

Treatment and follow-up of incidentally exposed workers

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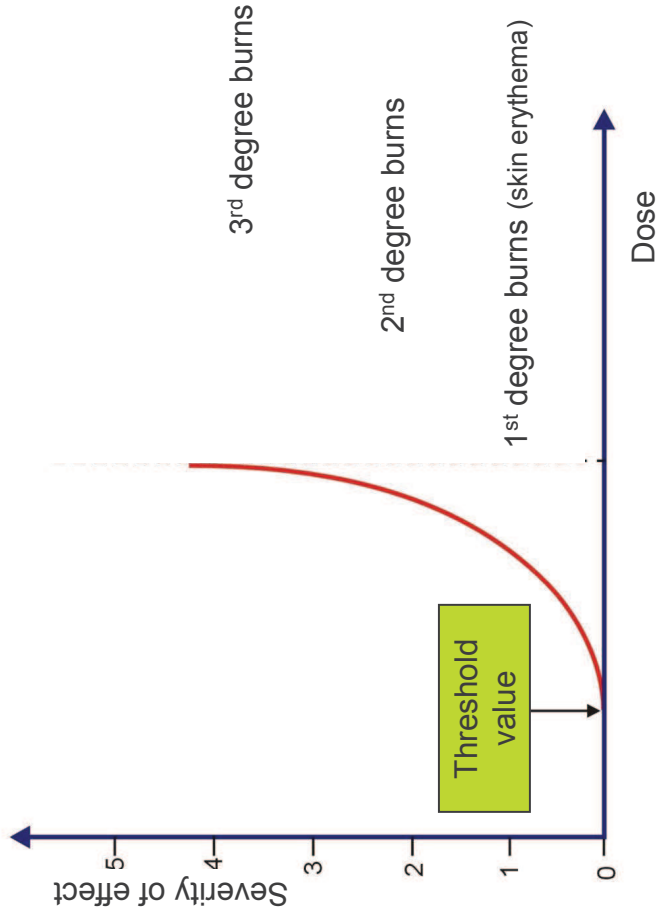
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1. Symptoms of whole body exposure

Acute radiation syndrome (ARS): appearance of **deterministic effects**

- when **threshold dose** is exceeded
- **severity** of damage depends on the dose received

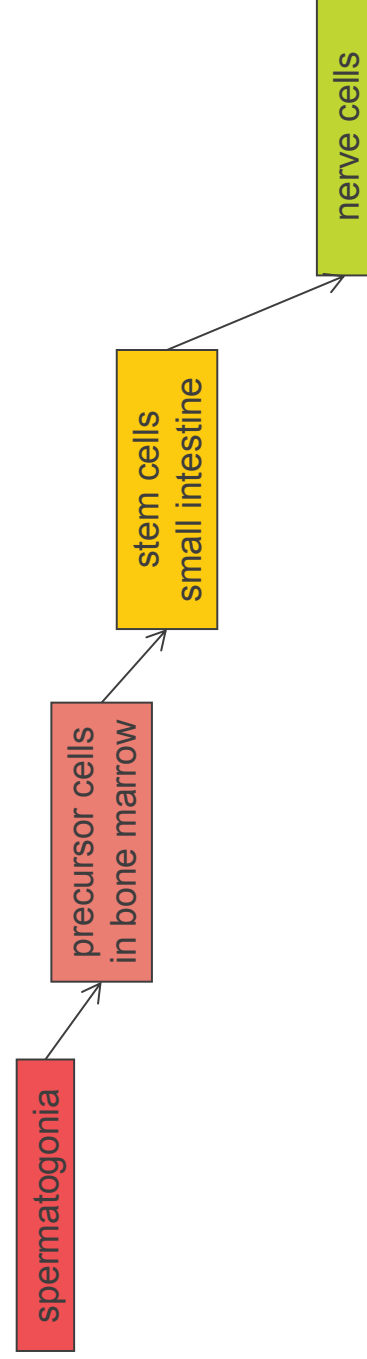


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Acute radiation syndrome (ARS)

Acute effects:

- **Threshold doses are (very) high compared to legal dose limits** for chronic professional exposure!
- **Dose rate** dependent
- **Radiosensitivity varies** directly with rate of cellular proliferation and the number of future divisions, and inversely with degree of morphologic and functional differentiation



