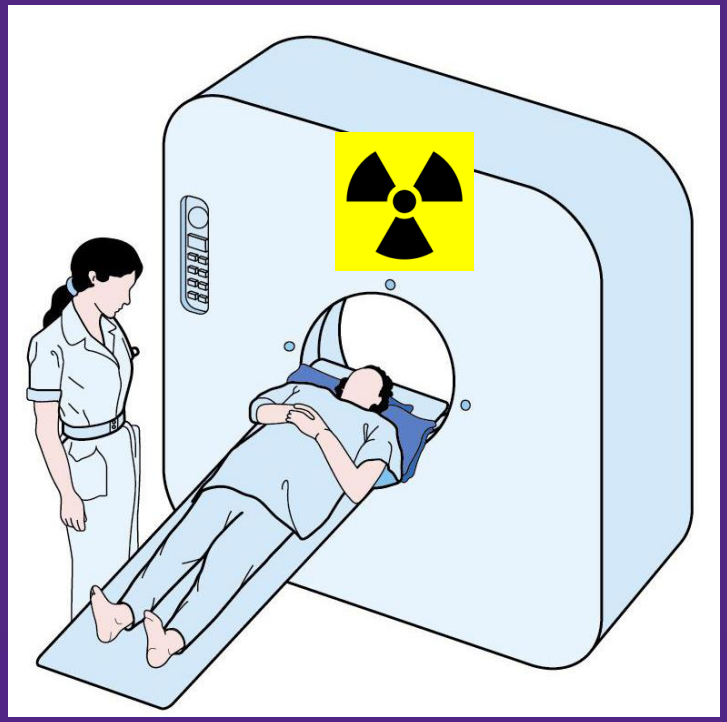
# "The Good Side of Radiation: Medical Applications"

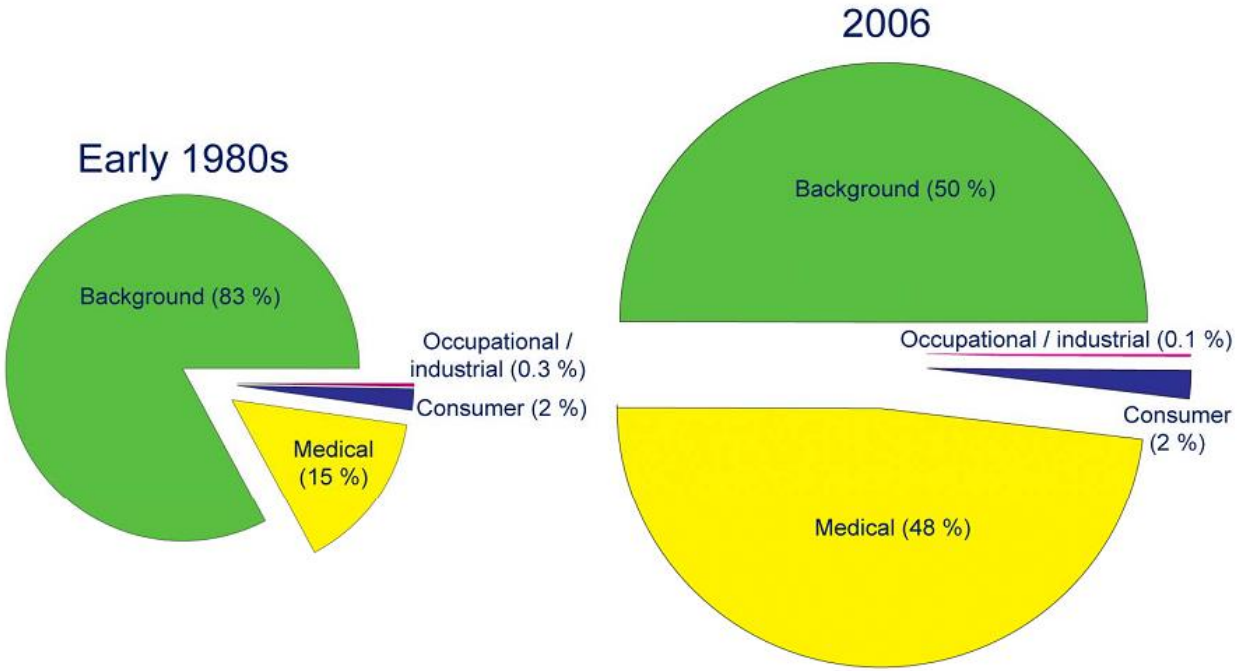


J. Battista, Ph.D.
Medical Physicist
London Regional Cancer Program LHSC

# Role of Medical Physicists

- Diagnostic Medicine
  - Imaging
- Therapeutic Medicine
  - radiation, lasers, heat, cold
- Biophysics
  - Radiation biology
- Radiation Protection
  - Radiation measurements
  - Room designs

# NCRP Report No. 160, *Ionizing Radiation Exposure of the Population of the United States*




| | Early 1980s | 2006 |
|---|---|---|
| Collective effective dose (person-Sv) | 835,000 | 1,870,000 |
| Effective dose per individual in the U.S. population (mSv) | 3.6 | 6.2 |

USA

# Outline

- What is Radiation?
- How does it injure cells, tissue, organs ?
- What do we know about its biological effects?
- What do we know about its risks?
- How is radiation used in medicine?
- Question and Answer Period
- Demonstration of CT scanning

# Radiophobia

The **Ugly**

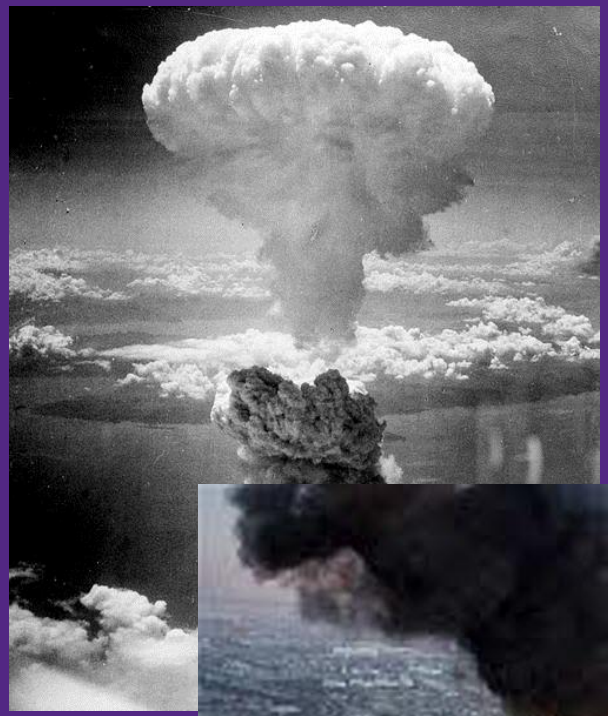
Warfare & Terrorism
Radiation Poisoning

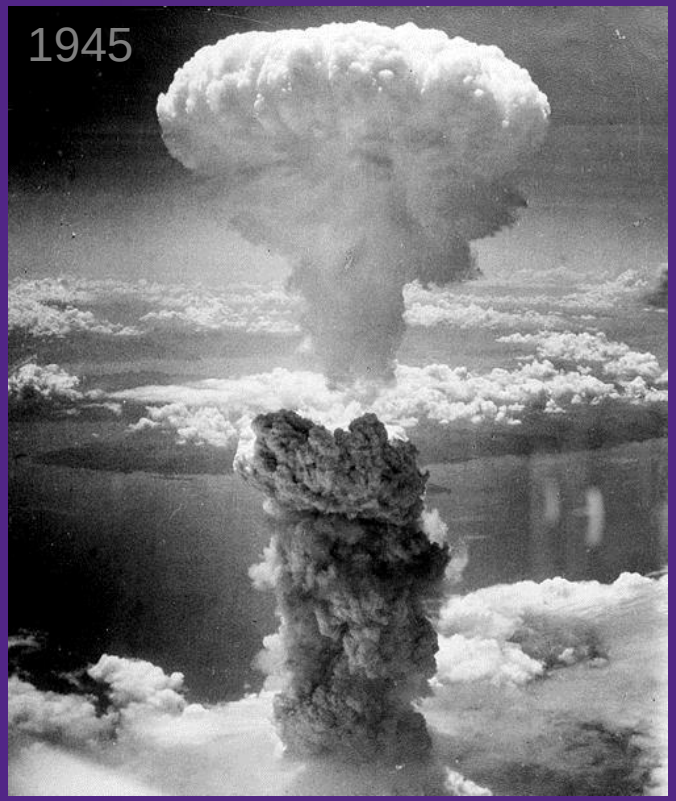
The **Bad**

Nuclear Accidents

The **Good**

Diagnostic imaging
Radiation therapy



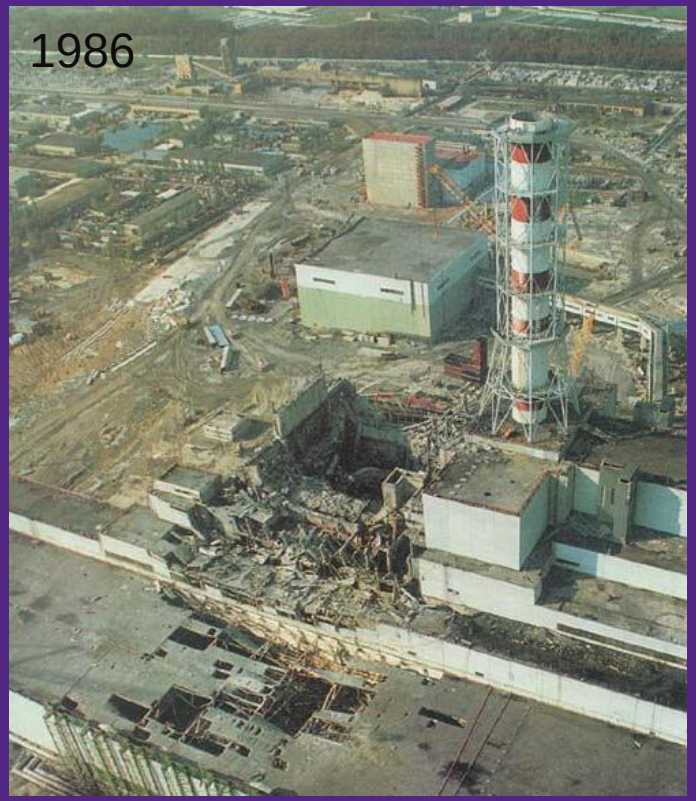



Hiroshima/Nagasaki

200,000 immediate deaths

40,0000 from radiation

120,000 still under study




Chernobyl Reactor

28 deaths from radiation

4000 deaths expected

(1800 thyroid cancer)

