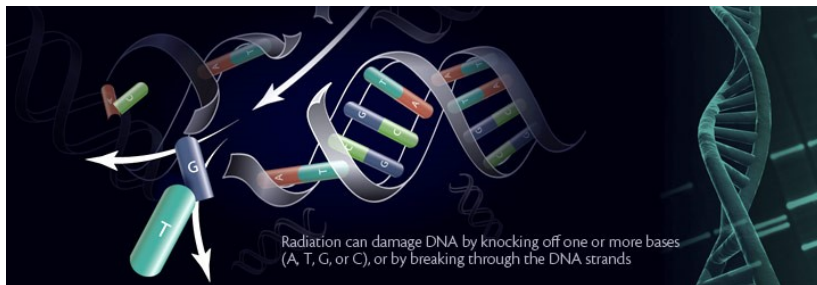
Detonating conventional nuclear weapon

# Radiation Damage

how radiation cause body damage

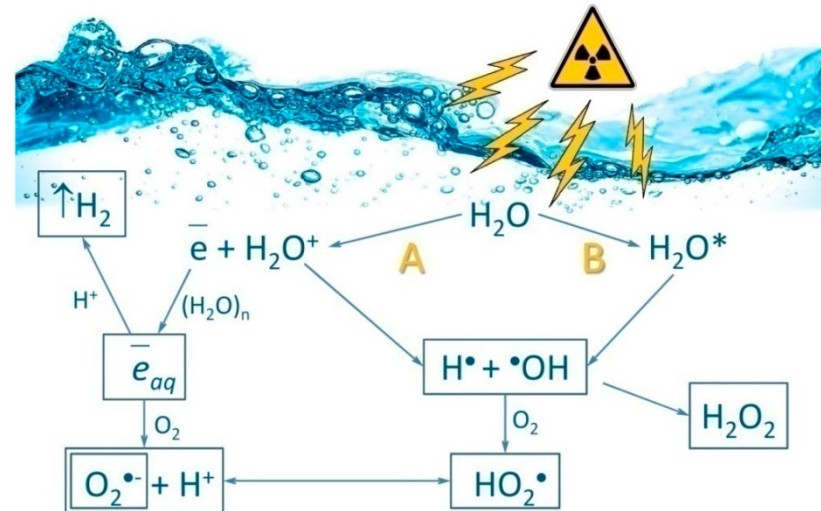
## Direct damage

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**



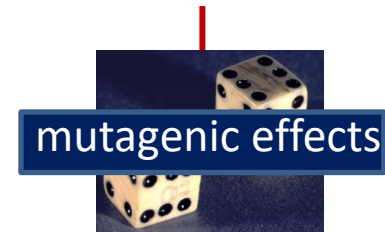
ACUTE RADIATION SYNDROME (ARS)  
CUTANEOUS RADIATION SYNDROME (CRI)

## Stochastic effects



a threshold dose  
does not exist

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

<b>Unit</b>	<b>Meaning</b>	<b>Symbol</b>	<b>Value</b>	<b>System</b>
<b>RAD</b>	<b>Radiation Absorbed Dose</b>	rad	1 cGy = 0.01 J/kg	USA
<b>Gray</b>	Eponym	Gy	100 rad = 100 cGy = 1 J/kg	SI

# Ionizing Radiation **ABSORBED** Dose

Unit	Meaning	Symbol	Value	System
<b>REM</b>	<b>Roentgen Equivalent Man</b>	rem	1 cSv	USA
<b>Sievert</b>	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