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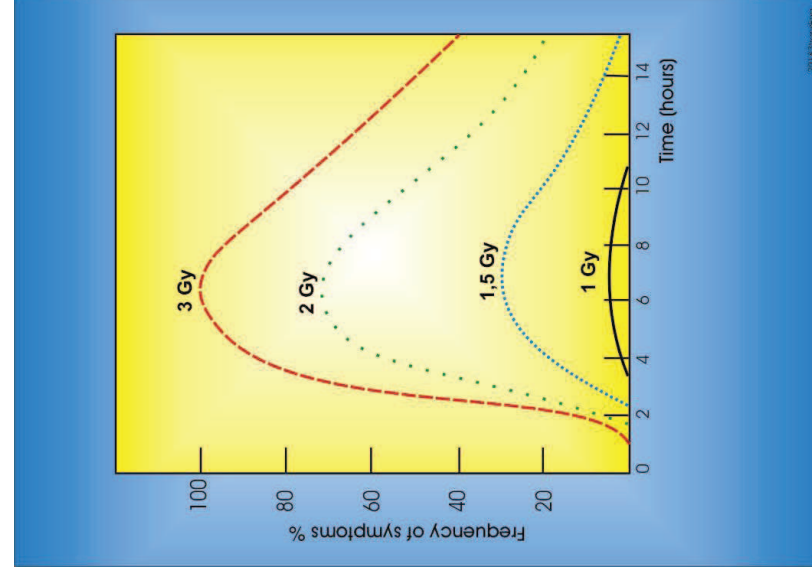
Acute radiation syndrome (ARS)

- Clinical symptoms depend on dose (rate) received by:
 - **bone marrow**
 - **gastrointestinal tract**
 - **skin**
 - **central nervous system**
- Evolution of clinical symptoms:
 - prodromal signs: usually appear in the first 48 hours
 - (latency phase: inversely related to radiation dose)
 - critical phase
 - (recovery)

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Acute Radiation Syndrome (ARS) *prodromal signs*

- **anorexia, nausea → vomiting** ($D > 1 \text{ Gy}$)
- xerostomia ($D > \pm 1,5 \text{ à } 2 \text{ Gy}$)
- headache ($D > \pm 2 \text{ à } 3 \text{ Gy}$)
- (transient) erythema: ($D > \pm 3 \text{ à } 4 \text{ Gy}$)
- diarrhea ($D > \pm 3 \text{ Gy}$)
- after very high doses ($D > \pm 7,5 \text{ à } 10 \text{ Gy}$): first prodromal symptoms within minutes! (+ fever, hypotension, severe apathy, extreme weakness, loss of consciousness)



2012/04/26/14

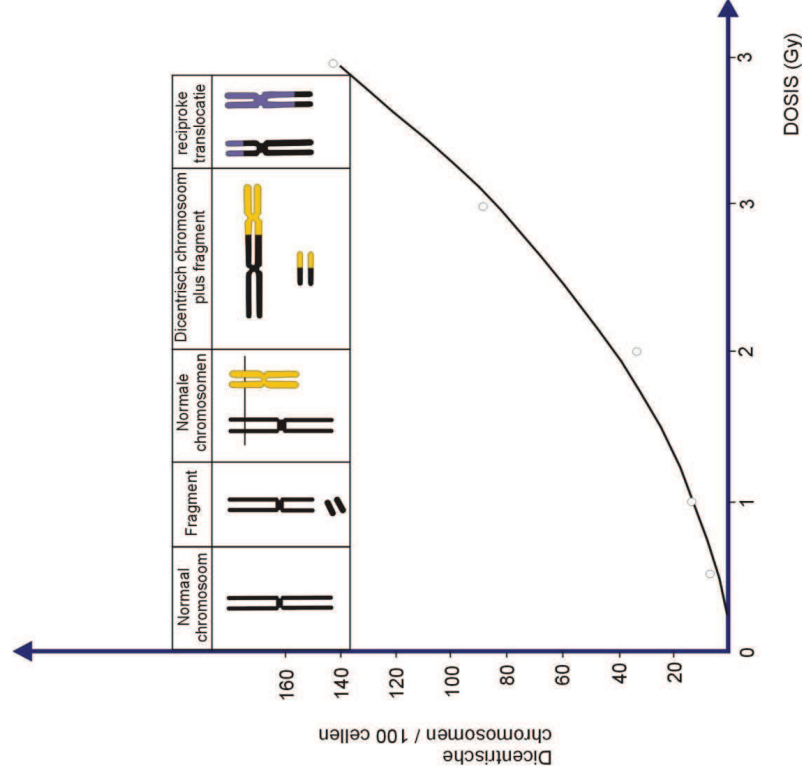
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Incidental radiation exposures:
Initial evaluations: *dose reconstruction techniques*

**A GOOD COLLABORATION BETWEEN EMPLOYER,
EMPLOYEE(S), HEALTH PHYSICS/AGREED BODY,
DOSIMETRY EXPERTS AND OCCUPATIONAL PHYSICIAN
IS MANDATORY**

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Acute Radiation Syndrome (ARS)
Initial evaluations: *biological dosimetry*



chromosomal anomalies

dicentric + fragments (+ rings)
DL: ± 100 mGy

micronucleus test

DL: ± 200 à $300 \rightarrow \pm 100$ mGy

lymphocyte count

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Dicentrics

Metafer4 - AutoCapt - Relocate
Mode File Slide Cells Scoring Training AutoCapt Configure Stage Filters Tools Help