# Radiophilia

The **Ugly**

- Warfare & Terrorism
- Radiation Poisoning

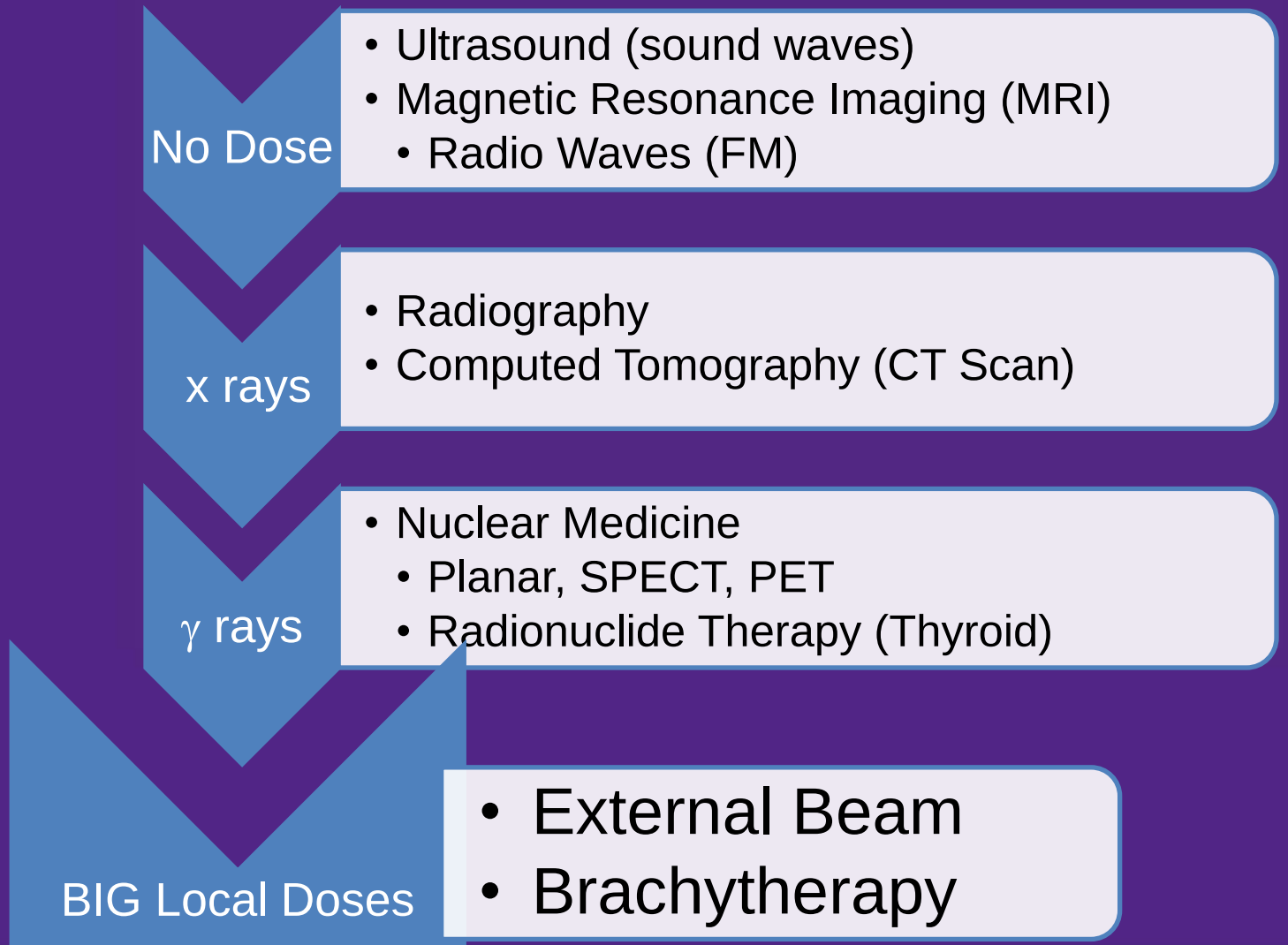
The **Bad**

- Nuclear Accidents

The **Good**

- Diagnostic imaging
- Radiation therapy

# Radiation in Medicine



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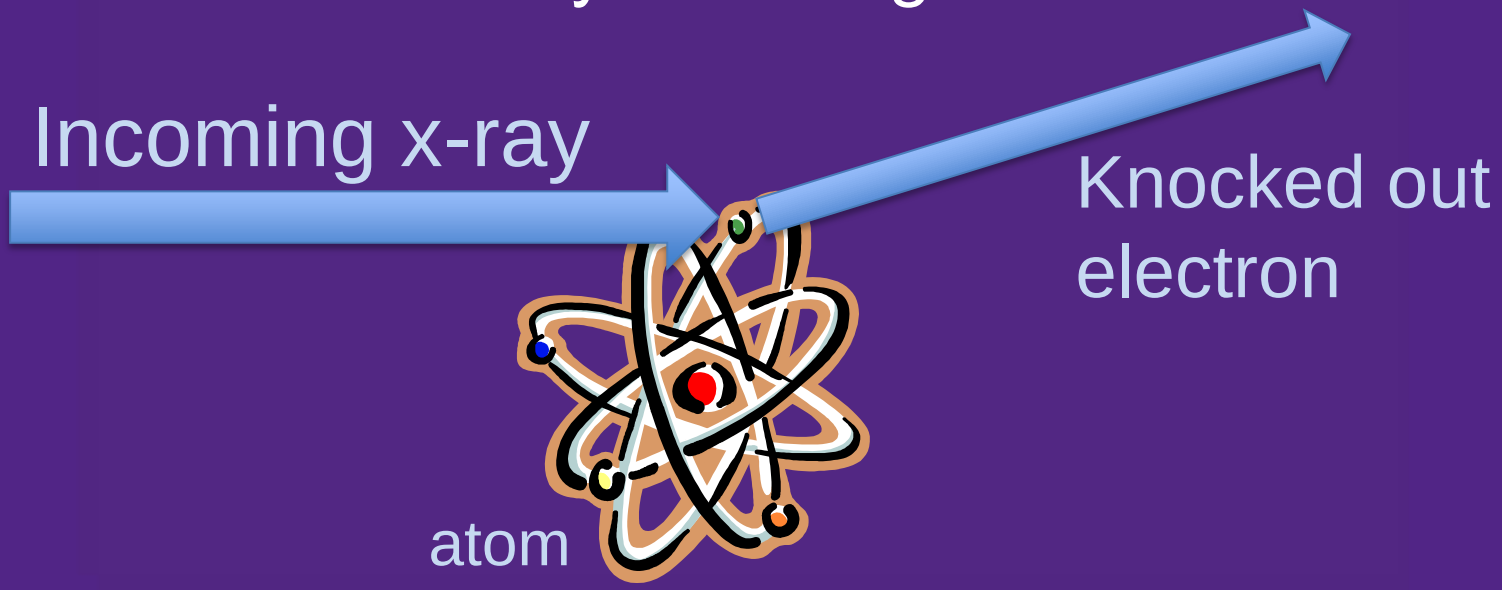
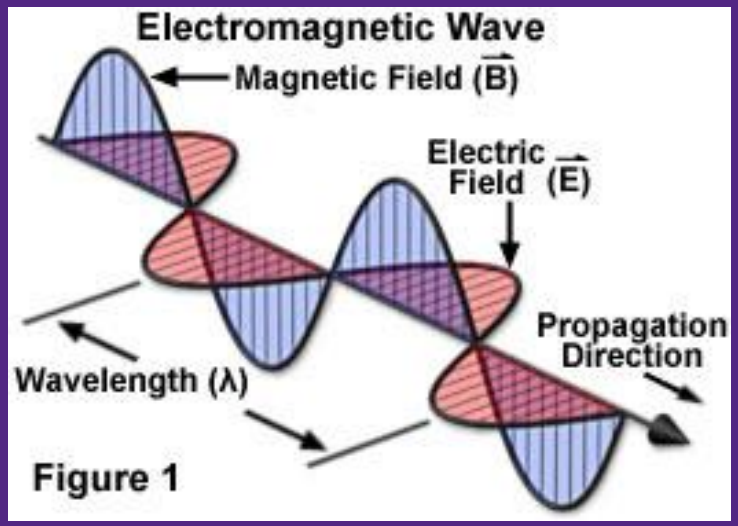
# Ionizing Radiation

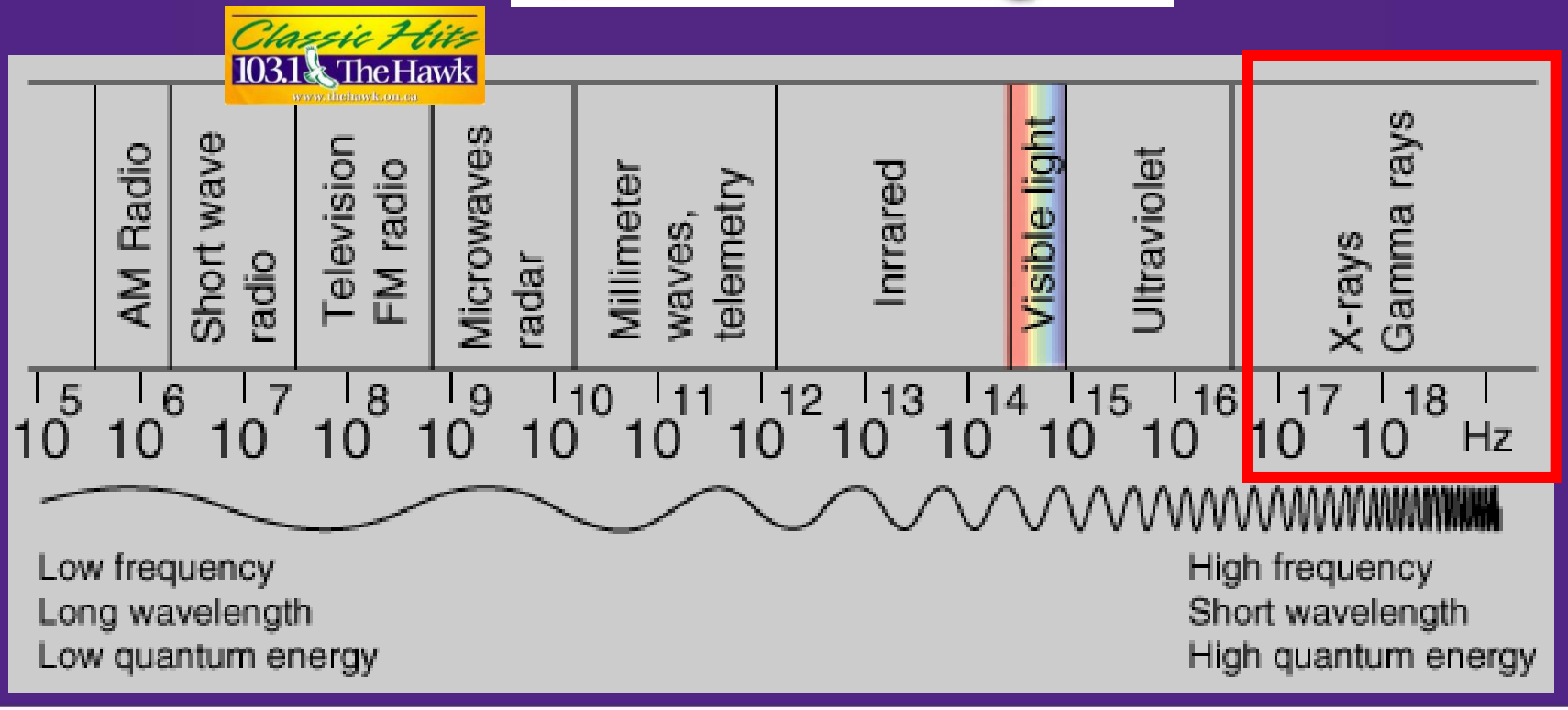
- "Ionizes" atoms by liberating orbital electrons




- High energy x-rays can do this to atoms

# X-rays



# What is this Thing Called Dose?

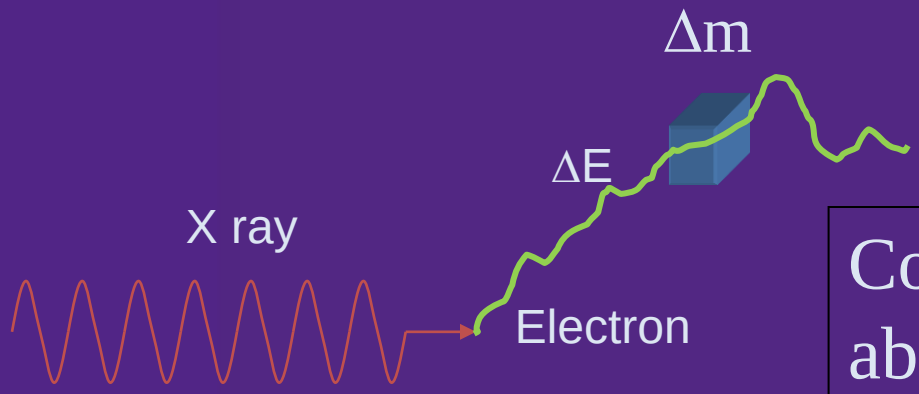
*When you can measure what you are speaking about, and express it in numbers, you know something about it;*

*but when you cannot measure it - when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind."*

*Lord Kelvin (1824-1907)*

# Radiation Dose

**a measure of concentration of energy locally absorbed in any absorber from any ionizing radiation**




Concentration of energy absorbed by a tissue sample

**D = ΔE (absorbed)/Δm**

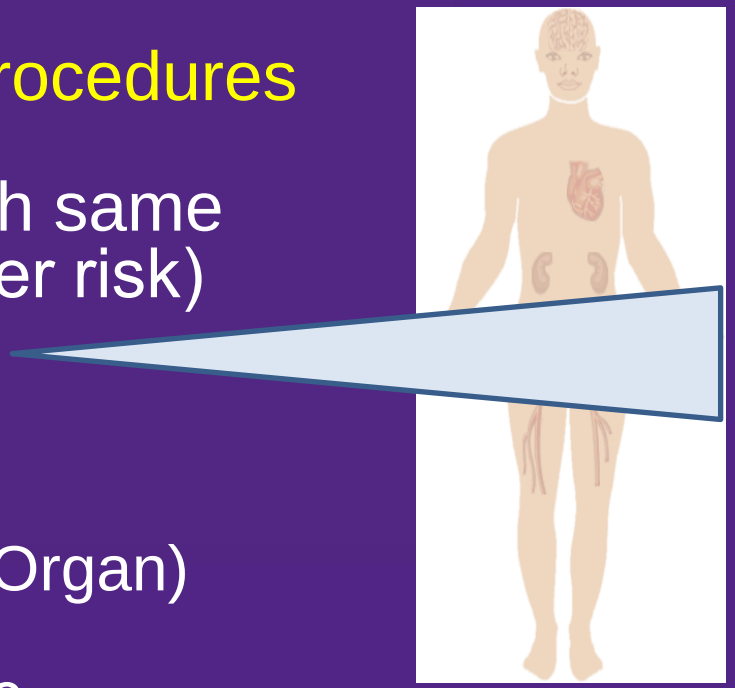
Unit is Joules/kg= Gray

# Effective Dose (Sv)

- For partial body exposures
- Useful to compare medical procedures
- Uniform whole body dose with same ‘detrimental effect’ (e.g. cancer risk)
- $E = \Sigma$ ( Dose to Organ

  x Tissue Weighting per Organ)

