

# Nuclear Accidents: Chernobyl & Fukushima

Robert Peter Gale MD, PhD, DSc  
(hon), FACP

# Radiation and Nuclear Accidents

Chernobyl Ukraine 1986

Goiania Brazil 1987

Nieshvesh Belarus 1993

Tokaimura Japan 1999

Fukushima Japan 2011

# Ionizing Radiations

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Humans have always been exposed to ionizing radiations

There are many types and sources of ionizing radiations in our normal lives

There are substantial differences in how much radiation we are exposed to without detectable health consequences

# Ionizing Radiations

Humans have always been exposed to ionizing radiations

There are many types and sources of ionizing radiations in our normal lives

There are substantial differences in how much radiation we are exposed to without detectable health consequences

# **Ionizing Radiations**

Humans have always been exposed to ionizing radiations from diverse sources

There are many types and sources of ionizing radiations in our normal lives

**There are substantial differences in how much radiation we are exposed to without detectable health consequences**

# Radiation Doses

Dose: Gy (Joule/Kg) 1 Gy=100 rad

Effective Dose: Sv (Dose adjusted for biological effect) 1Sv=100 rem

Collective effective dose: ManSv  
(Effective dose X persons exposed)

# Sources of Ionizing Radiations

Cosmic

Terrestrial

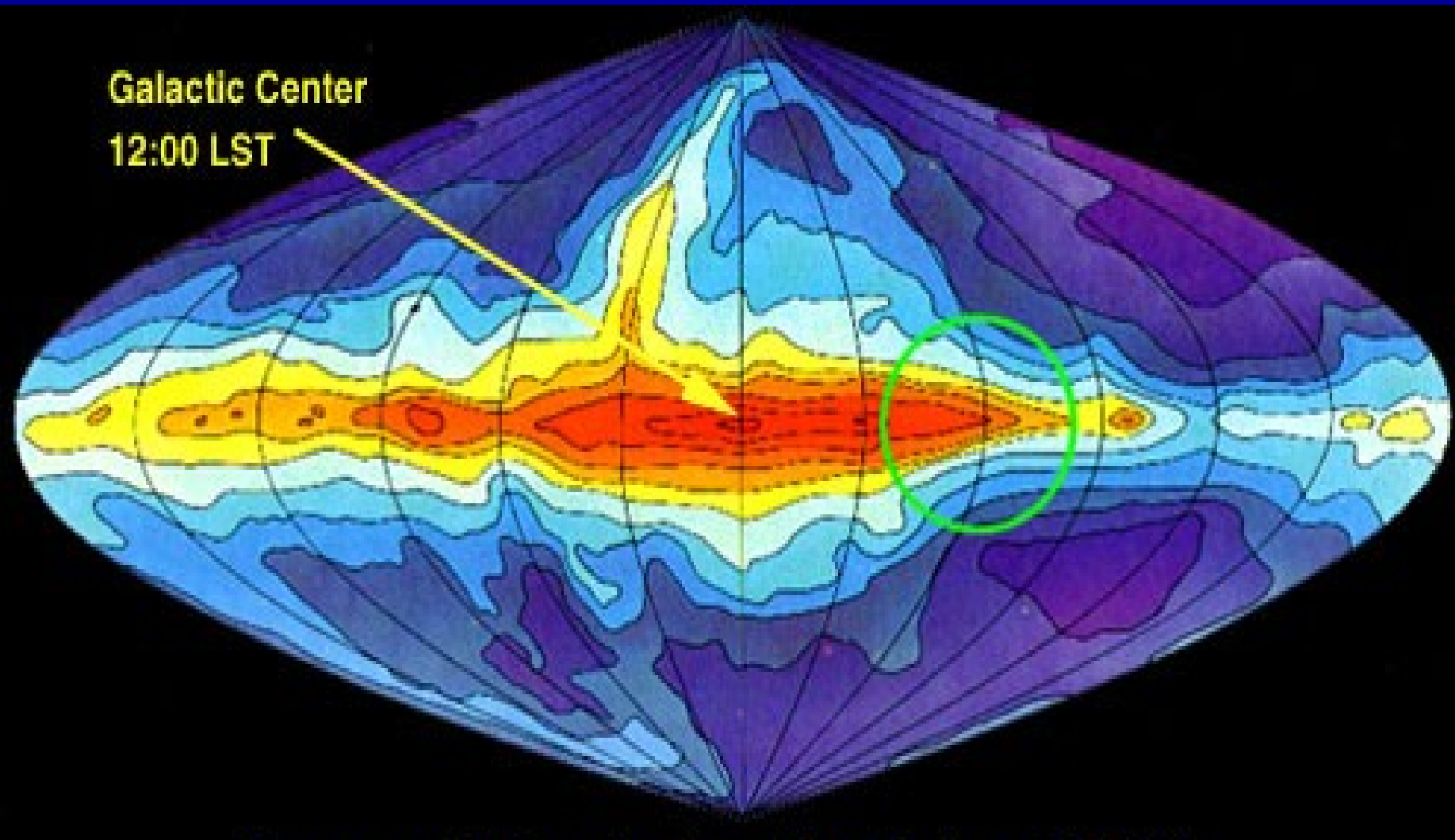
Food/Drink

Other humans

Medical procedures



Galactic Center  
12:00 LST



# Cosmic Radiations (mrem)

<b>Altitude (m)</b>	<b>Dose Rate</b>	
Sea level	31	Los Angeles
1,525	55	Denver
9,140	1900	Jetliner
15,240	8750	Concorde
24,340	12,200	U2 Spy plane