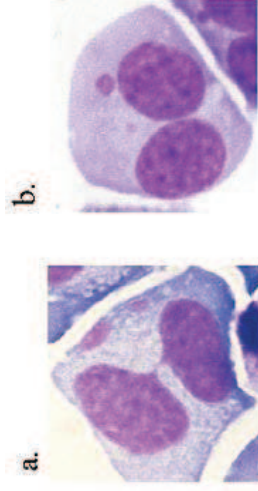
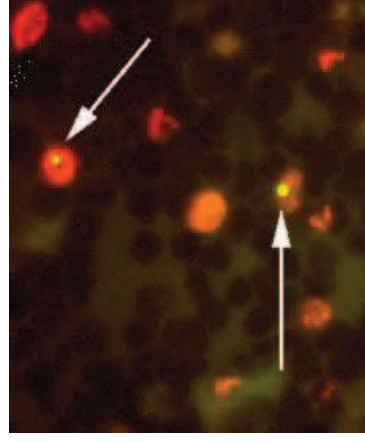


AFD38E3g-A

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776 Marked	327	Quality Rank :	327	3	3	47	0
200 Rejected	83	Quality Score :	83	ADics	NClas3	NChrs	AuxVar5
0 Deleted	501	Cell ID :	501	3	3	25	0
		Status :	Marked	AuxVar1	AuxVar2	AuxVar3	AuxVar4
		Class :	O.K.	0	0	0	0

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Micronuclei



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Incidental exposure of workers to ionizing radiation
Initial evaluations: *biological dosimetry*

UGent

Vakgroep Medische Basiswetenschappen

Straling en DNA repair

Campus Heymans, UZ, gebouw 6B3

De Pintelaan, 185 B-9000 Gent

Prof. Dr. H. Thierens

Tel: 09/ 332 46 64 – 09/264 65 19

GSM: 0496/ 24 64 83

Hubert.Thierens@UGent.be

Prof. Dr. A. Vral

Tel: 09/ 332 51 29 (35)

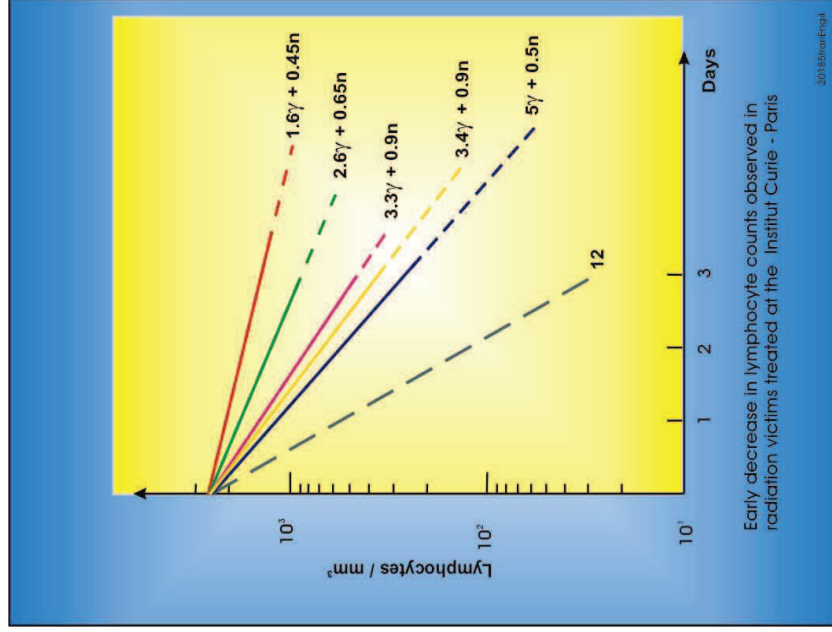
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Acute Radiation Syndrome (ARS)

Initial evaluations: *biological dosimetry*



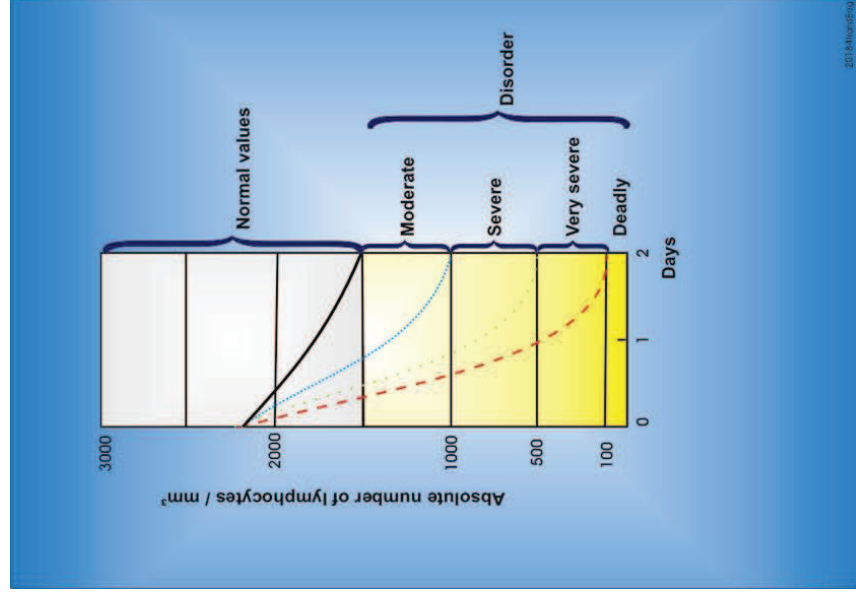
drop in absolute number of lymphocytes is related to mean total body dose