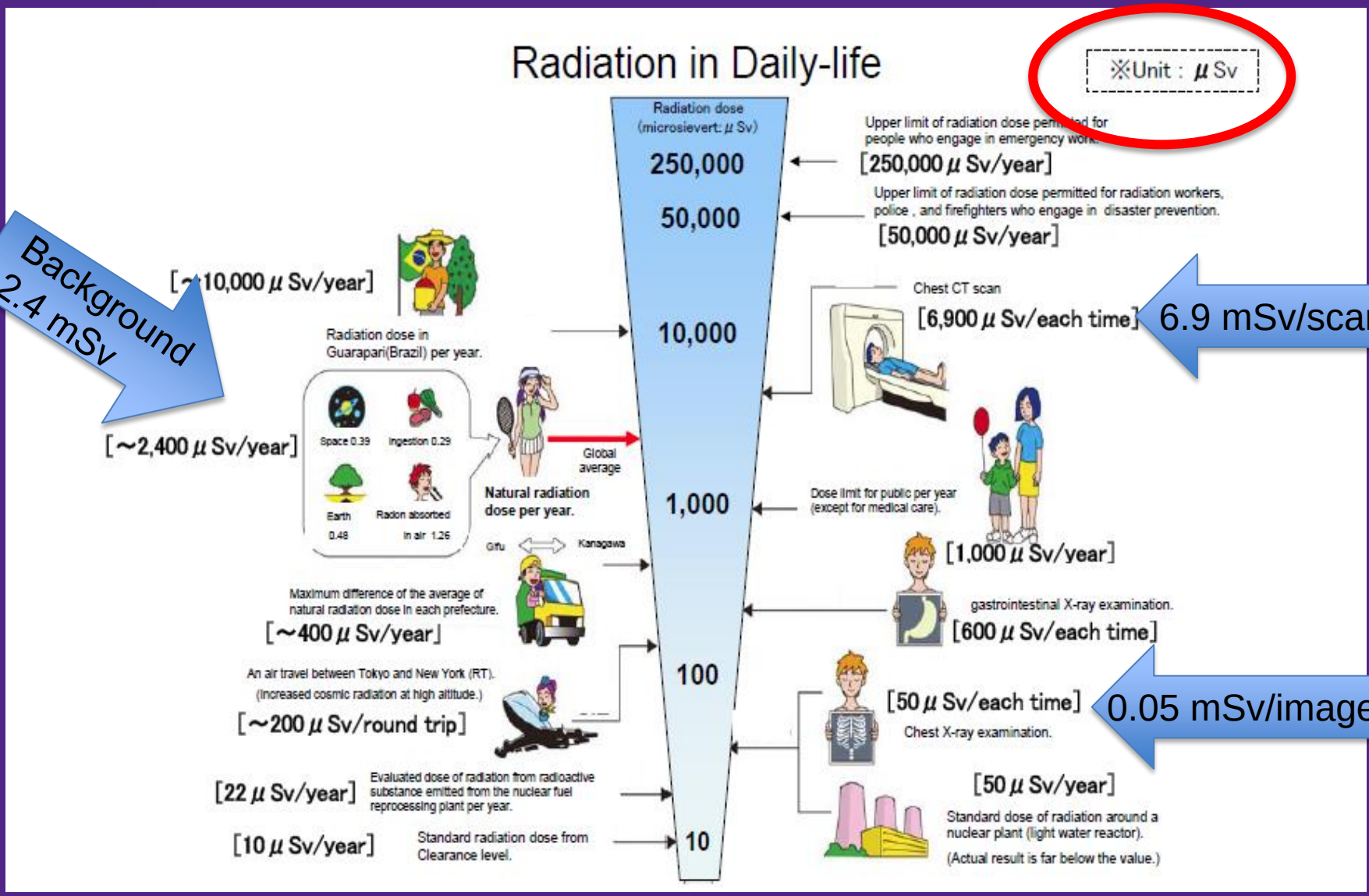
  $= D_1W_1 + D_2W_2 + D_3W_3$ …etc…



# We can measure Dose

**Optically Stimulated Luminescence Dosimeter in a "phantom"**

# Effective Dose Spectrum (Micro-Sv)




Japan

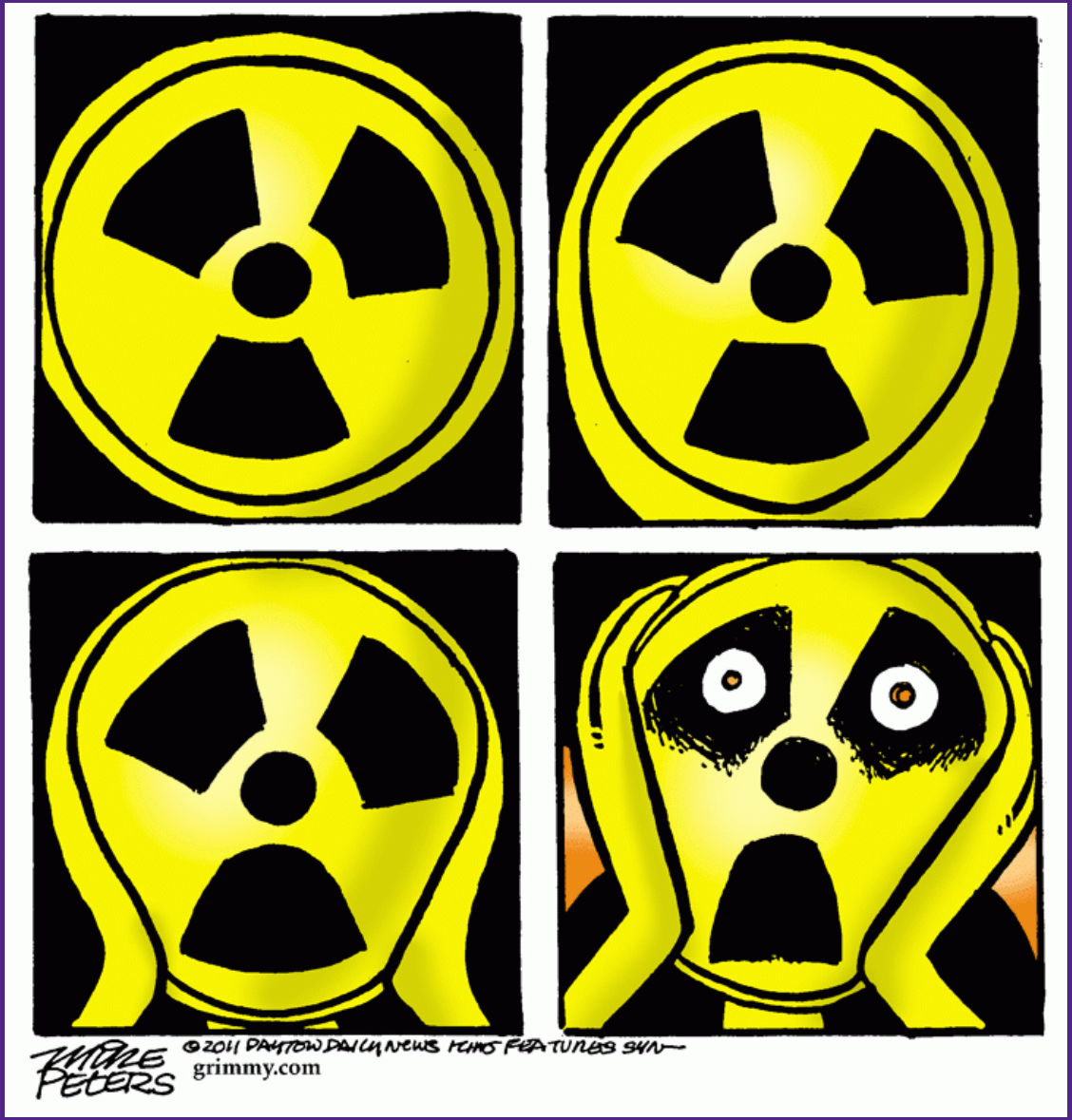
As of 19:00 March 20, 2011
Ministry of Education, Culture, Sports, Science and Technology (MEXT)

# Effective Doses (milli-Sv)

- Typical Natural Radiation near Earth — 3.0 mSv/yr
  - Airport Security Scan — +0.00005 mSv
  - Passenger Flight (transatlantic) — + 0.05 mSv
  - Flight Crew — + 5 mSv/year
- Medical Diagnosis
  - Dental x-rays — 0.005 mSv
  - Chest x-rays — 0.05 mSv
  - GI x-ray study — 1 to 8 mSv
  - CT scan procedure — 1 to 10 mSv
  - Cardiac Fluoroscopy — > 10 mSv
- A-Bomb survivors — < 2,000 mSv
- Lethal Dose (whole body acute) — 4,000 mSv
- Radiotherapy Effective Dose — 7,000 mSv (assuming W = 0.1)