# Sources of Ionizing Radiations

Cosmic

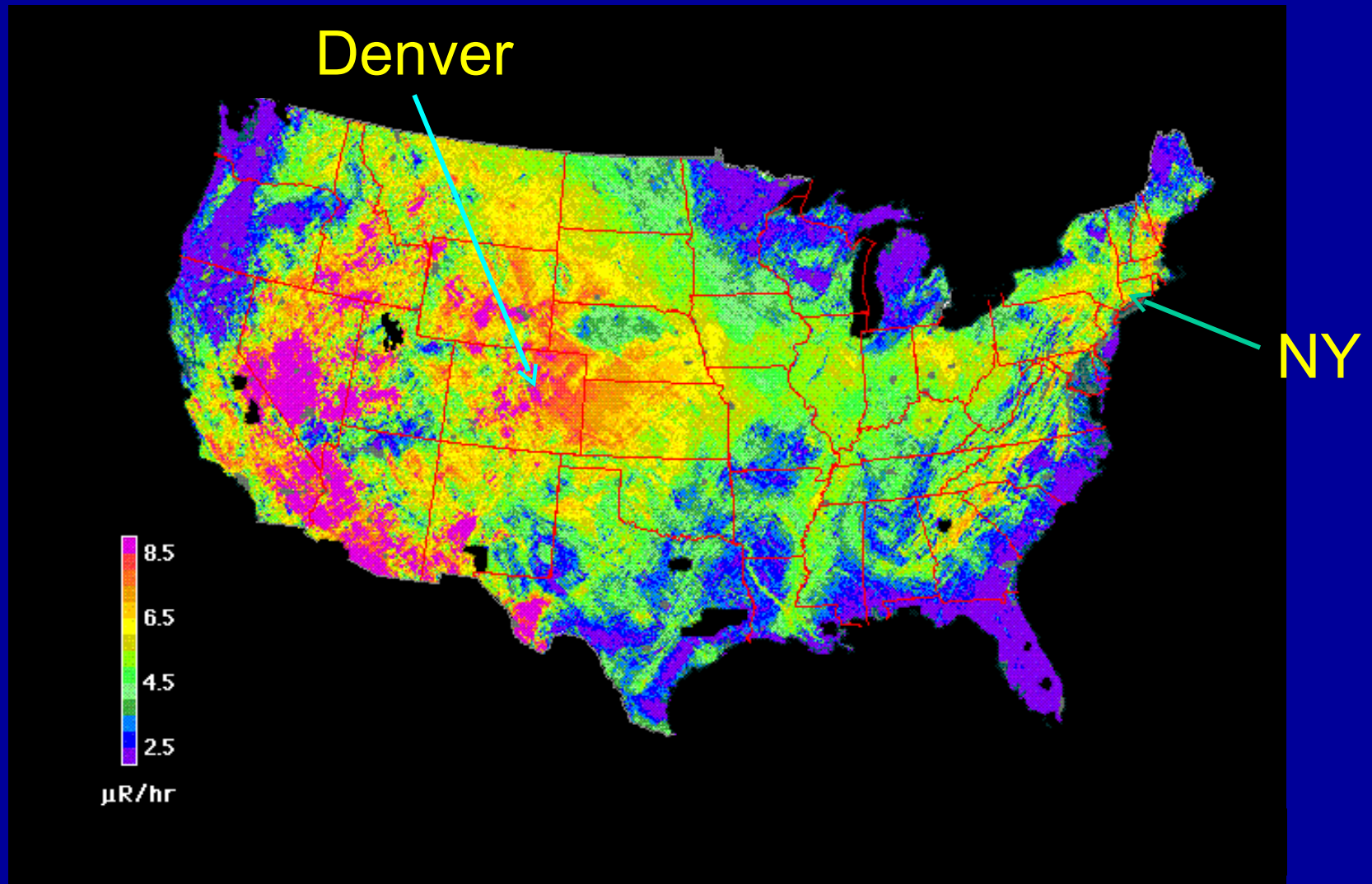
**Terrestrial**

Food/Drink

Other humans

Medical procedures

# US Terrestrial Radiation



# Sources of Ionizing Radiations


Cosmic

Terrestrial

**Food/Drink**

Other humans

Medical procedures

A clear glass filled with water, set against a light blue background. The glass is centered and contains a clear liquid. Overlaid on the water in red text is the radiation level and the elements measured.