- 50 % after 1 - 2 days: → potentially fatal dose in range 5 – 10 Gy

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Acute Radiation Syndrome (ARS)

Initial evaluations: *biological dosimetry*



- Lymphocyte count within 50 % of normal values during first week after (total body) irradiation:

- → suggests exposure $D < 1$ Gy
- → survival > 90 %

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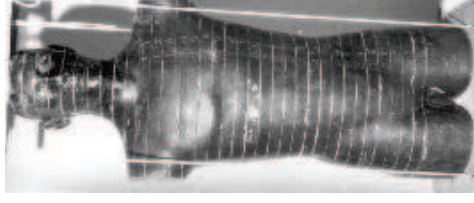
ARS: Initial evaluations: *dose reconstruction techniques*

- Acute exposure:
 - Partially body irradiation/localised irradiation
 - Personal dosimeters worn by victims are often not sufficient
 - Many of the accidents involve members of the public
 - no personal dosimeter available

↑ Different techniques need to be combined to reconstruct the dose received



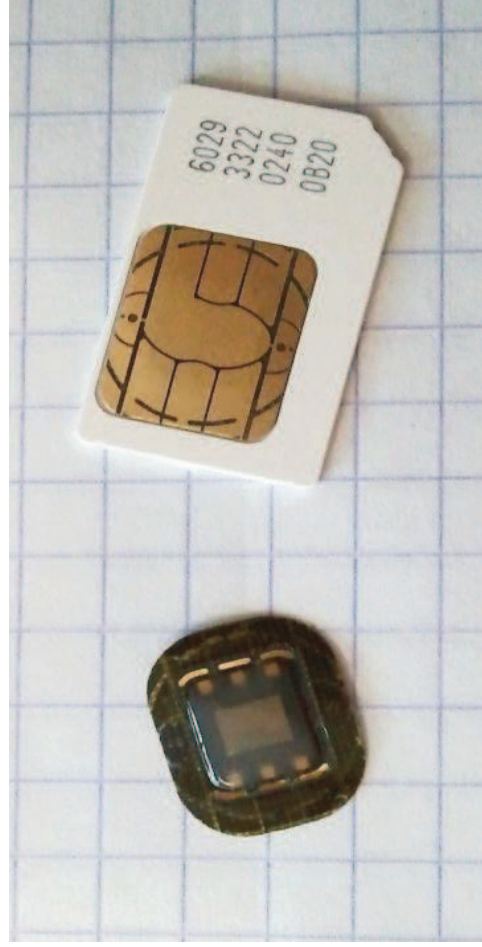
- Possibilities at SCK•CEN – Mol:
 - Monte Carlo simulations
 - Reconstruction of accident geometry with Rando Alderson phantom
 - Use of personal objects: chip cards, mobile phone components...



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Example: Telephone chip cards as accident dosimeter

- Presence of silica particles in the encapsulating epoxy
 - **Optically Stimulated Luminescent properties**
- But only when chips are covered with transparent plastic cover



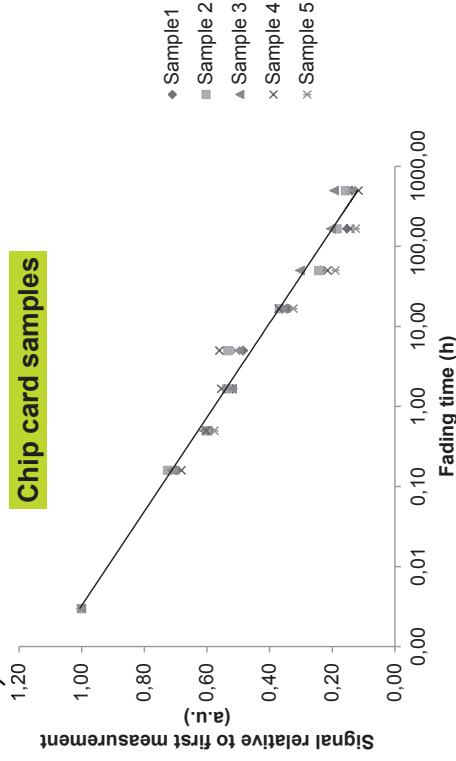
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Telephone chip cards as accident dosimeter