1 mSv

10 mSv




100 mSv

1000 mSv

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# Biological Damage

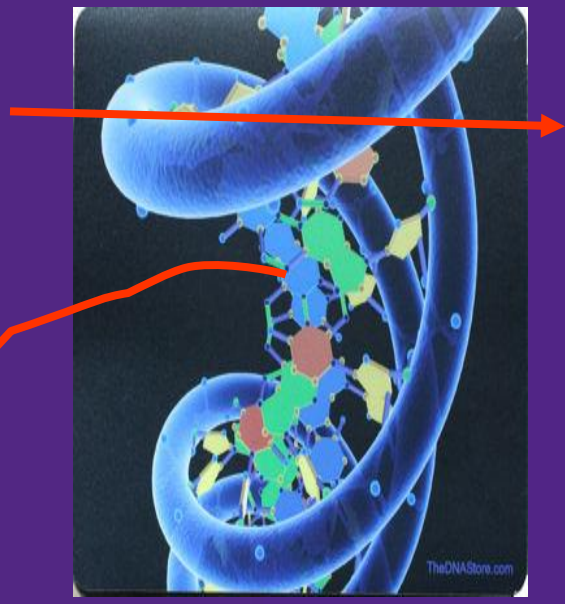
Electrons “hit” DNA

Electrons hit water

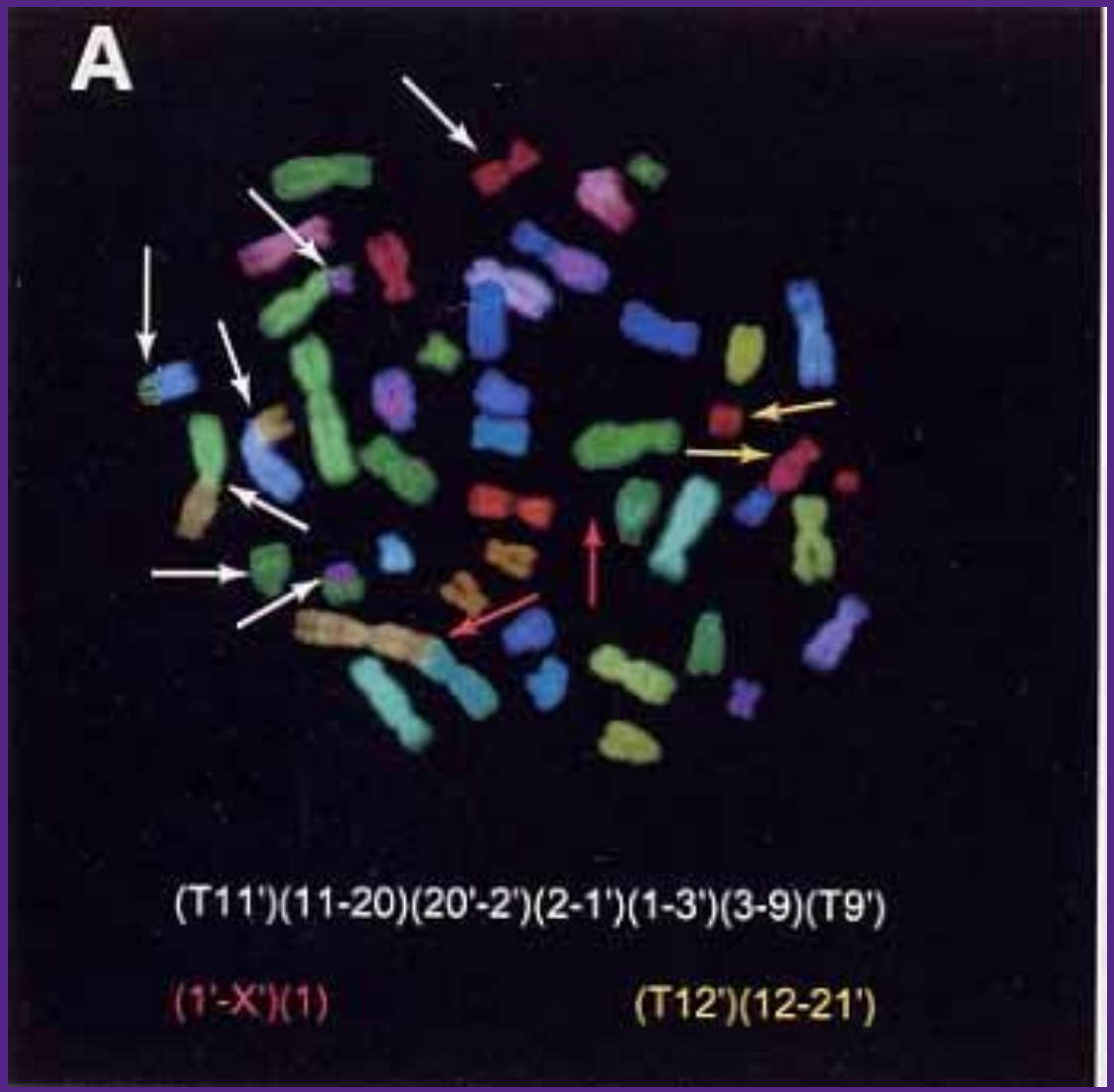
Chemical Radicals

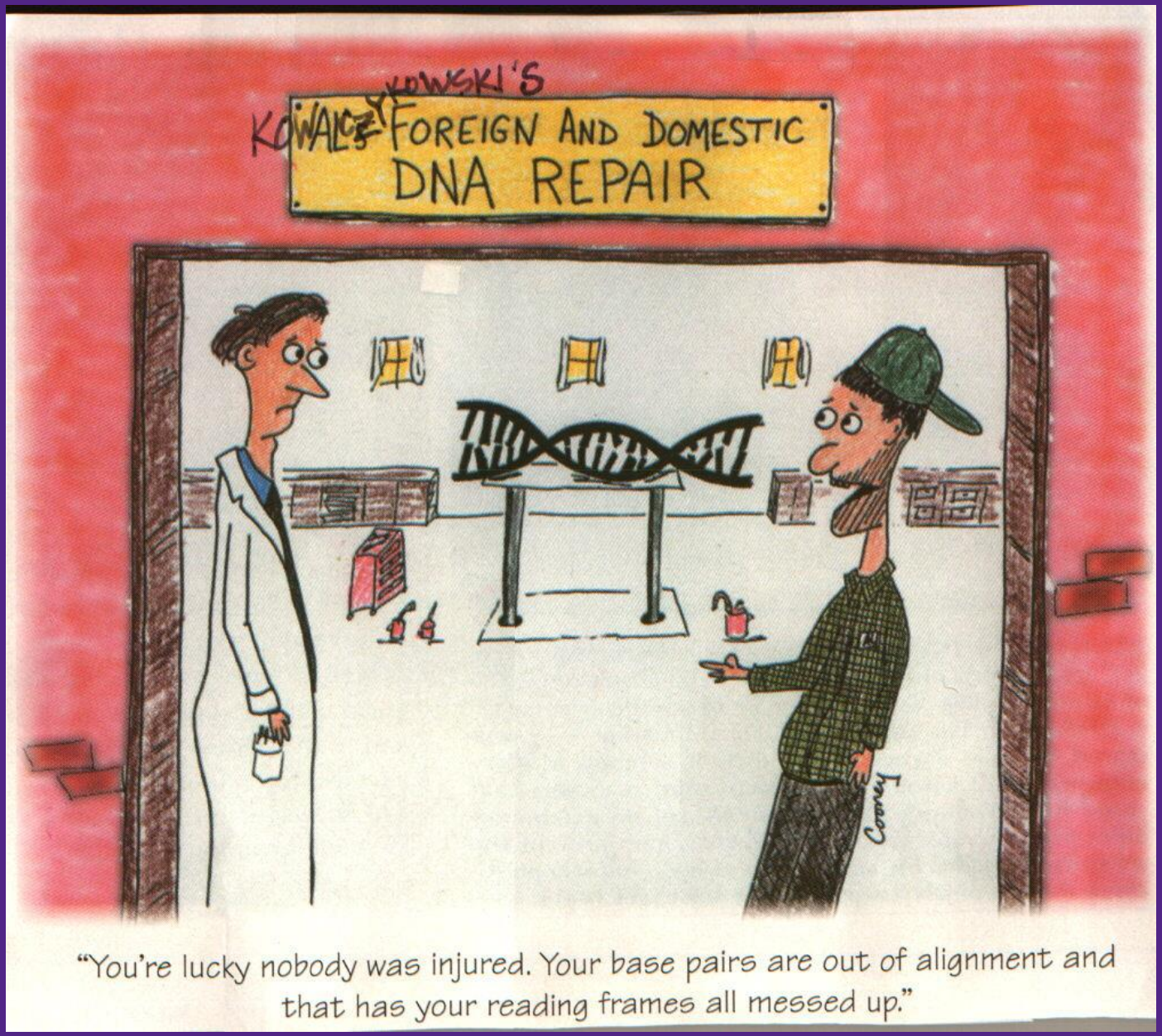
DNA Damage

Chromosome abberations




# Chromosome Aberrations in Irradiated Cells



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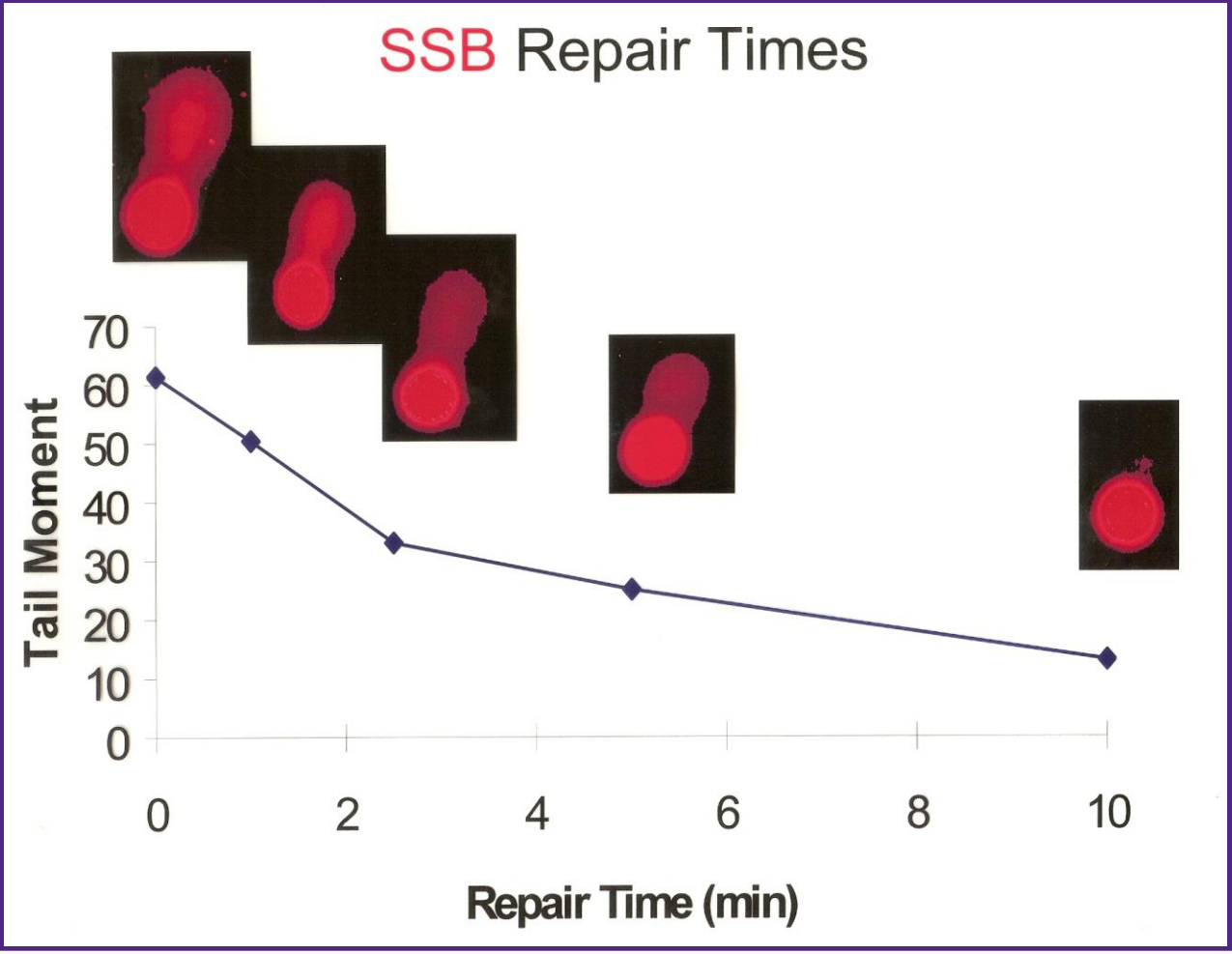
http://microbiology.ucdavis.edu/kowalczykowski/genetic%20recomb.htm

Western

# DNA Repairs itself !
## (if damage is limited)

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# DNA is Naturally Damaged

DNA damage, due to environmental factors and normal processes inside the cell, occurs at a rate of 1,000 to 1,000,000 molecular DNA lesions per cell per day !

BUT this constitutes potential turnover of a very small fraction of the human genome's (Billions of DNA bases)

Un-repaired or mis-repaired DNA sites:

- In critical genes (e.g. oncogenes), can appreciably increase the likelihood of tumour formation
- In other genes, can impede a cell's ability to produce normal proteins and reduce cell functions.

- A “perfect storm” of accumulated lesions triggers cancer

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200,000 immediate deaths
40,0000 from radiation
200,000 still under study



## RERF A-Bomb Cohorts

| Cohort | Size |
|---|---|
| **Life Span Study** | **120,000**<br><br>Allows an estimate of cancer incidence and mortality |
| **In-Utero Cohort** | **3,600**<br><br>Allows estimates of mental retardation, microcephaly, etc. |
| **Children of exposed individuals** | **77,000**<br><br>Allows estimate of heritable effects |

# Atomic Bomb Survivors Study

**TABLE 1**
**General Summary of the 1958–1994 Cancer Incidence Data**

| Colon dose, Sv | Subjects | Solid cancers | Estimated excess[a] |
|---|---|---|---|
| beyond >3,000 m | 23,493 | 3,230 | 0 |
| <0.005 Sv within <3,000 m | 10,159 | 1,301 | 1 |
| 0.005–0.1 | 30,524 | 4,119 | 77 |
| 0.1–0.2 | 4,775 | 739 | 60 |
| 0.2–0.5 | 5,862 | 982 | 164 |
| 0.5–1 | 3,048 | 582 | 177 |
| 1–2 | 1,570 | 376 | 165 |
| >2 | 470 | 126 | 80 |

# Cancer Mortality Risk Factors

- From A-Bomb survivors
- Lifetime risk of cancer mortality is:

**5 % per Sv of effective dose**

**0.005% per mSv**

**0.000005% per uSv**

NOTE : Natural lifetime mortality probability
0.25 % per year (Ontario)

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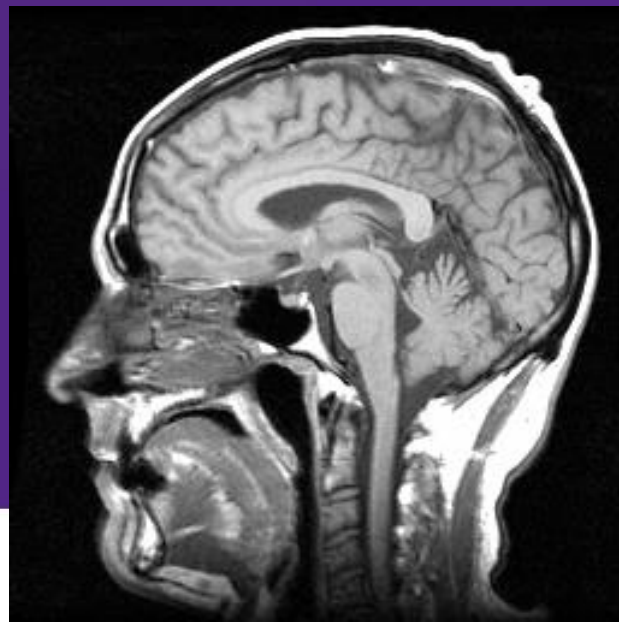
# Medical Imaging with Radiation

## Ultrasound
"Echos"

## Radiography and CT scans
"Shadows"

## MRI
"Music"



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MEDICINE & DENTISTRY

# CT is 3D x ray Vision !


***Fig. 1.7*** *The three images demonstrate a haemoperitoneum, shattered right kidney and a lacerated spleen in axial* ***(A)****, sagittal* ***(B)*** *and coronal* ***(C)*** *planes.*

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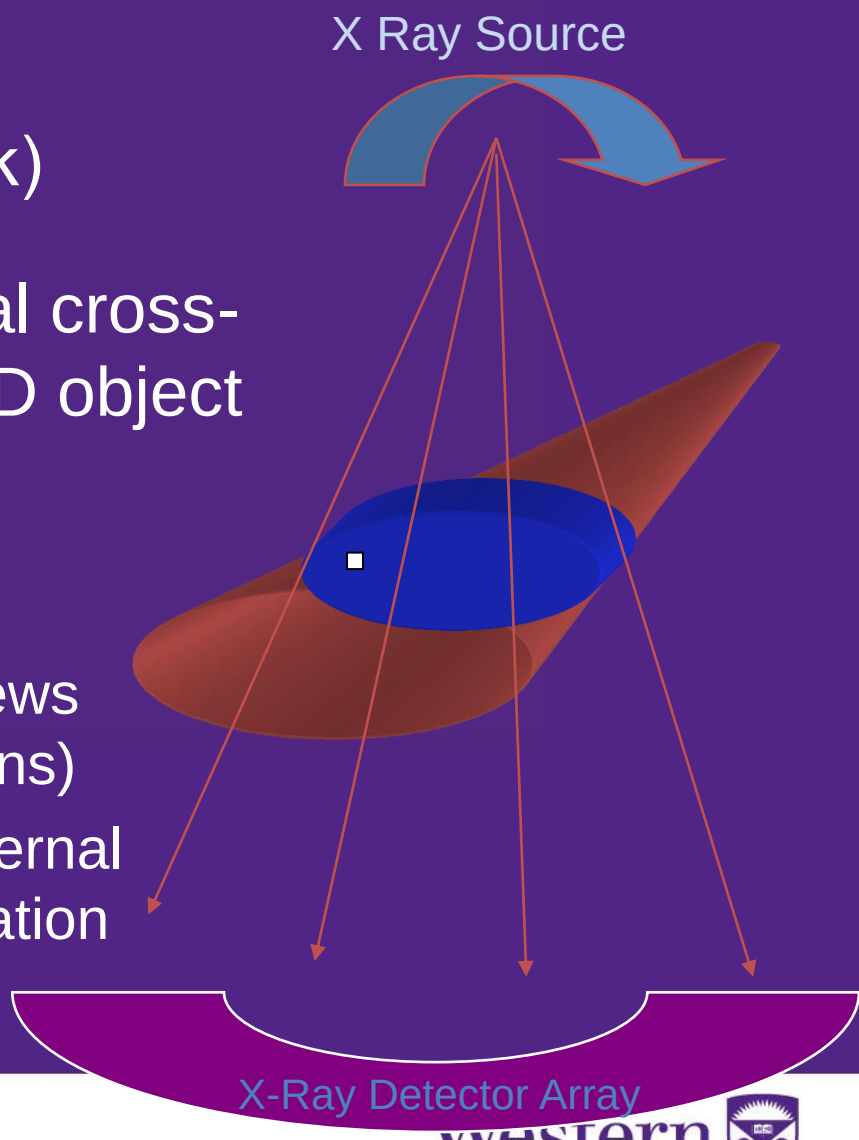
http://www.fleshandbones.com/readingroom/pdf/940.pdf

Western

# Computed Tomography (CT)

- *Tomos* means “slice” (Greek)
- A method of imaging internal cross-sectional slices through a 3D object
- Transmission CT Problem
  - **Given**: multiple transmission views through the object (i.e. projections)
  - **Required**: to reconstruct the internal distribution of local x ray attenuation