0.2 Bq/L  
Ra U Th Rn

# Sources of Ionizing Radiations

Cosmic

Terrestrial

Food/Drink

**Other humans**

Medical procedures



$^{40}\text{K}$   $^{14}\text{C}$



$^{40}\text{K}$   $^{14}\text{C}$



# Sources of Ionizing Radiations

Cosmic

Terrestrial

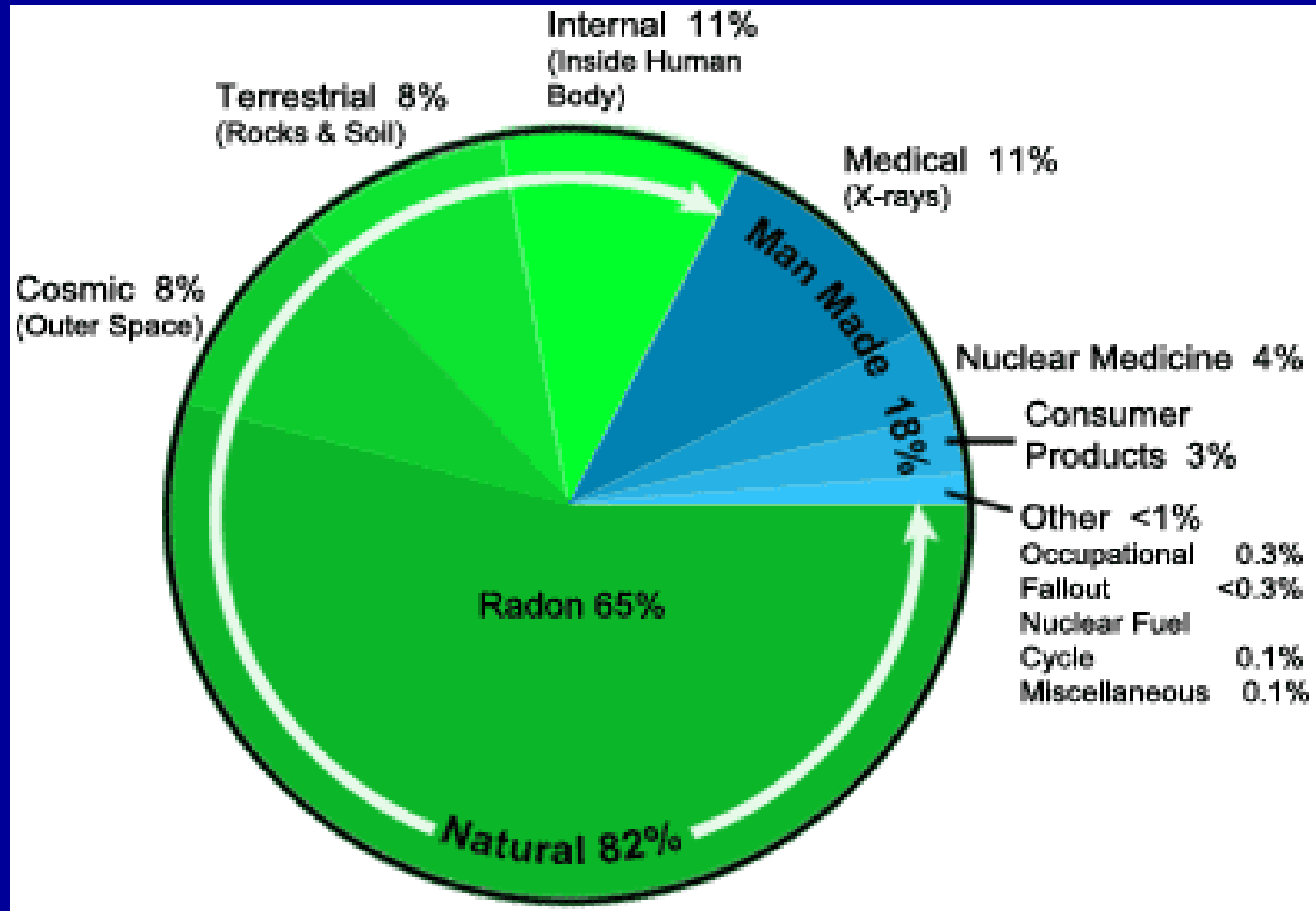
Food/Drink

Other humans

**Medical procedures**



# Sources of Ionizing Radiations



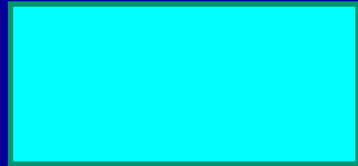
How much radiation are we normally exposed to?

How much radiation are we normally exposed to?

That depends!