Dosimetric properties of telephone chip cards

Fading

$$I = I_c \left(1 - \kappa \ln \left(\frac{t}{t_c} \right) \right)$$

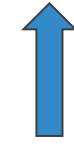


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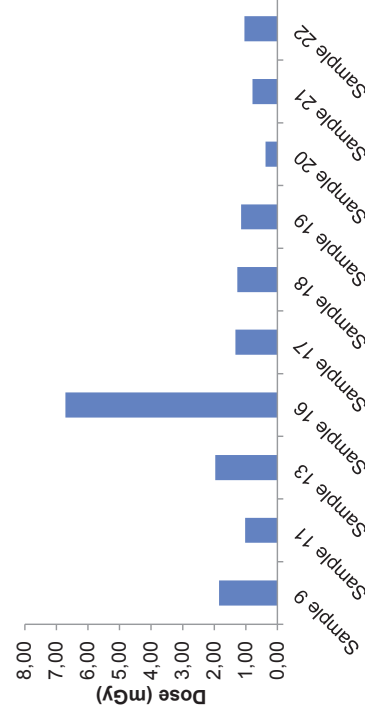
Telephone chip cards as accident dosimeter

Dosimetric properties of telephone chip cards

● **Lowest level of detection**



Depending on the time after exposure due to fading
Depending on the sensitivity of the sample



Average: 1.8 mGy

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Incidental exposure of workers
to ionizing radiation

Biological and physical dosimetry
are complementary. The combination of
both methods is superior!

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Acute Radiation Syndrome (ARS) *the latency phase*

- duration ≠ dose
- can last until 20th day after irradiation
- quiescent period = time between
 - initial cell damage and
 - its expression as interference with cell renewal in the affected organs
- (high) radiation doses interfere with ability of cells with high mitotic activity to renew themselves

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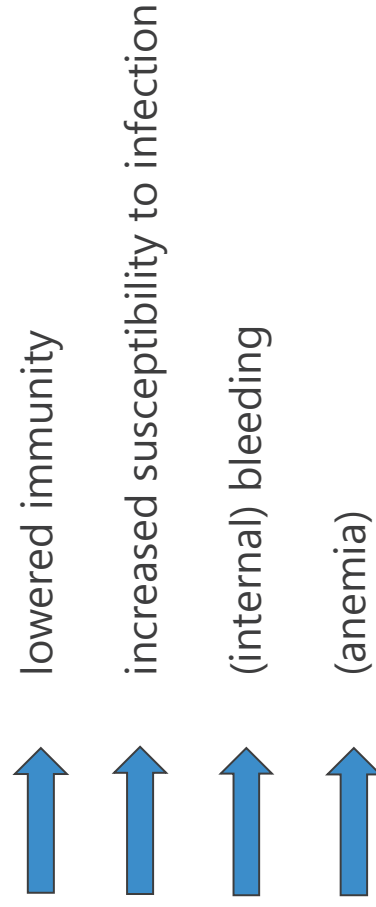
Acute Radiation Syndrome (ARS) *critical phase: hematopoietic syndrome*

- damage to the radiosensitive bone marrow (hematopoietic stem cells)
- damage blood forming stem cells can occur for doses $D > \pm 100 - 500 \text{ mGy}$
 - ➔ diminishing the subsequent supply of mature
 - red blood cells
 - white blood cells
 - platelets

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Acute Radiation Syndrome (ARS) *critical phase: hematopoietic syndrome*

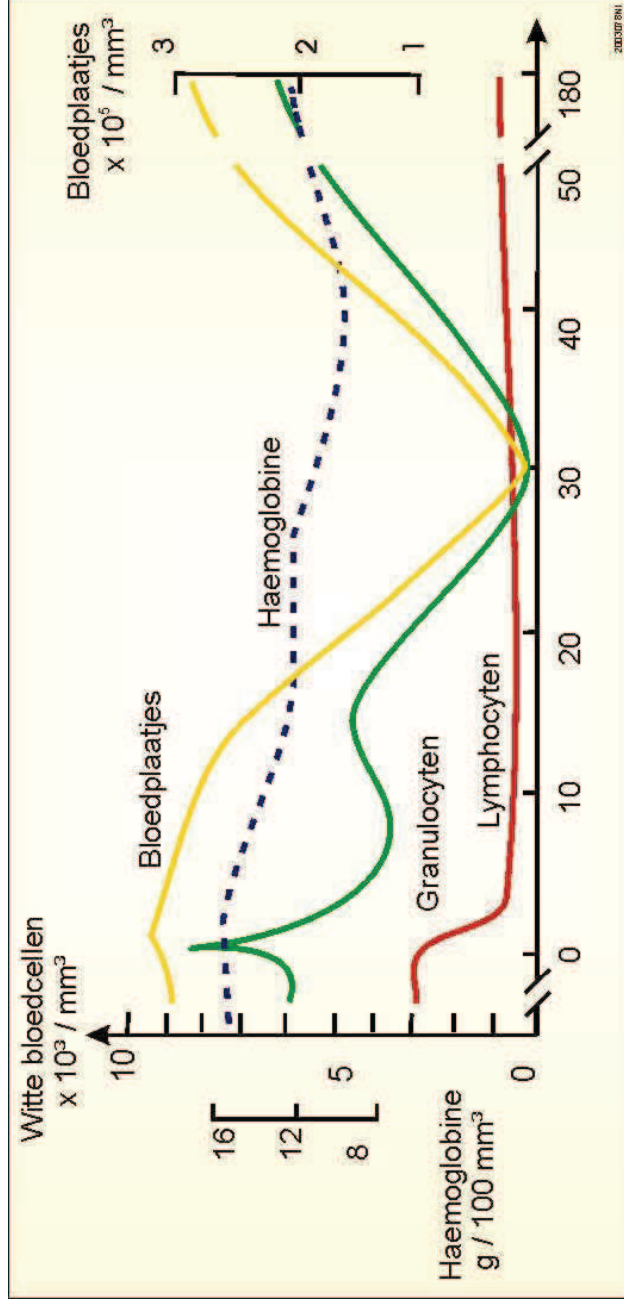
When radiation dose to the bone marrow increases ($D > 1 - 1,5 \text{ Gy}$):