Nobel Award Address

# Early two-dimensional reconstruction and recent topics stemming from it

A. M. Cormack

*Department of Physics, Tufts University, Medford, Massachusetts 02155*

Alth. fund research, Allan Cormack
Edmonton 3 Sept '81

In 1955 I was a Lecturer in Physics at the University of Cape Town when the Hospital Physicist at the Groote Schuur Hospital resigned. South African law required that a properly qualified physicist supervise the use of any radioactive isotopes and since I was the only nuclear physicist in Cape Town, I was asked to spend 1½ days a week at the hospital attending to the use of isotopes, and I did so for the first half of 1956. I was placed in the Radiology Department under Dr. J. Muir Grieve, and in the course of my work I observed the planning of radiotherapy treatments. A girl would superpose

had to be found by measurements made external to the body. It soon occurred to me that this information would be useful for diagnostic purposes and would constitute a tomogram or series of tomograms, though I did not learn the word "to-

mogr

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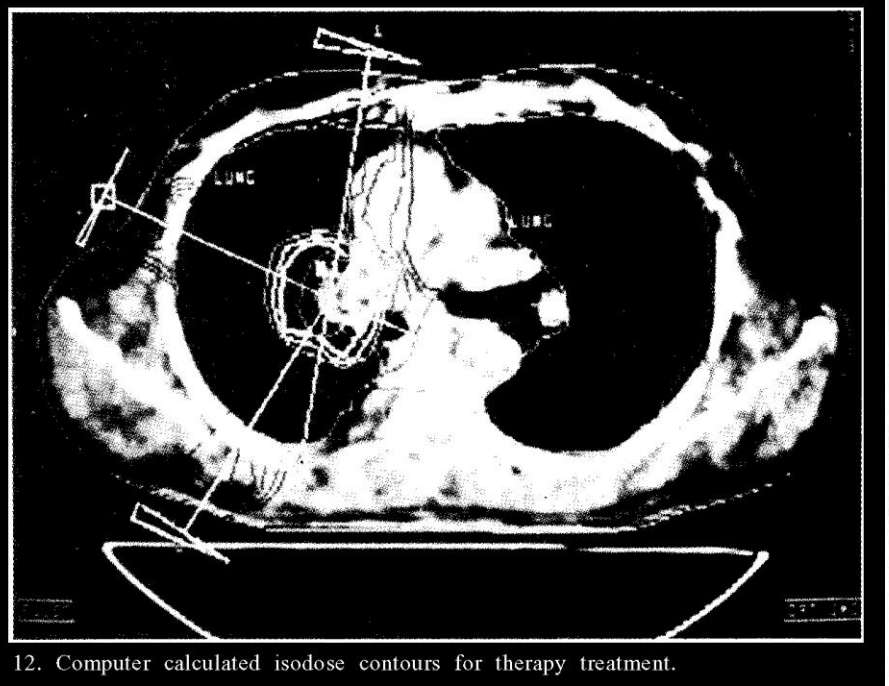
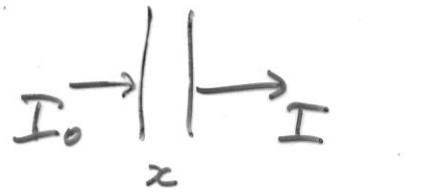
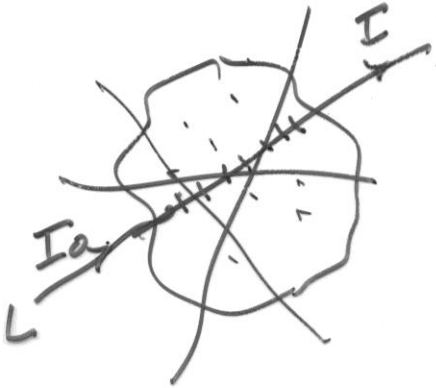


Fig. 12. Computer calculated isodose contours for therapy treatment.




$$I = I_0 e^{-\mu x}$$



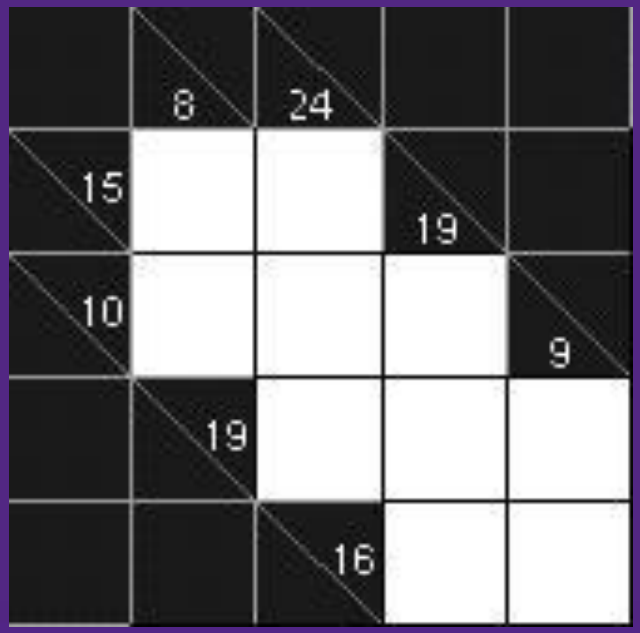

$$I = I_0 e^{-\int_L \mu\, dx}$$

$$\ln\left(\frac{I_0}{I}\right) = \int_L \mu\, dx$$

$$g_L = \int_L \mu\, dx.$$


3 DIMENSIONAL

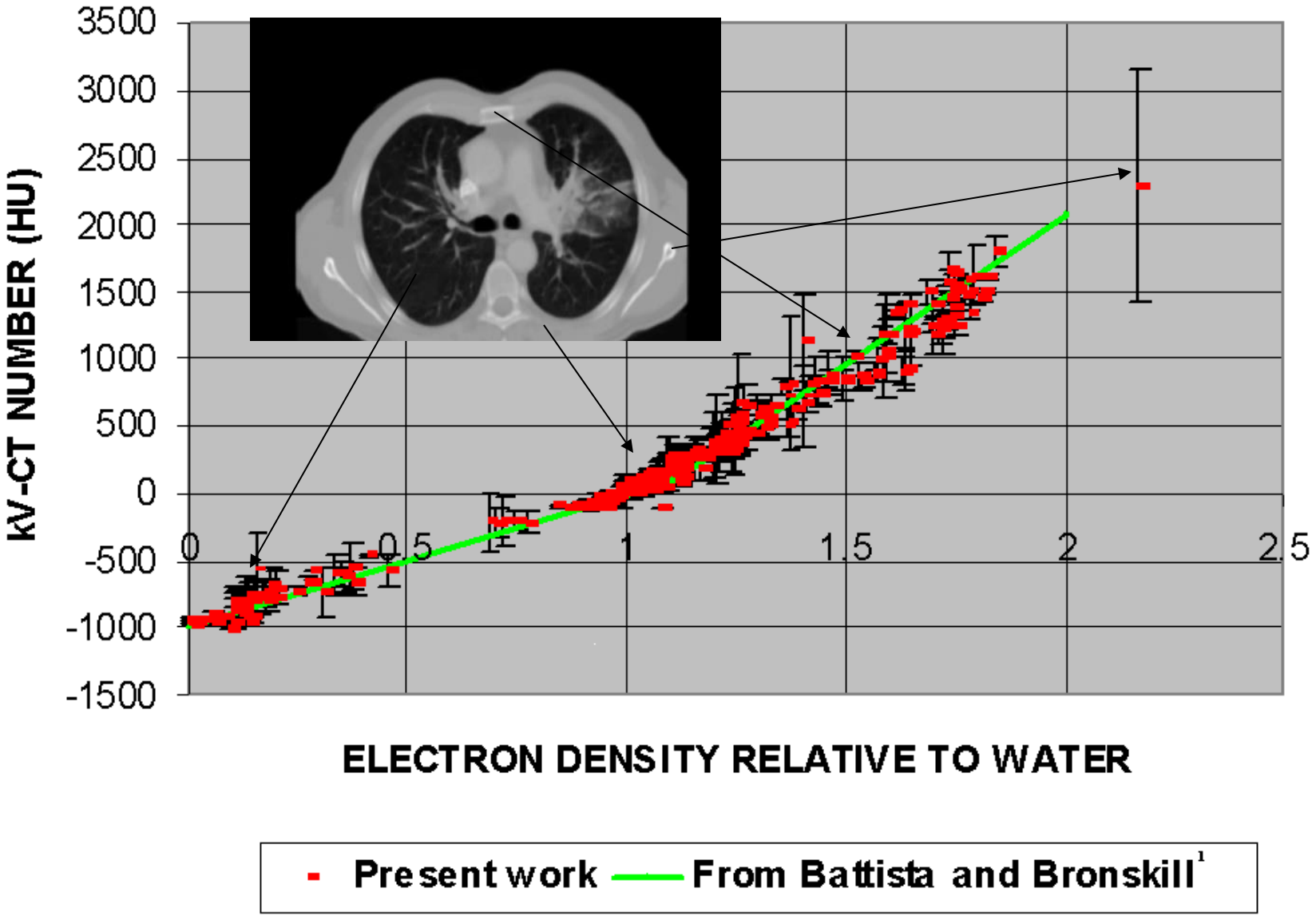
# Kakuro.com




**Rules:**

**The clues for ACROSS and DOWN numbers is the sum of digits.**
**Only the digits 1-9 can be used (no repeats).**

# CT – measures tissue density



# Raise a Drink to CT



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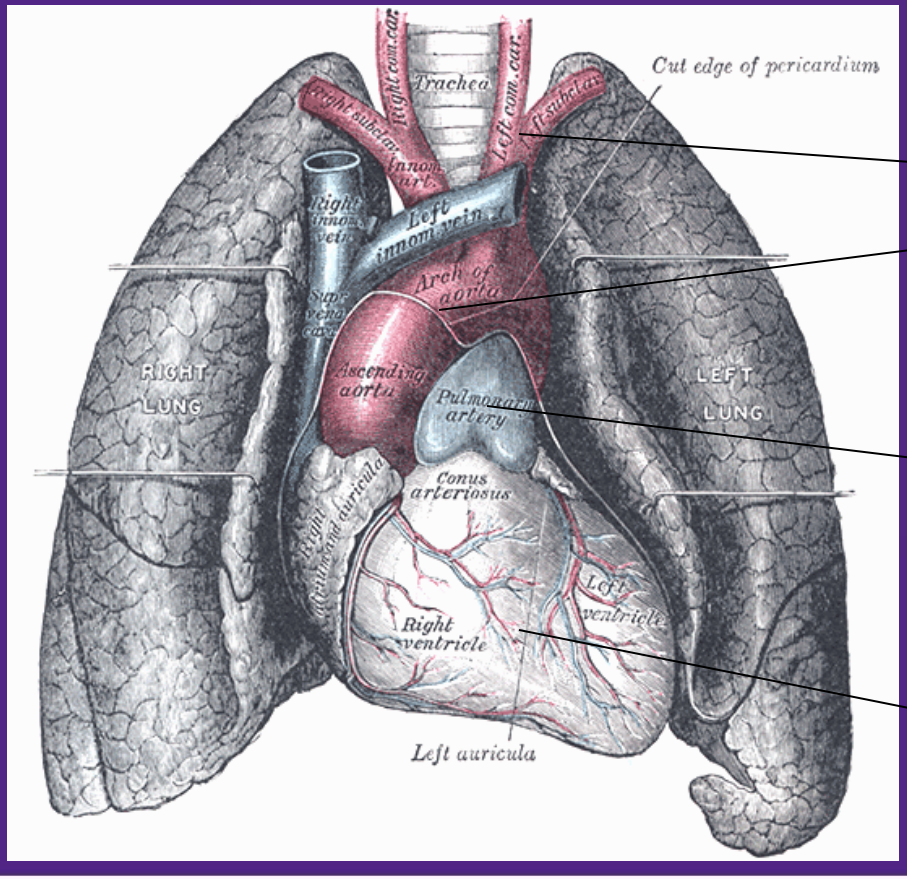
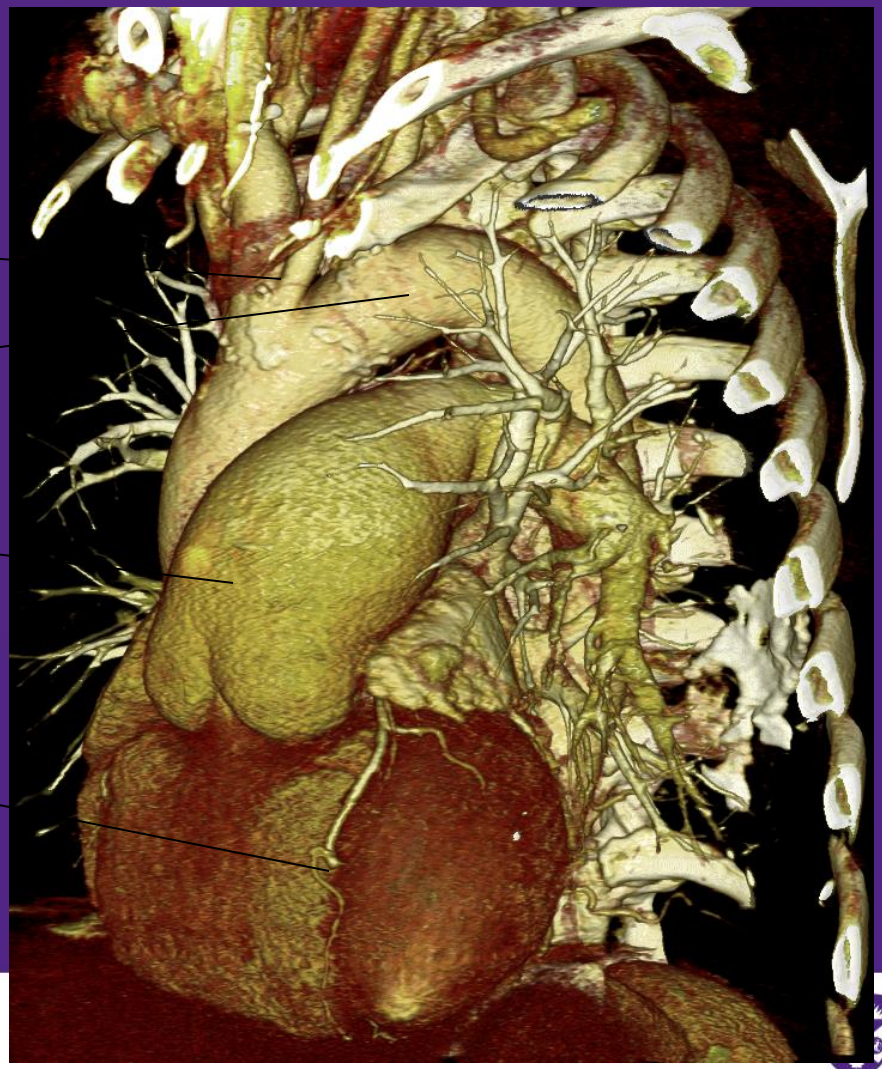
Western