# Average Radiation Exposure

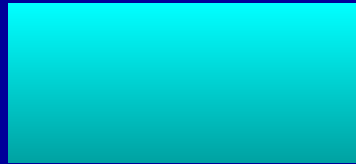
NY



6.2 mSv

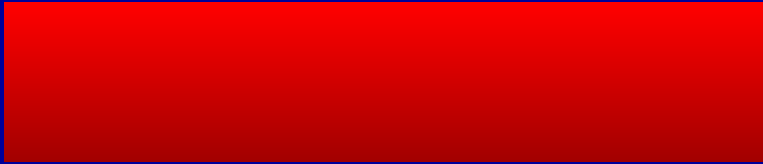
# Average Radiation Exposure

NY



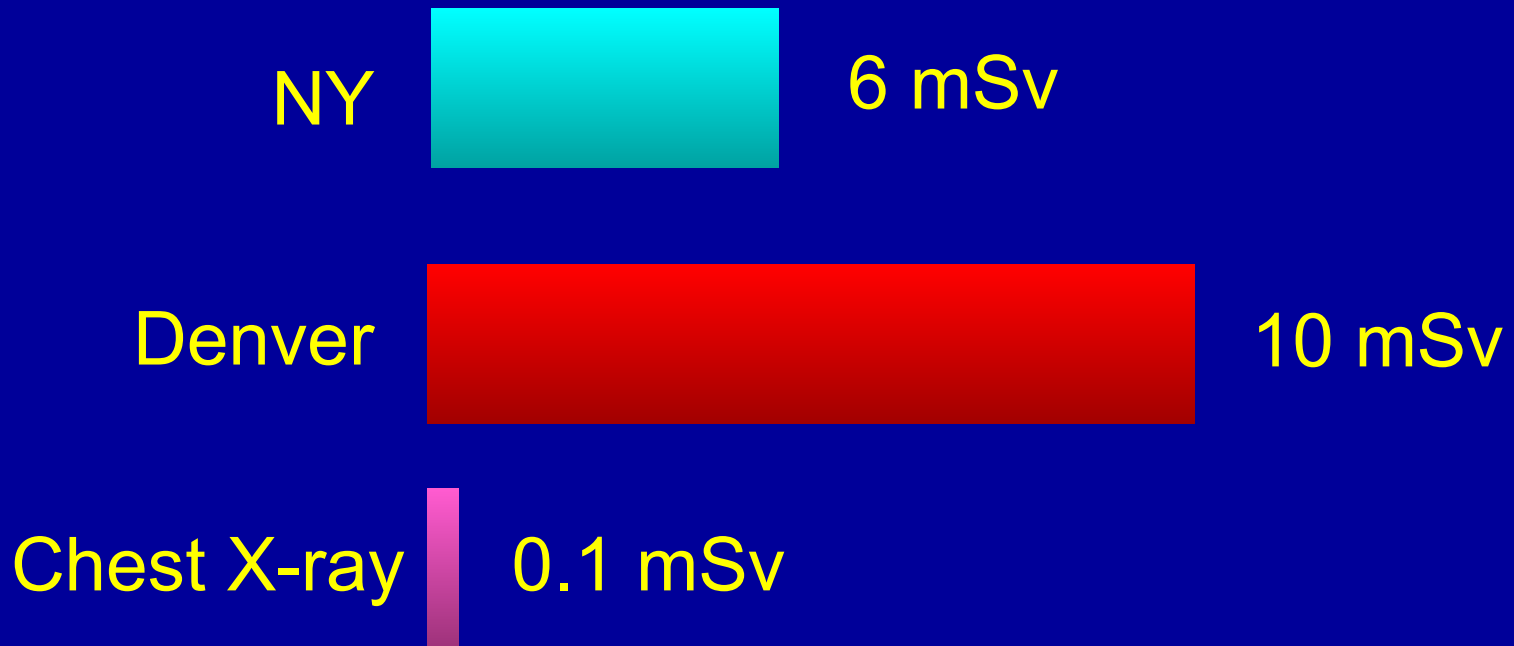
6 mSv

Denver



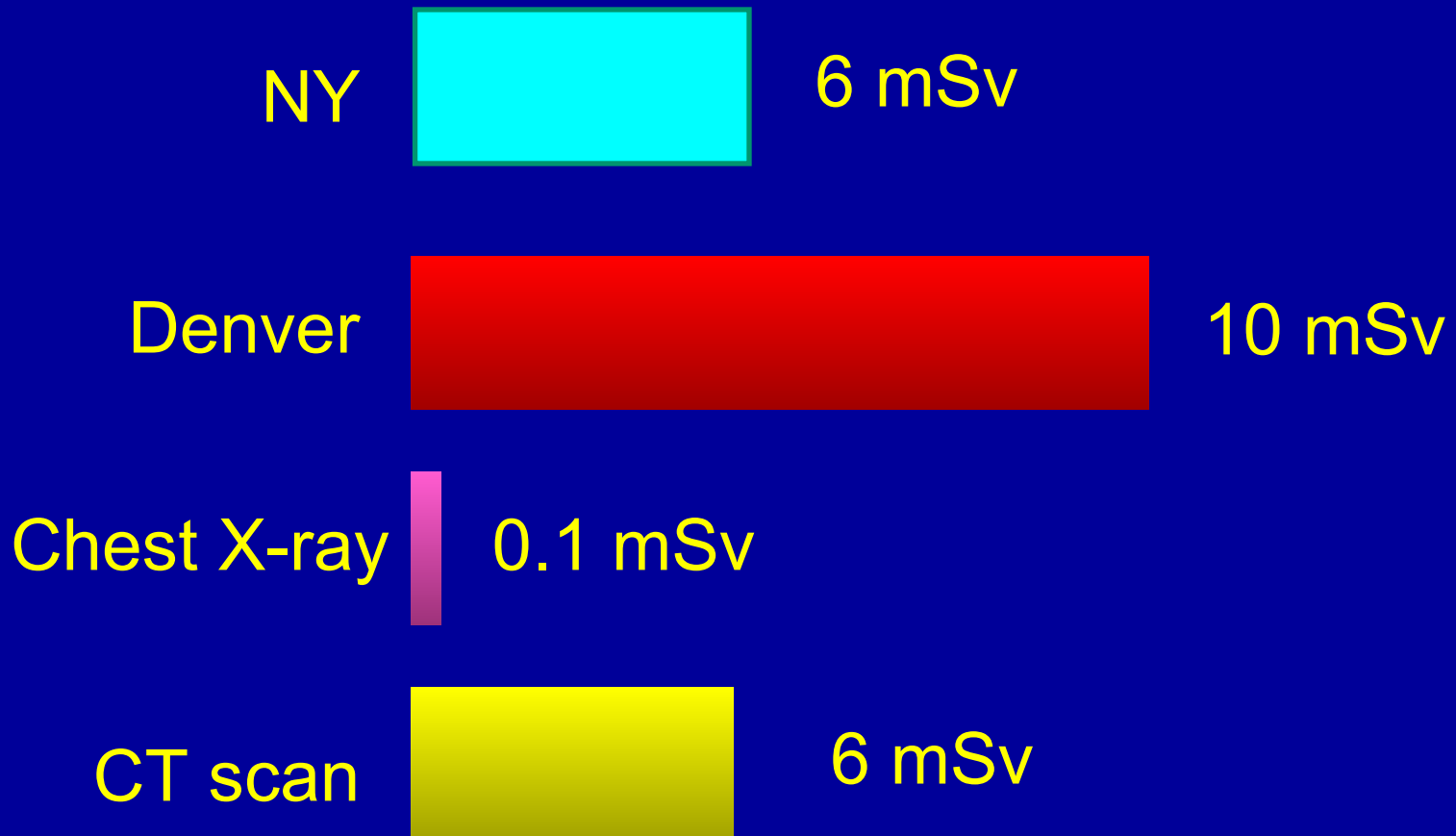
10 mSv

# Average Radiation Exposure





# Average Radiation Exposure



What are the effects of exposure to ionizing radiations?

What are the effects of exposure  
to ionizing radiations?

Deterministic



Stochastic

What are the effects of exposure to ionizing radiations?