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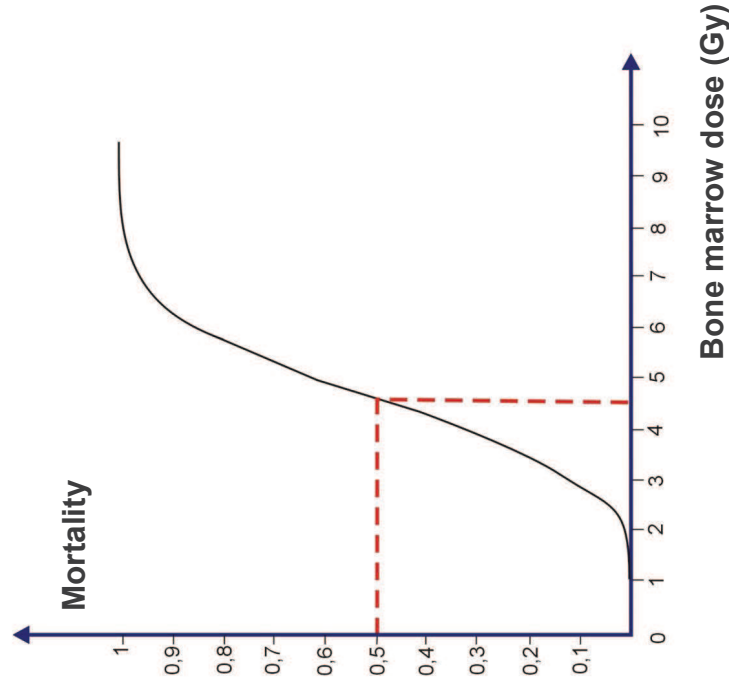
ARS

hematological data after a 3 Gy total body irradiation



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Probability of death ($\text{LD}_{50/60\text{d}}$) as a function of bone marrow dose (without supportive medical care)



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Acute Radiation Syndrome (ARS) *critical phase: gastrointestinal syndrome*

Clinical symptoms:

- vomiting, cramping, abdominal pain
- diarrhea ++, gastrointestinal bleeding → anemia
- dehydration + electrolyte imbalance
- malabsorption
- ulceration of intestinal wall, fever
- escape of bacterial endotoxins into bloodstream → sepsis complicated by immunosuppression/cytopenias...
- (death after several days)

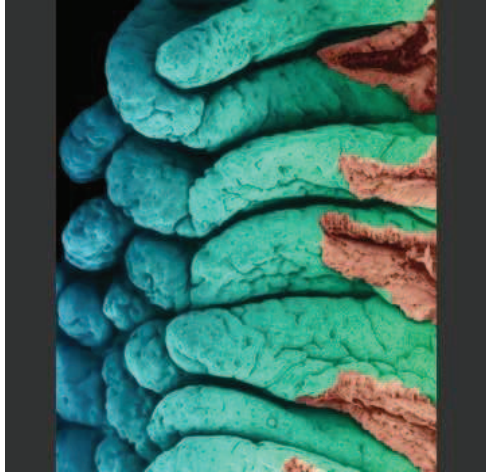
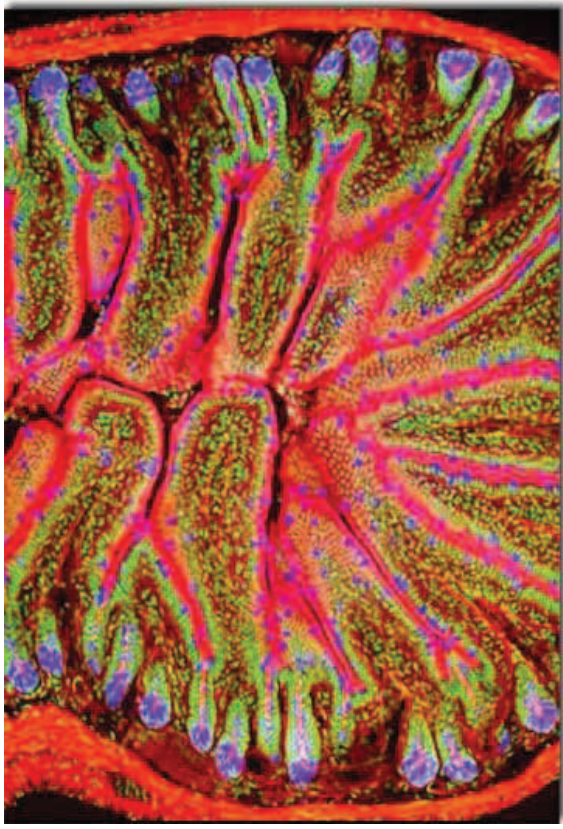
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Acute Radiation Syndrome (ARS) *critical phase: gastrointestinal syndrome*