Ian Cunningham & J. Battista 1990

# Cardiac CT Imaging

Coronary study in 5 heart beats



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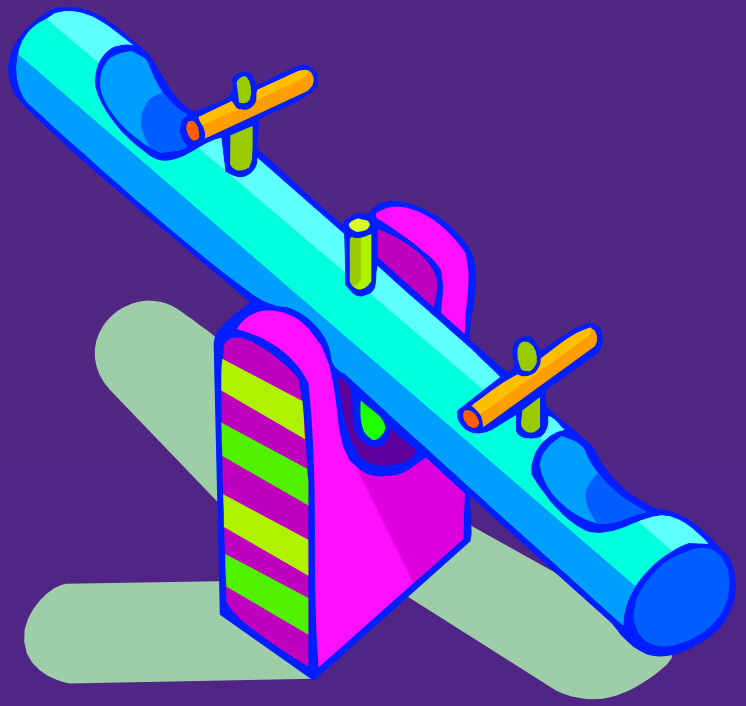
# Effective Doses from Diagnostic Radiology

| Procedure | Typical Effective Dose (mSv) | Equivalent # of Chest x ray | Equivalent Background Radiation (@3mSv/yr) | |
|---|---|---|---|---|
| Chest x ray | 0.02 | 1 | 2.4 days | |
| Barium x ray | 7.0 | 350 | 2.3 yrs | |
| CT Scan head | 2.0 | 100 | 243 days | |
| CT Scan Abdomen | 10.0 | 500 | 3.3 yrs | |
| | | | | |


# Compromise

More Dose increases cancer risk



Less Dose jeapardizes diagnosis – also very risky !

www.pedrad.org/associations/5364/ig/

ell WebAc... | Google | 2011 MBP Graduate A... | The 99 Percent - It's n... | Buzz Blog: Looking int... | AAPM/COMP DeskCAT | Jerry Battista | Scholar | OWL : Gateway : Wel... | University of Western

Home :: Campaign Overview :: The Alliance :: Conferences :: Contact :: Translate  enter keyword or search term

image gently®

# The Alliance for Radiation Safety in Pediatric Imaging

Test Procedures | In The News | Parent | Radiologic Technologist | Medical Physicist | Radiologist | Referring Physician | Partners in Industry | Global Resources | FAQs

***image gently*** when we care for kids! The ***image gently*** Campaign is an initiative of the Alliance for Radiation Safety in Pediatric Imaging. The campaign goal is to change practice by increasing awareness of the opportunities to promote radiation protection in the imaging of children.

## Image Gently Impact

The image gently campaign launched 1/22/08. This is a snapshot of what has happened since:

18,180 medical professionals have taken the pledge

This website has been visited 391,142 times

The CT protocol has been downloaded over 26,425 times


*Click here to take the image gently pledge!*

## Image Gently at the FDA

On July 16, 2012, Image Gently representatives attended the FDA Public Workshop: Device Improvements for Pediatric X-ray Imaging. Use this link for transcripts of this very important meeting.

Back to Basics | IG at the FDA | IAEA Video | Posters | TO PARENTS

## Recent News

NCRP Report 172 Available

*News from Image Wisely*

http://www.washingtonpost.com/loca
s-ledley-physicist-who-inv...

Visit our website to learn how radiology organizations are responding to the Lan...

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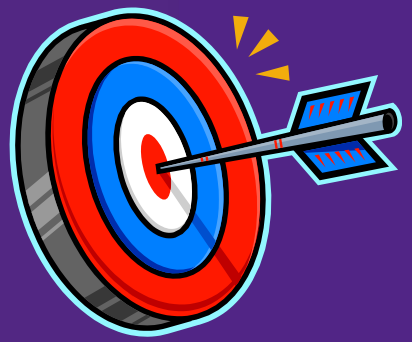
Western

# Radiation Therapy of Cancer

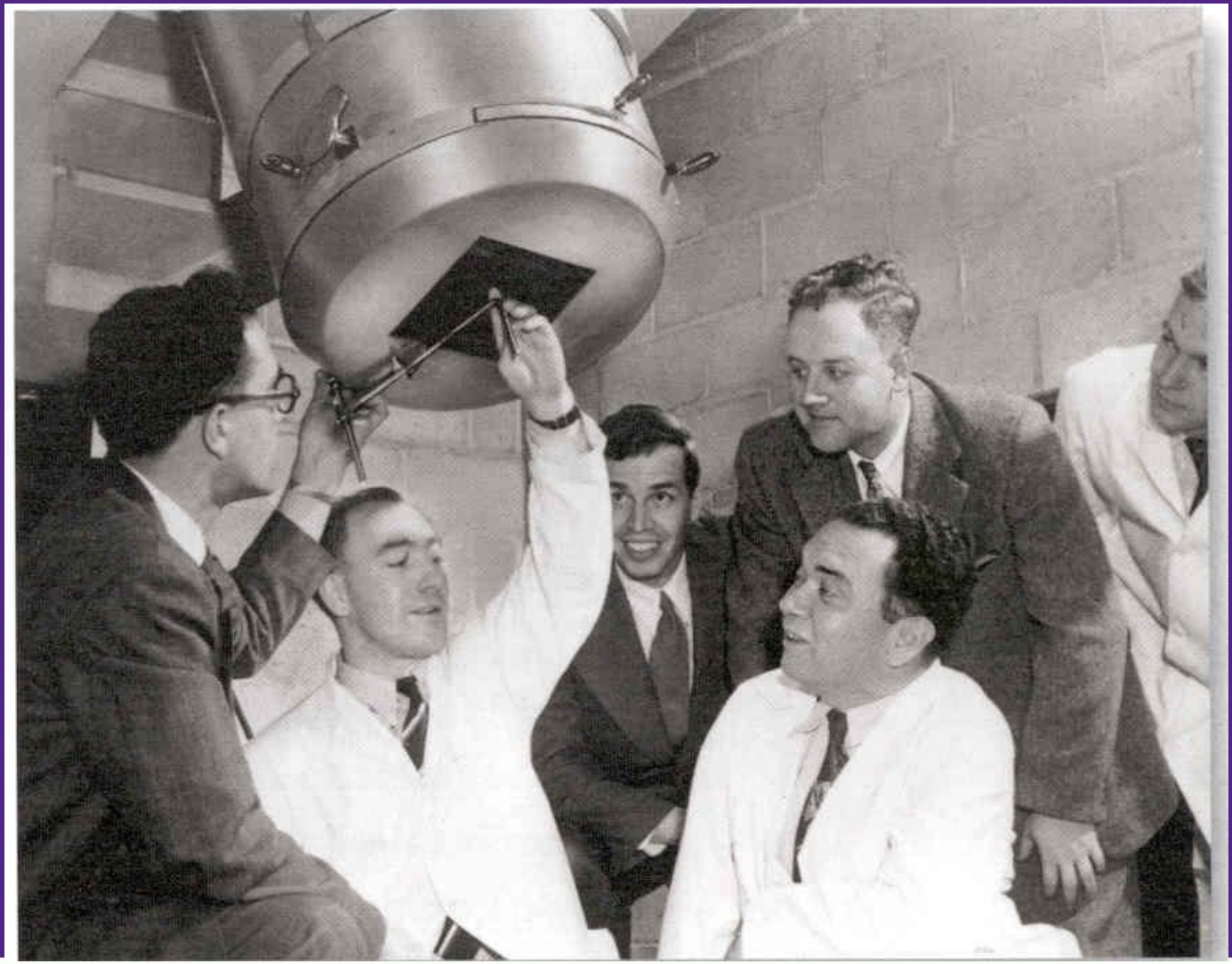
- Ultra-High Dose to the tumour
  - Cell killing to < 1 cell
  - Increases odds of tumour control



- Very Low Dose elsewhere
  - Keep healthy cells as much as possible to avoid ‘organ’ dysfunction
  - Reduce Side-Effects