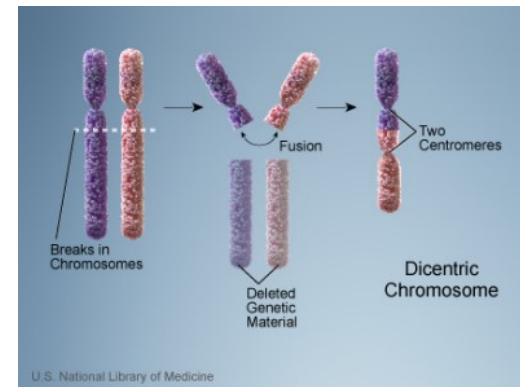
- **Biodosimetry**

- **Clinical**

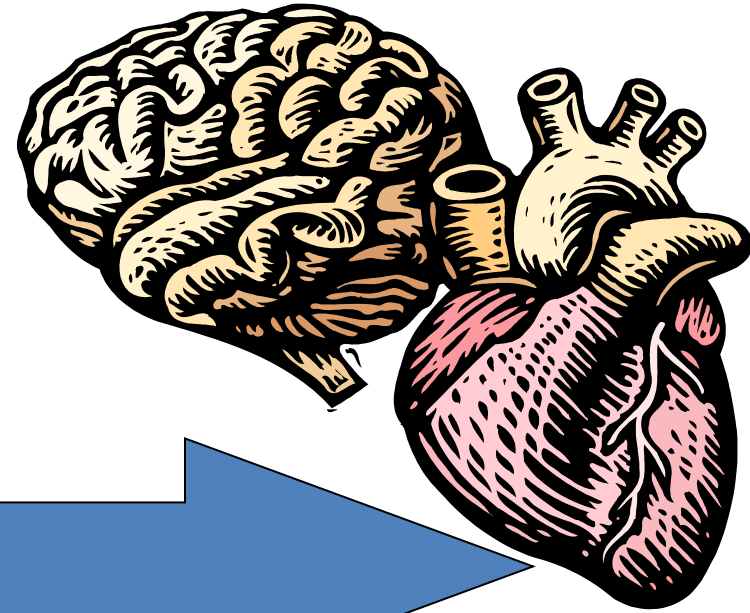
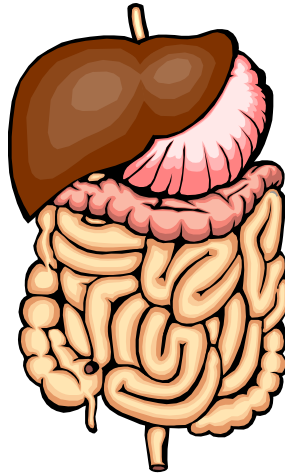
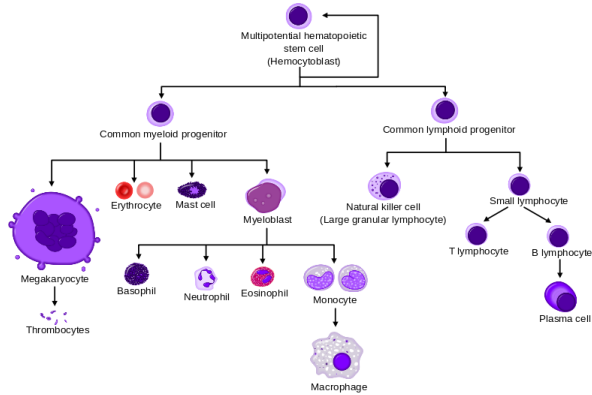
- Signs & symptoms
- Conventional labs