- Irradiation inhibits renewal of short-lived cells lining the small intestine
 - mature mucosal cells are progressively shed and are not replaced when radiation kills the stem cells in the crypts
- Damage to the most radiosensitive stem cells of the small intestine can occur for doses > 6000 à 7000 mGy
 - For doses:
 - 7 - 10 Gy: septicemia + dehydration
 - 10 - 15 Gy: denudation mucosa → loss of fluids + electrolytes

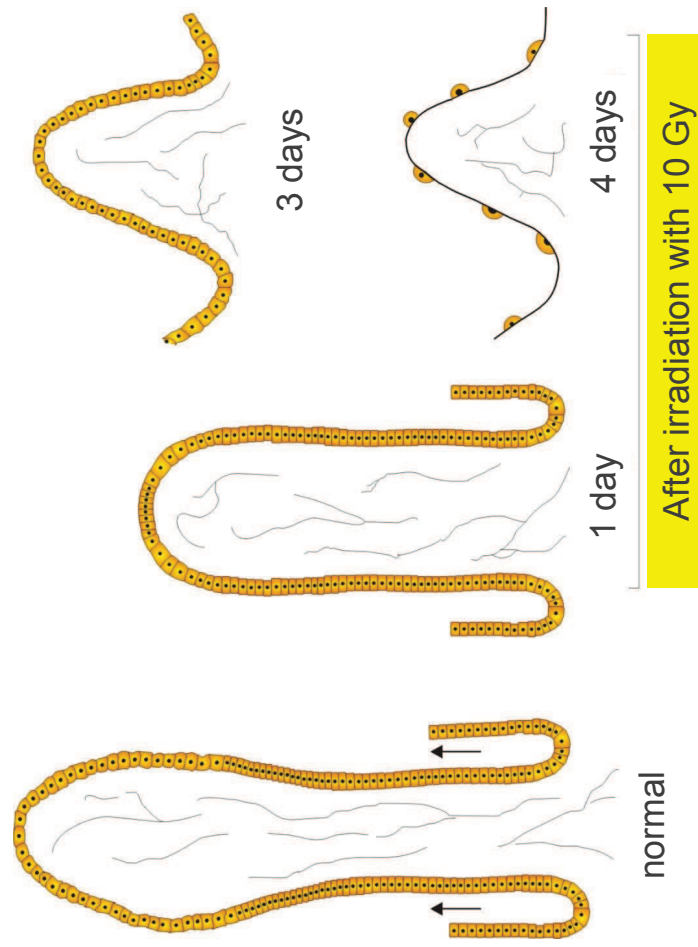
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Villi small intestine



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Acute Radiation Syndrome (ARS) *critical phase: gastrointestinal syndrome*



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Acute Radiation Syndrome (ARS) *critical phase: gastrointestinal syndrome*

- Irradiation inhibits renewal of short-lived cells lining the small intestine
 - mature mucosal cells are progressively shed and are not replaced when radiation kills the stem cells in the crypts
- Damage to the most radiosensitive stem cells of the small intestine can occur for $D > 5 \text{ à } 7 \text{ Gy}$
 - For doses:
 - 5 - 10 Gy: septicemia + dehydration
 - 10 - 15 Gy: denudation mucosa → loss of fluids + electrolytes

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Acute Radiation Syndrome (ARS) *critical phase: cerebrovascular syndrome*

- Death occurs very quickly (within 2 days) when $D > 10 - 15 \text{ Gy}$
- "CV-syndrome":
 - disorientation, impairment of cognitive function
 - loss of muscular coordination (ataxia)
 - convulsive seizures
 - loss of consciousness → coma → death
- Etiology: microvascular damage + cerebral edema (anoxia) + petechial hemorrhages + meningitis
 - massive loss of serum + electrolytes through leakage into extravascular tissues / damage of blood – brain barrier
 - build-up of intracranial pressure