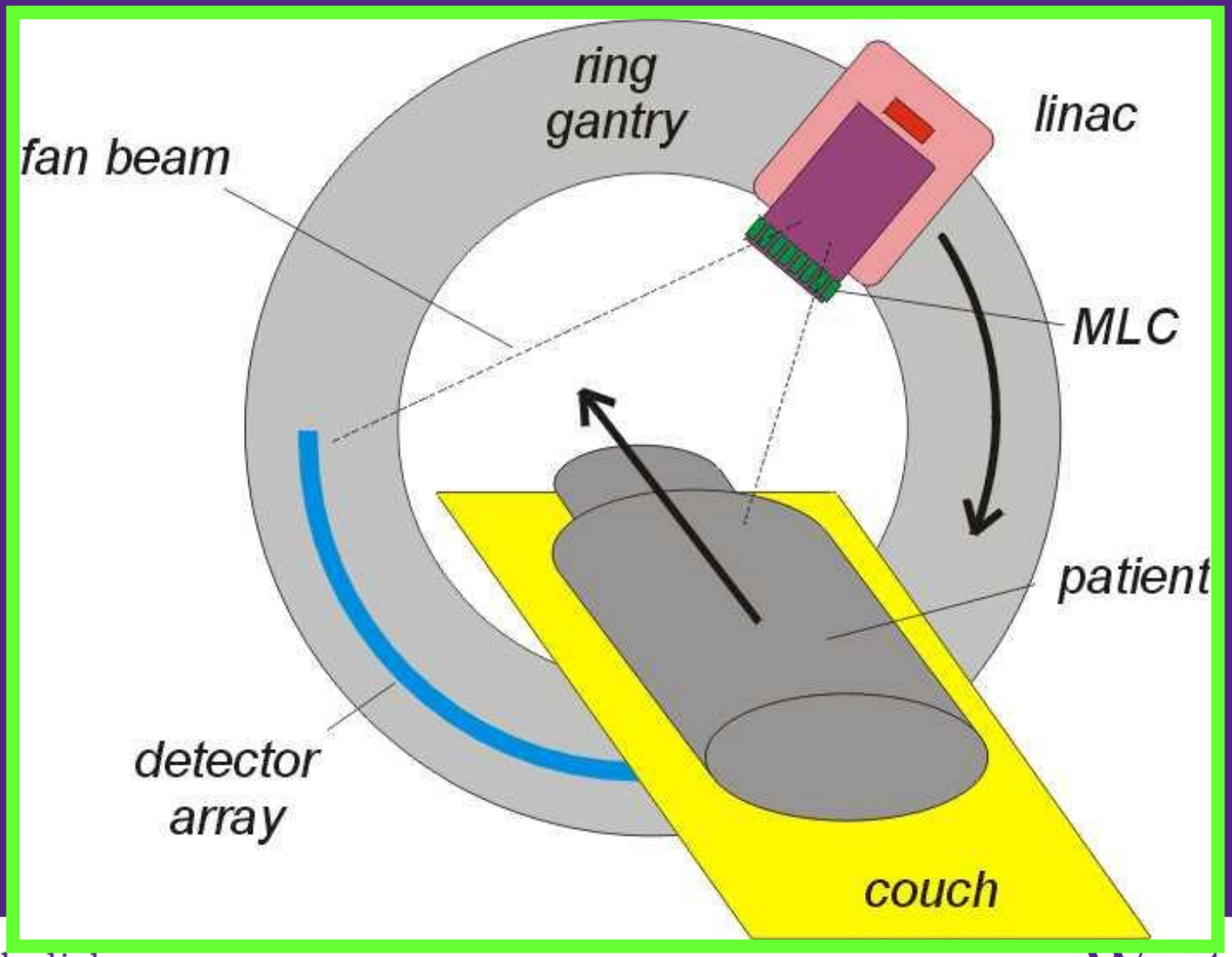
# World's First Cobalt-60 Treatment

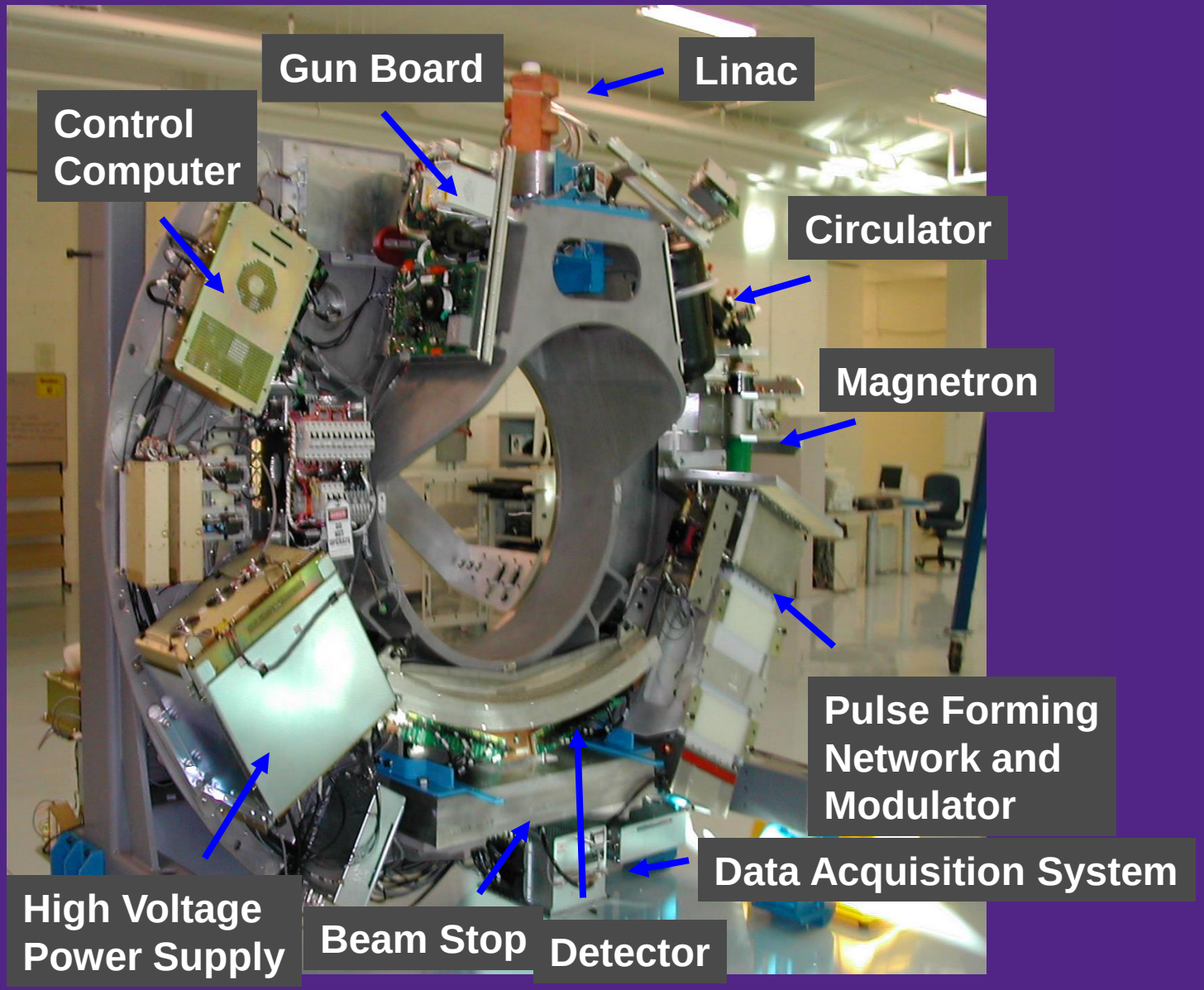
London, Ontario October 27, 1951



# Tomotherapy

# Tomotherapy

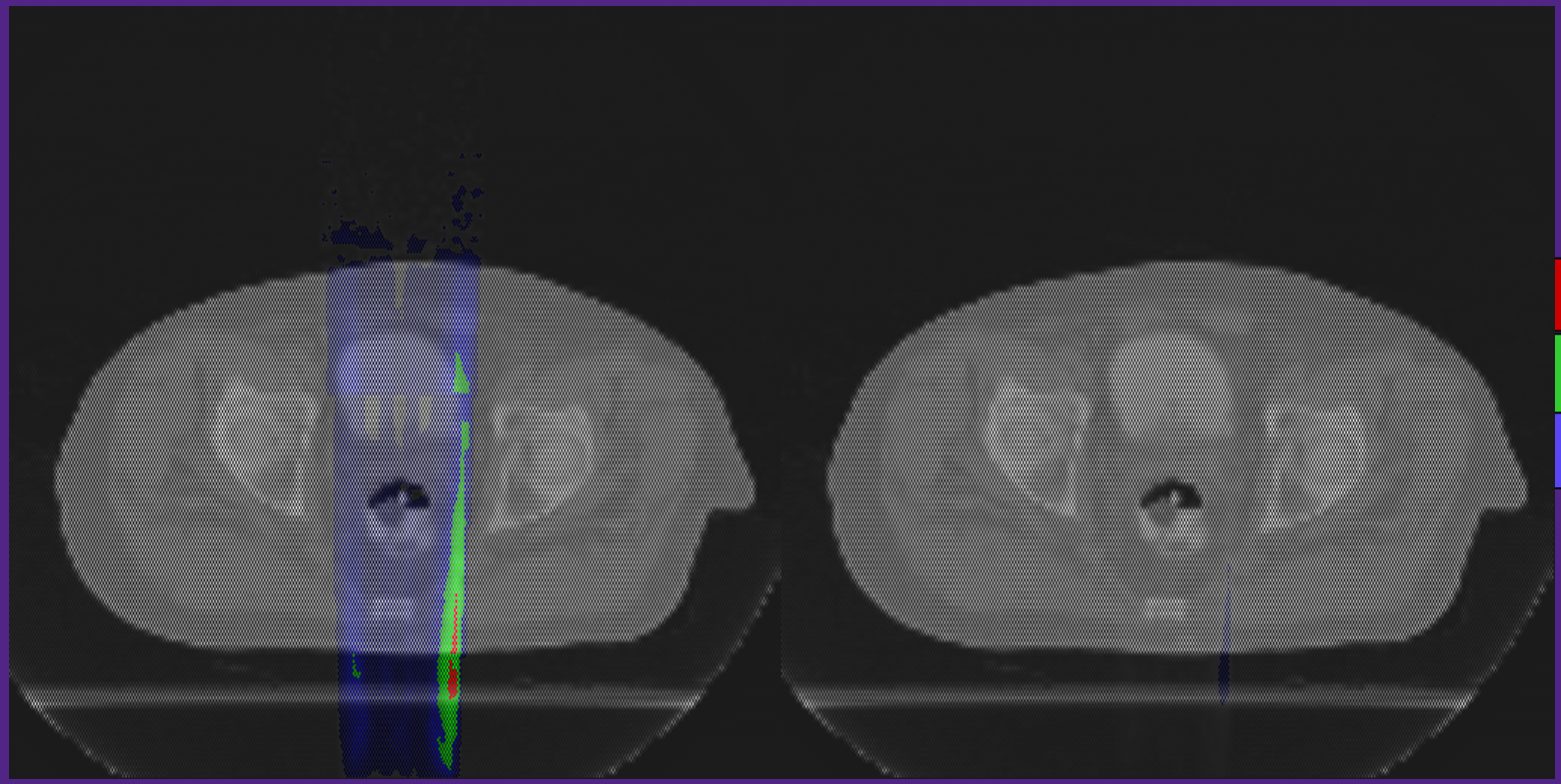



Gun Board
Linac
Control Computer
Circulator
Magnetron
Pulse Forming Network and Modulator
Data Acquisition System
High Voltage Power Supply
Beam Stop
Detector

# Intensity-Modulated Radiotherapy

Dose Rate

Dose

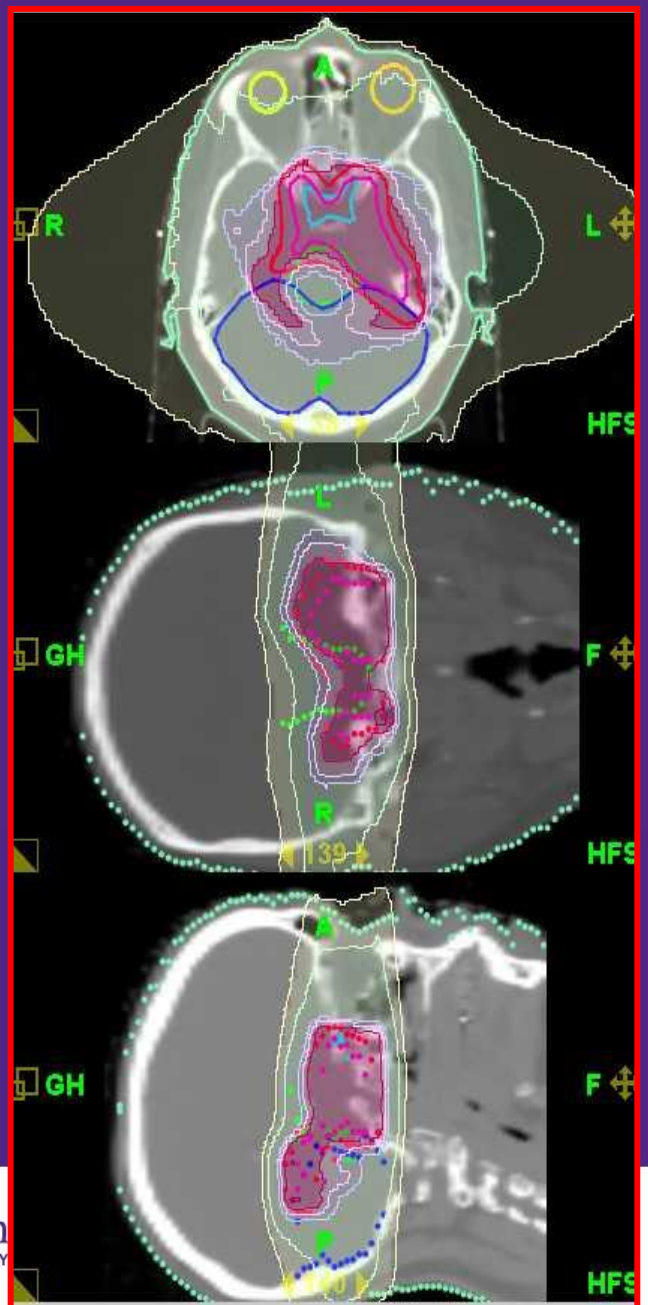


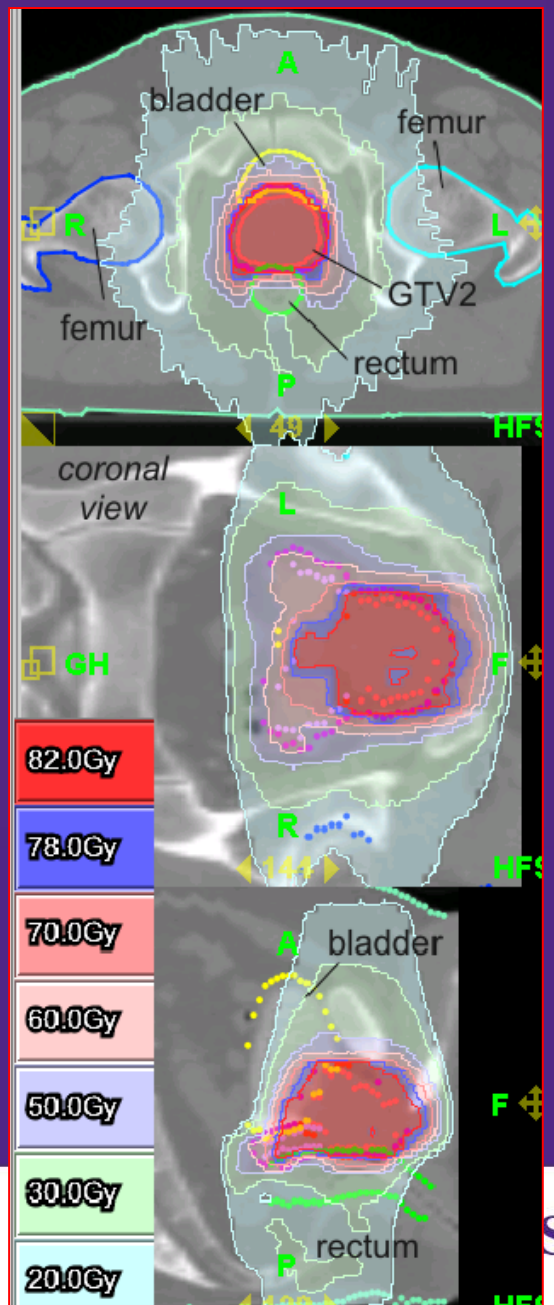
90 to 100%

**30 to 90%**

00 to 30%

# 3D Dose Sculpting

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Western

# When Imaging meets Therapy

## Image-Guided Radiotherapy

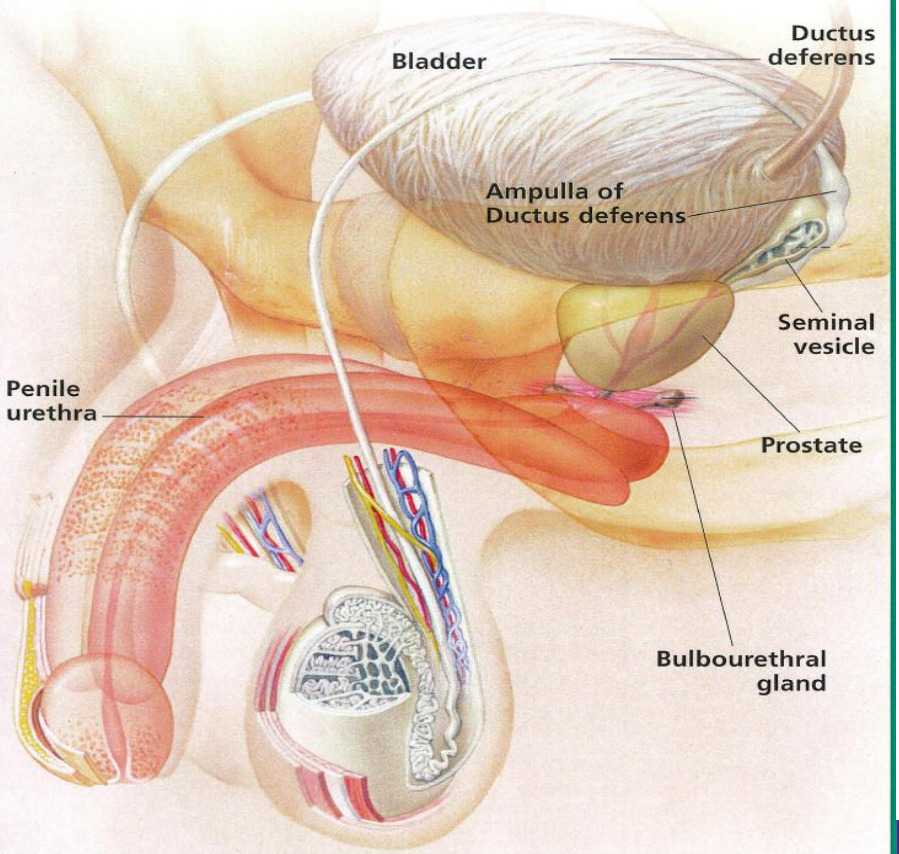

"Point Focus and Shoot"