Deterministic

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Stochastic

# Deterministic Effects

Skin

Gastro-intestine

Bone marrow

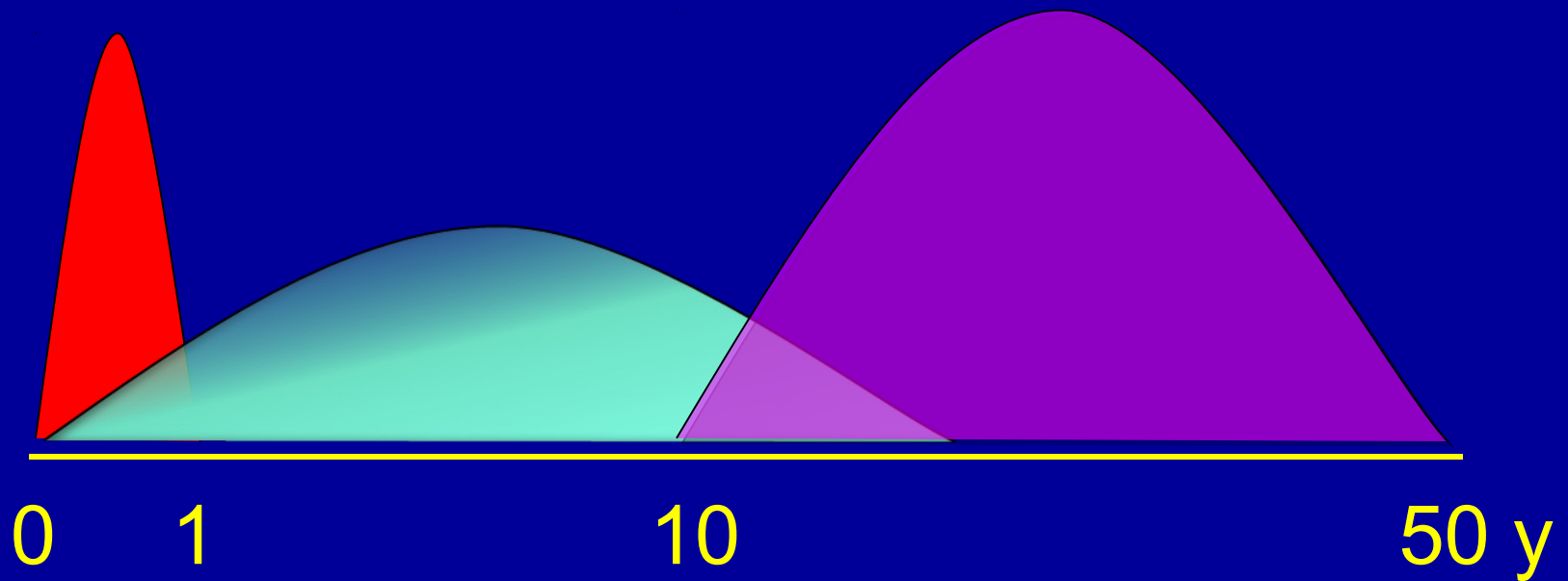
CNS/CV

Eyes

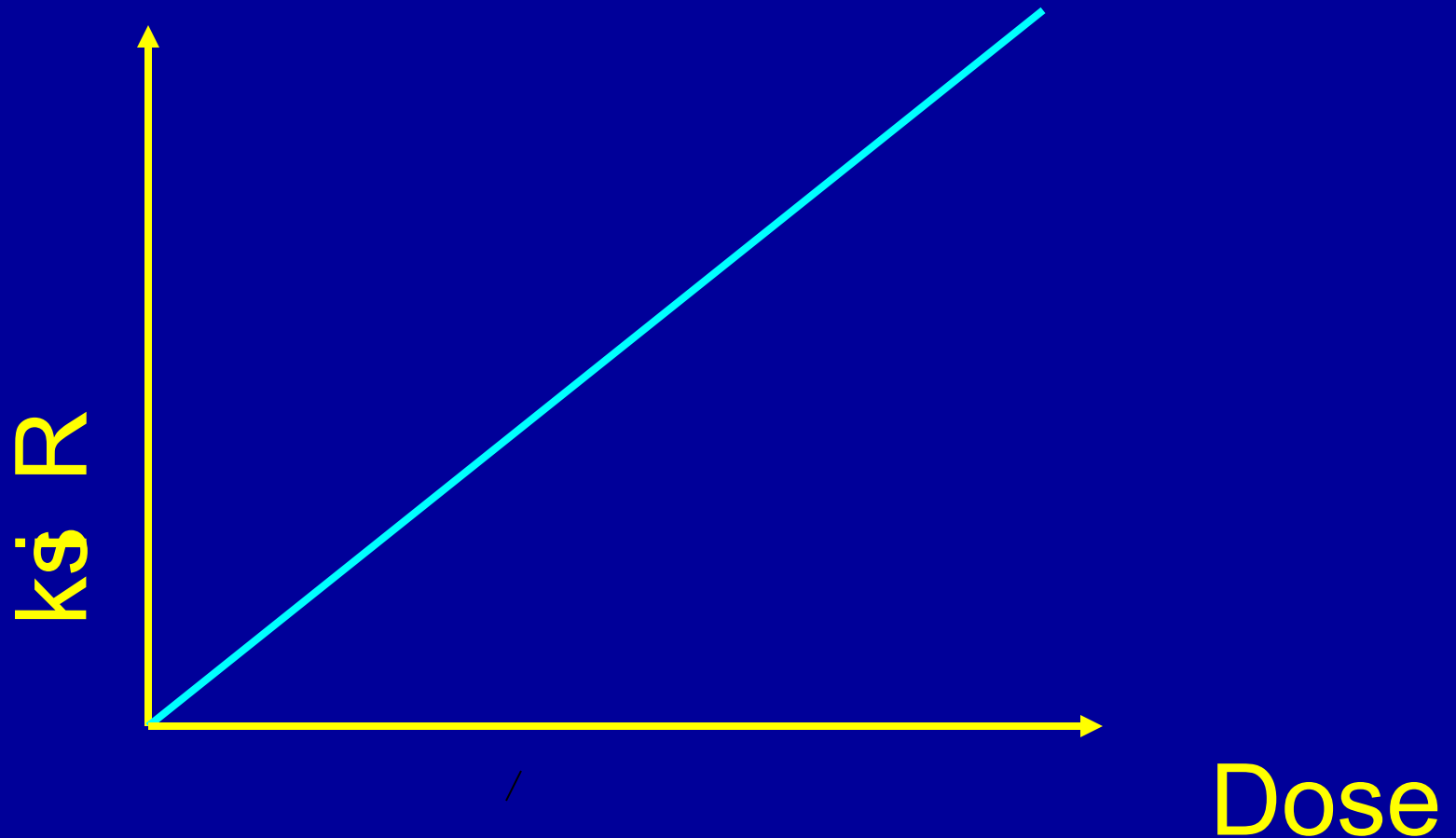