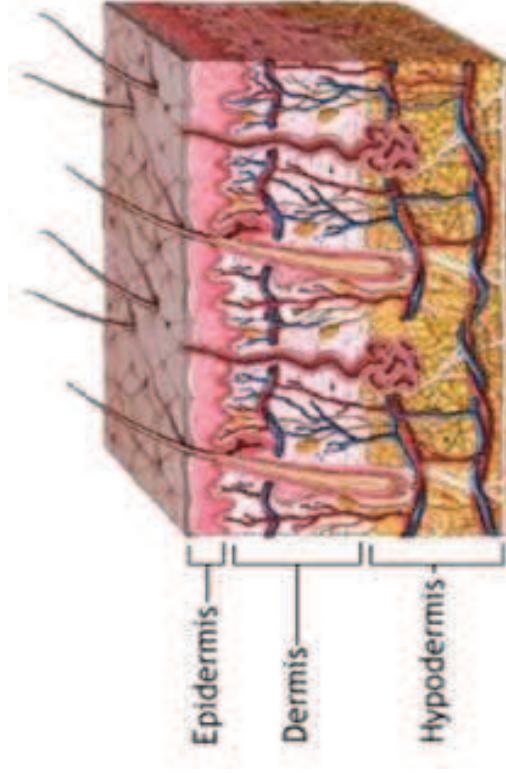
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2. Symptoms of local radiation injury (ARS or partial body irradiation)

- only after exceeding a high dose threshold
→ (serious) injury to the skin

A Functional signs:

- burning sensation
- itching
- electrical discharges
- intense pain
- insensitivity
- ...



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2. Symptoms of local radiation injury (ARS or partial body irradiation)



B Clinical signs:

- erythema: $D > \pm 3$ à 4 Gy (transient)
- epilation: $D > \pm 3$ à 4 Gy
when $D > \pm 7$ Gy: permanent
- 2nd degree burns: $D > \pm 12$ Gy
- 3rd degree burns: $D > \pm 15$ à 20 Gy
- sclerosis tendons: $D > \pm 30$ Gy → functional disorders

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3. Treatment of irradiated persons

- **Hematopoietic syndrome:**
 - > 1 Gy: observation in hospital
 - higher doses:
 - transfusions of granulocytes and platelets
 - multicytokine therapy (G-CSF, GM-CSF, SCF, EPO, TPO,...)
 - antibiotics, anti-fungal medication
 - (B.M.T.)
- **Gastrointestinal syndrome:**
 - cf. hematopoietic syndrome
 - I.V. correction of dehydration and electrolyte imbalance
 - I.V. feeding
 - gut antiseptics, antibiotics
- **Cerebrovascular syndrome:**
 - therapy is conservative / no survival possible...

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3. Treatment of irradiated persons

- **Skin injuries:**
 - conservative...
 - sympathectomy
 - KGF: Keratinocyte Growth Factor
 - acetylsalicylic acid
 - (hyperbaric oxygen therapy)
 - surgical excision and simultaneous wound closure by...
 - skin grafting + mesenchymal stem cell injections around the lesions (+ adipose tissue-derived stem cells?)
 - surgical reconstructions: axial skin flaps from distant tissue (myocutaneous and fasciocutaneous types)
 - amputation of (parts of) limbs

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3. Treatment of irradiated persons

Short term treatment after high local (D > 15 - 20 Gy!)
and high total body doses (D > 2 – 3 Gy) :

→ university hospitals, but preferably:

Hôpital d'Instruction des Armées Percy
Avenue Henri Barbusse, 101
92140 Clamart
France

Tel: +33 1 41 46 60 00

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4. Follow-up after incidental external exposures

- By recognised occupational physician or by the FBZ/FMP (after high dose exposures **in collaboration with specialised clinics**)
 - **deterministic long term effects:**
 - cataract (H&N: D > ± 0,4 Gy!!)
 - ischaemic heart disease (H&N: + 14 %/Gy)
 - stroke (H&N: + 9 %/Gy)
 - infections / immunosuppression
 - infertility
 - poor wound healing / delayed ulcers / keratoses / telangiectasias / pigment changes / fibrosis / inflammatory waves
 - intestinal stenosis
 - organ dysfunction / fibrosis / atrophy
 - sclerosis of (flexor) tendons
 - necrosis

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4. Follow-up after incidental external exposures

For deterministic long term effects: Tolerance doses are strongly **influenced by the irradiated tissue or organ volume !**

Organ or tissue	Irradiated volume			Long term effect
	1/3	2/3	3/3	
Lung	45	30	17,5	fibrosis
Liver	50	35	30	loss of function
Kidney	50	30	23	sclerosis capillaries and glomeruli, atrophy, fibrosis
Tolerance doses TD (5/5) in Gy for different organs after radiotherapeutic irradiation with low LET radiation (Emami-1991)				

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4. Follow-up after incidental external exposures

- **stochastic effects:**

Tissue/organ	Average cancer incidence risk (ERR at 1 Sv – LSS) all ages	
	males	females
Bone marrow (leukemia)	4,66	5,05
Female breast	-	1,49
Skin (non melanoma)	1,27	1,37
Thyroid	0,78	1,89
Urinary bladder	0,63	1,74
Lung	0,32	1,48
Colon	0,85	0,42
Oesophagus	0,48	0,70
Stomach	0,26	0,51
Epidemiological studies of radiation and cancer (UNSCEAR 2006)		

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