- **Cytogenetics**

- REAC/TS
- AFRRI



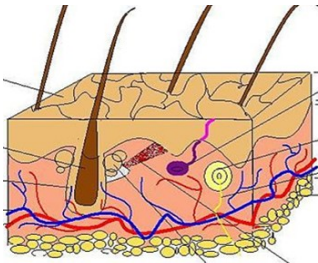
# Radiation Subsyndromes



**Hematopoietic**  
1 to 8 Gy

**Gastrointestinal**  
6-8 to 20 Gy

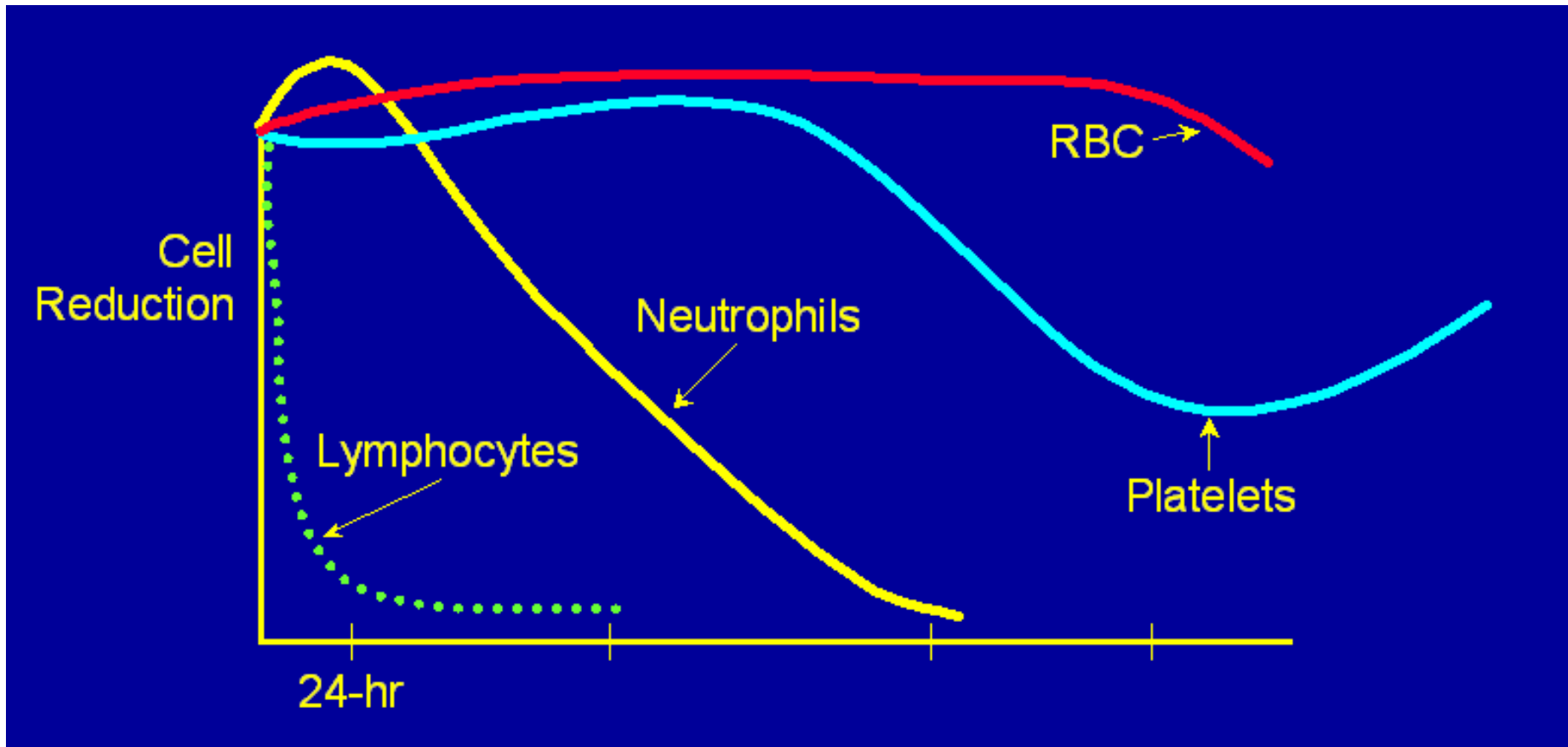
**Neurovascular**  
>20 Gy



**Cutaneous (blistering)**  
>1 Gy

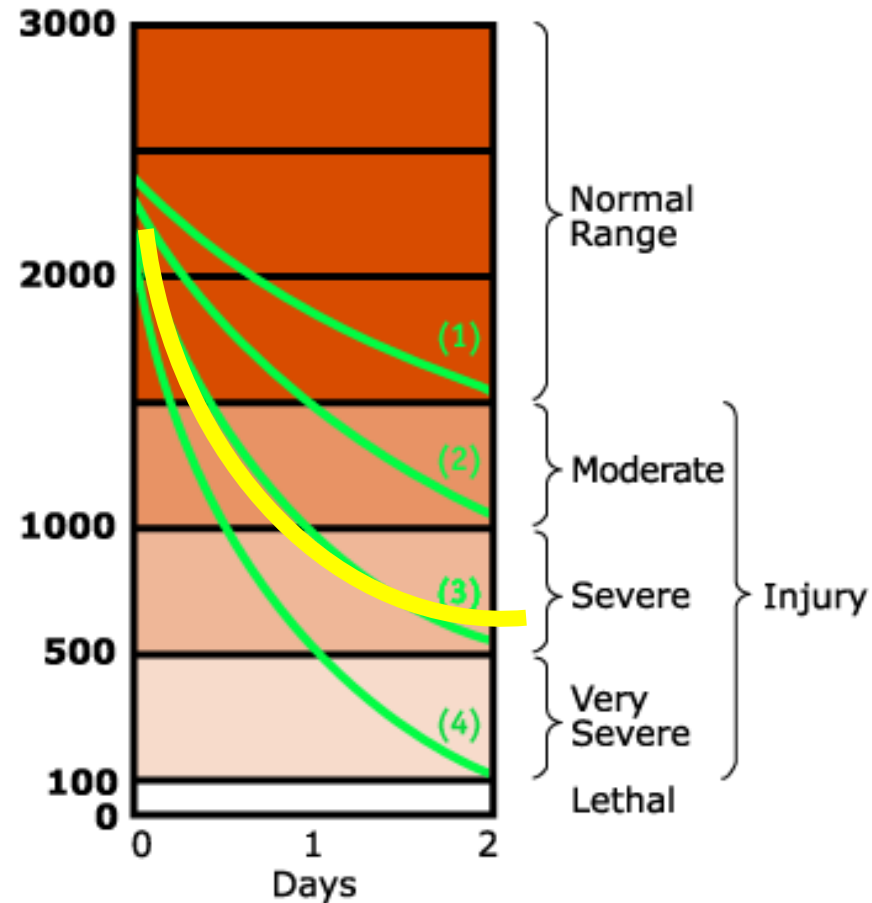


# Hematopoietic Subsyndrome



# 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]
<b>Emesis (Puke)</b>	≥2h	1 to 2h	<b>&lt;1h</b>	<10min
<b>Diarrhea (Poop)</b>	None	None	Mild 3-8h	Heavy <b>&lt;1h</b>
<b>Level of Consciousness (Pass out)</b>	Normal	Normal	Normal	<b>Unconscious (Pass out)</b> 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 <sup>9</sup> /L)	60 to 100	30 to 60	25 to 35	<20
Death (%) Onset (days - weeks)	0% N/A	0 to 50% 6 to 8 weeks	20 to 70% 4 to 8 weeks	100 % 1 <sup>st</sup> 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
<b>Prodromal</b>	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
<b>Manifest Illness (Critical)</b>	No specific treatment	<p>Antibiotics as needed.</p> <p>Platelets as needed.</p> <p>Blood as needed.</p> <p>Colony stimulating factors (CSF).</p> <p>Reverse isolation from days 10 to 20.</p>	<p>Reverse isolation from first day.</p> <p>Antibiotics, IV fluids, platelets, &amp; blood, as needed.</p> <p>Colony stimulating factors (CSF).</p> <p>Gut bacterial prophylaxis.</p>	<p>Same as 4 to 6 Gy.</p> <p>Consider stem cell transplant (BMT or cord blood).</p>	Palliative symptom therapy