# CT -Guided Adaptive Radiotherapy

ELIGARD
leuprolide acetate

# The prostate and accompanying structures

A teaching tool for your convenience



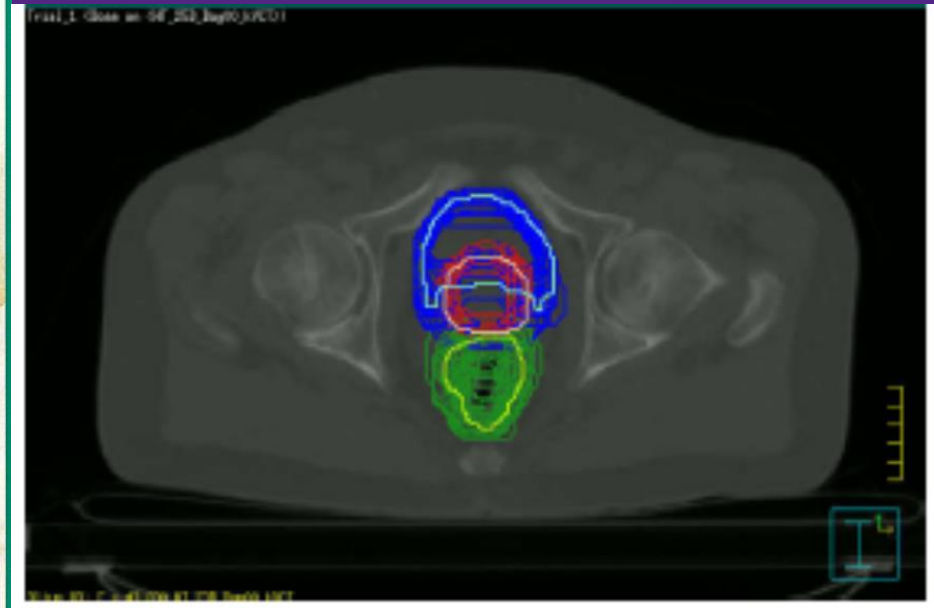



**Fig. 2.** Kilovoltage CT image of the pelvis showing contours of the bladder (anterior), target clinical target volume (central), and rectum (posterior) segmented from 35 megavoltage CT scans. The brighter contours are derived using the Simultaneous Truth and Performance Level Estimation algorithm.

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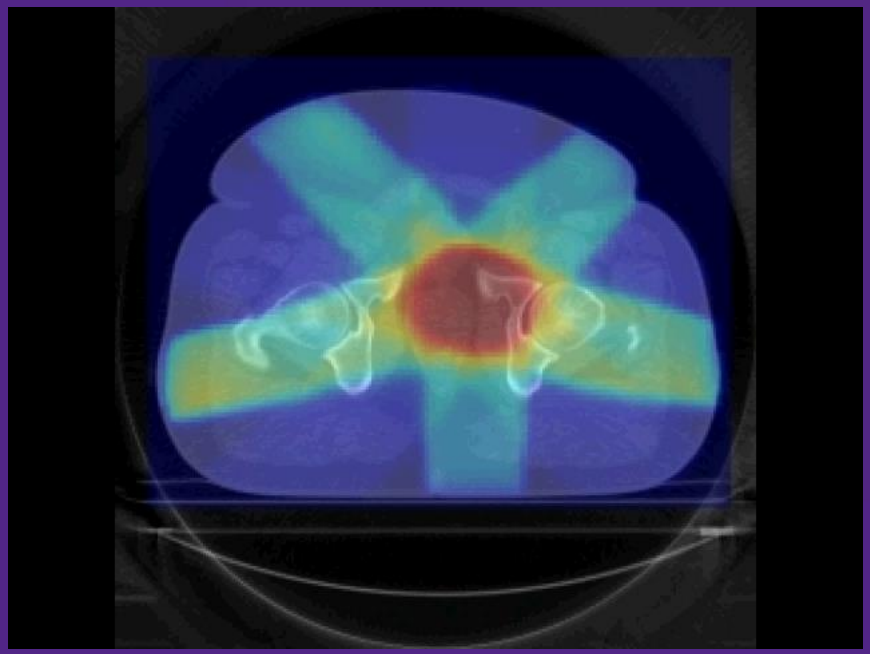
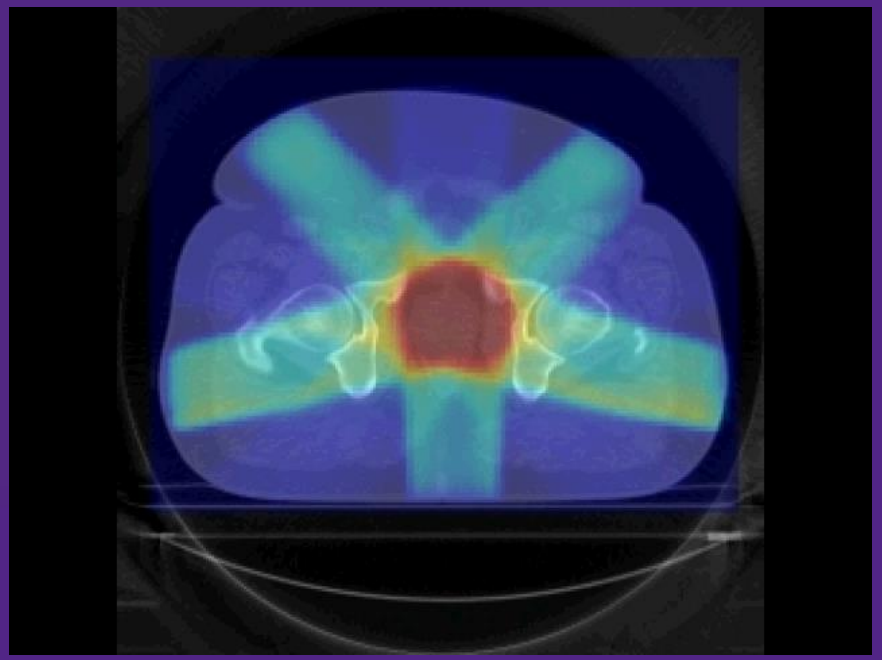
# Image-Guided Radiotherapy

Laser-Guided ONLY
(no Portal Image)



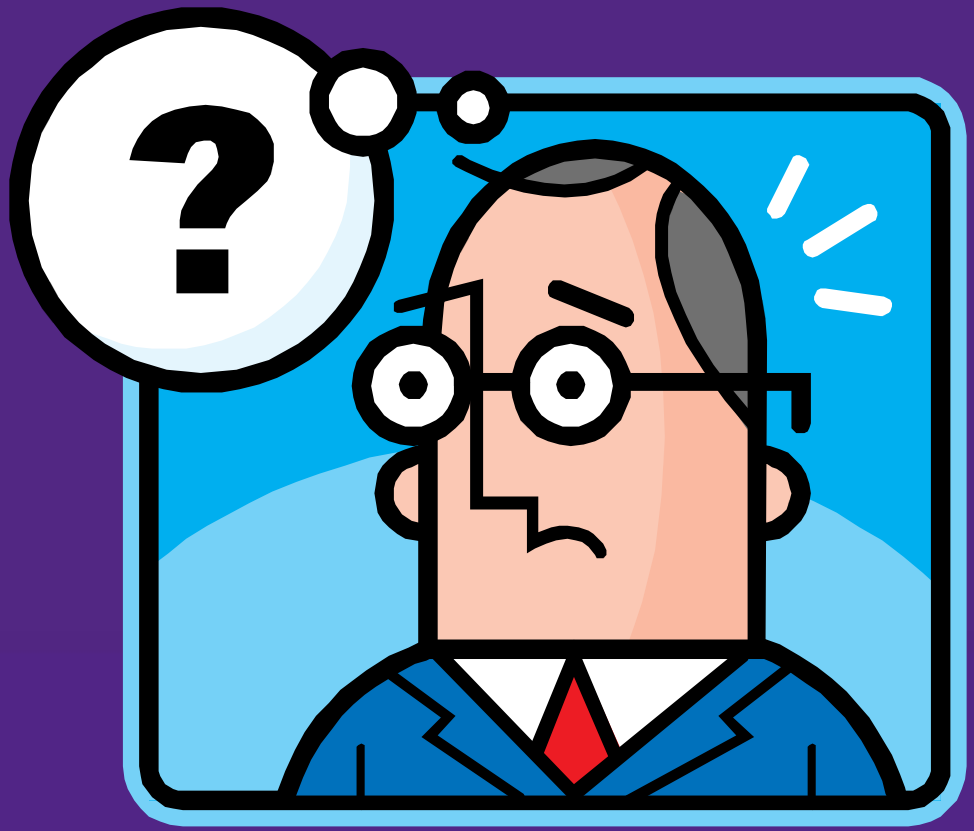
Daily CT-Guided



# Summary

- Uncontrolled radiation has the potential to be harmful
- Highly controlled radiation is used for diagnosis and therapy
- For diagnosis, radiation doses are kept “as low as possible”
  - Whenever possible, ultrasound and MRI are used (no dose)
- For therapy, high doses of x-rays are routinely used.
  - Focussed onto the tumour as much as possible
  - Approximately 50% of cancer patients undergo radiation at some point
- A combination of 3D/4D imaging and treatment leads to better tumour control with far less side effects.

# Question and Answer Period



# Outline

- What is Radiation?
- How does it injure DNA, cells, tissue, organs ?
- What do we know about its biological effects?
- What do we know about its risks?
- How is radiation used in medicine?
- Question and Answer Period
- **Demonstration of CT scanning**

# CT Scanners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# Optical Scanner for Interactive Teaching of CT Imaging Principles

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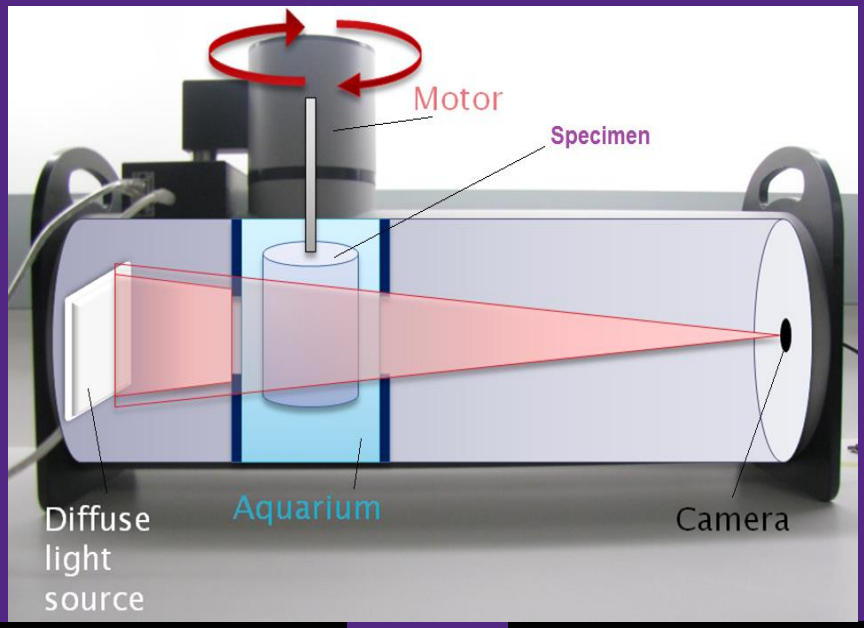
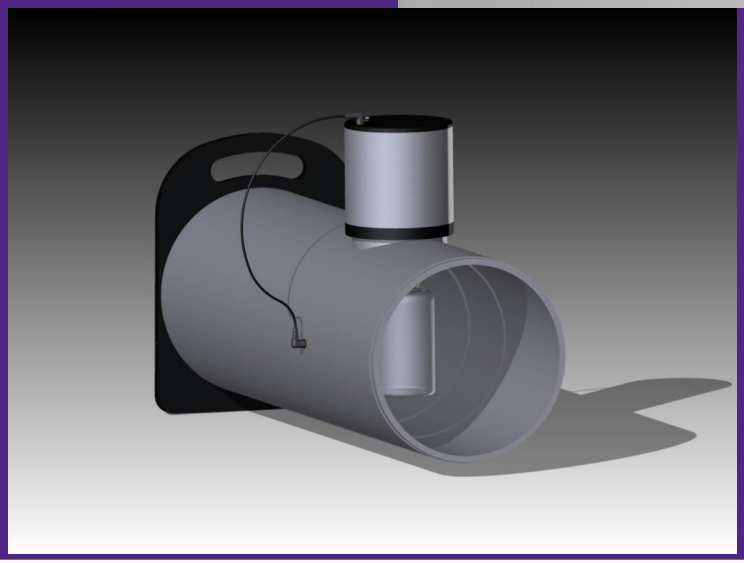
# DeskCAT – 3D Optical Scanner



# DeskCAT Demonstration