# Cutaneous Radiation Injury

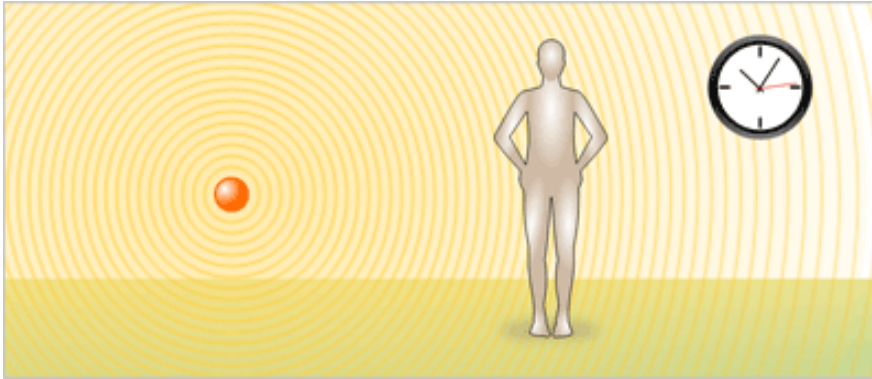
## 5 Skin Lesions

## Dose (Gy)

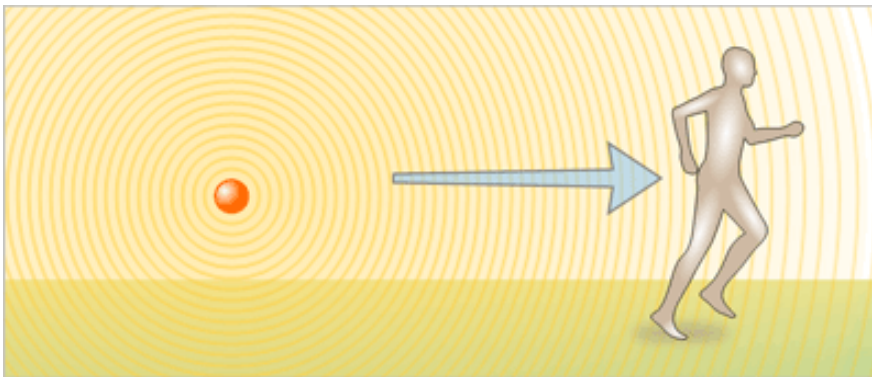
- **Epilation** (hair loss) > 0.3
  - 17 – 21 days
- **Erythema** (redness) > 0.6
  - Early (initial)
    - Within hours, not minutes
      - Within minutes implies chemical burn
    - $\leq$  24-48h
  - Examine hourly for 24h
    - Take photos & note time
- **Blistering (wks)** > 1
- **Ulceration (2-3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



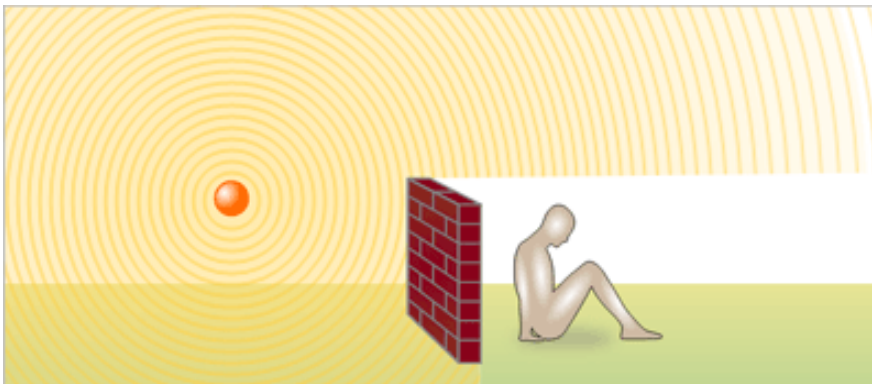
# Radiation Protection



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

<u>Distance from source (m)</u>	<u>Dose rate (Gy/h)</u>
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 ( $H^3$ ) internal contamination
- Bicarbonate diuresis for
  - Uranium internal contamination

# Radiation Treatment:

## Enhance Elimination

– DTPA

– **Potassium iodide** →



### HOW POTASSIUM IODIDE (KI) WORKS

**How does KI work?**

The thyroid gland cannot tell the difference between non-radioactive and radioactive iodine. It will absorb both kinds.

KI works by keeping radioactive iodine out of the thyroid gland where it can cause damage. When a person takes KI, the thyroid absorbs the non-radioactive iodine in the medicine. Because KI contains so much non-radioactive iodine, the thyroid becomes "full" and cannot absorb any more iodine—either stable or radioactive—for the next 24 hours.

KI is a pill or liquid that can be used in radiation emergencies that involve radioactive iodine. KI contains non-radioactive iodine. Non-radioactive iodine helps prevent radioactive iodine from being absorbed by the thyroid gland.

**Without KI**

**With KI**

KI does not keep radioactive iodine from entering the body and cannot reverse the health effects caused by radioactive iodine once the thyroid gland is damaged.

**Do not use table salt or food as a substitute for KI.** Table salt and foods rich in iodine do not contain enough iodine to block radioactive iodine from getting into your thyroid gland. Too much table salt can be harmful.

**Do not use dietary supplements that contain iodine in place of KI.** Only use KI products that have been approved by the Food and Drug Administration (FDA).

**Only take KI on the advice of a medical doctor, public health, or emergency management officials.** Taking too much KI or taking KI when it is not recommended can have serious health risks.

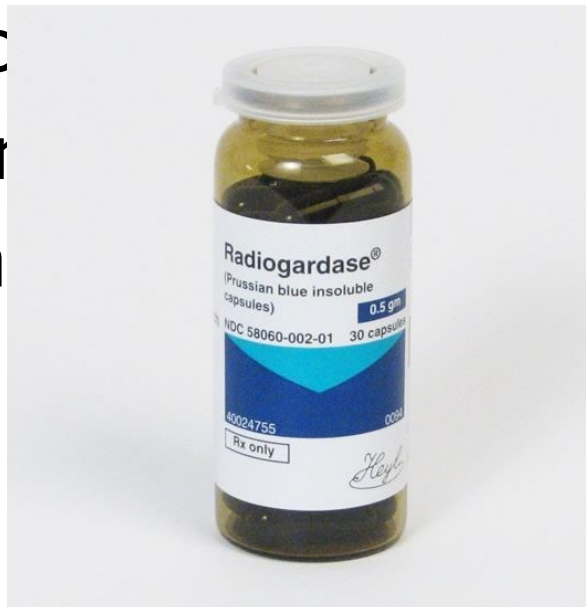
For more information about KI dosage and side effects visit <http://emergency.cdc.gov/radiation>

U.S. Department of Health and Human Services  
Centers for Disease Control and Prevention

# Radiation Treatment:

## Enhance Elimination

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



### HOW PRUSSIAN BLUE WORKS

Prussian blue is a pill that may be used in a radiation emergency to help remove radioactive cesium (Cs) and thallium (Tl) from inside a person's body.

Prussian blue traps radioactive cesium and thallium in the intestines and keeps them from being reabsorbed by the body.

The radioactive materials then move through the intestines and are passed (excreted) in bowel movements.

Because Prussian blue reduces the time that radioactive cesium and thallium stay in the body, it helps limit the amount of time the body is exposed to radiation.

Prussian blue is available only by prescription. Public health and medical professionals will determine if Prussian blue is needed.

People **SHOULD NOT** take Prussian blue artist's dye in an attempt to treat themselves. This type of Prussian blue is not designed to treat radioactive contamination and can be harmful.

U.S. Department of Health and Human Services  
Centers for Disease Control and Prevention  
<http://emergency.cdc.gov/radiation>

# 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