# Timing of Radiation Effects

## Deterministic

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# Dose vs Deterministic Effects



What are the effects of exposure to ionizing radiations?

Deterministic



Stochastic



# Stochastic Effects

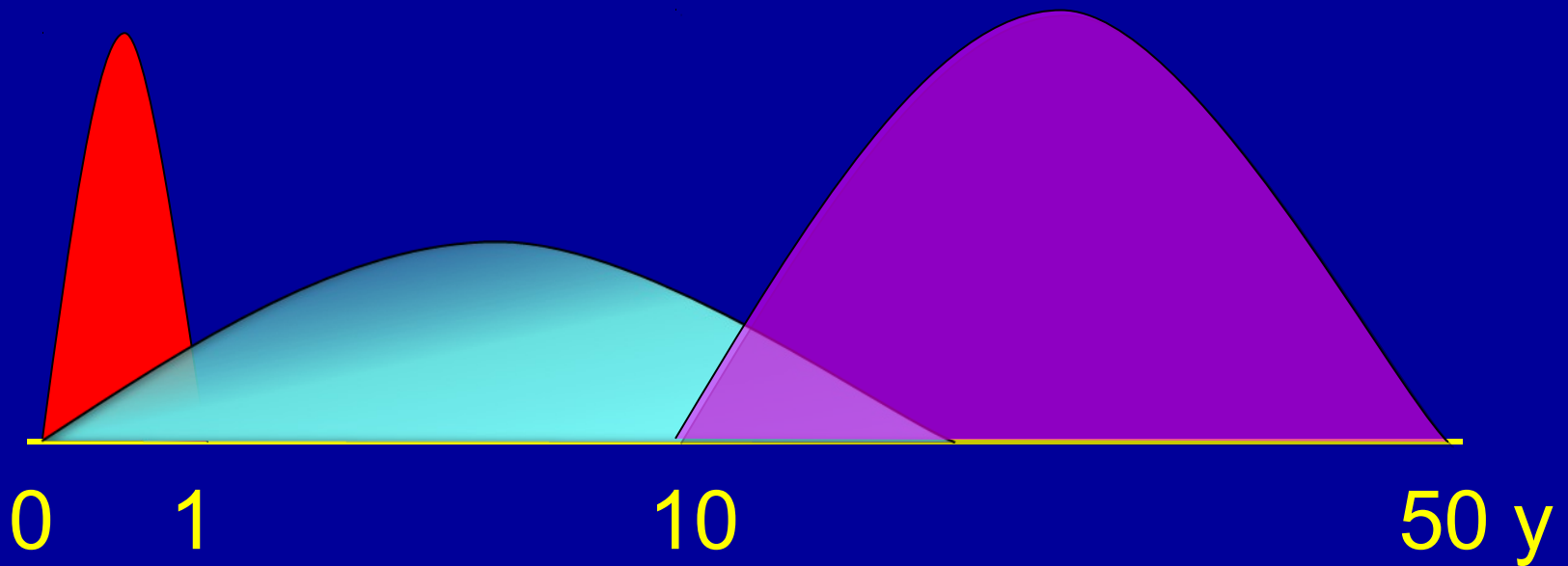
Cancer

Birth defects

Genetic disorders

# Timing of Radiation Effects

Stochastic



# Stochastic Effects

Cancer

Birth defects

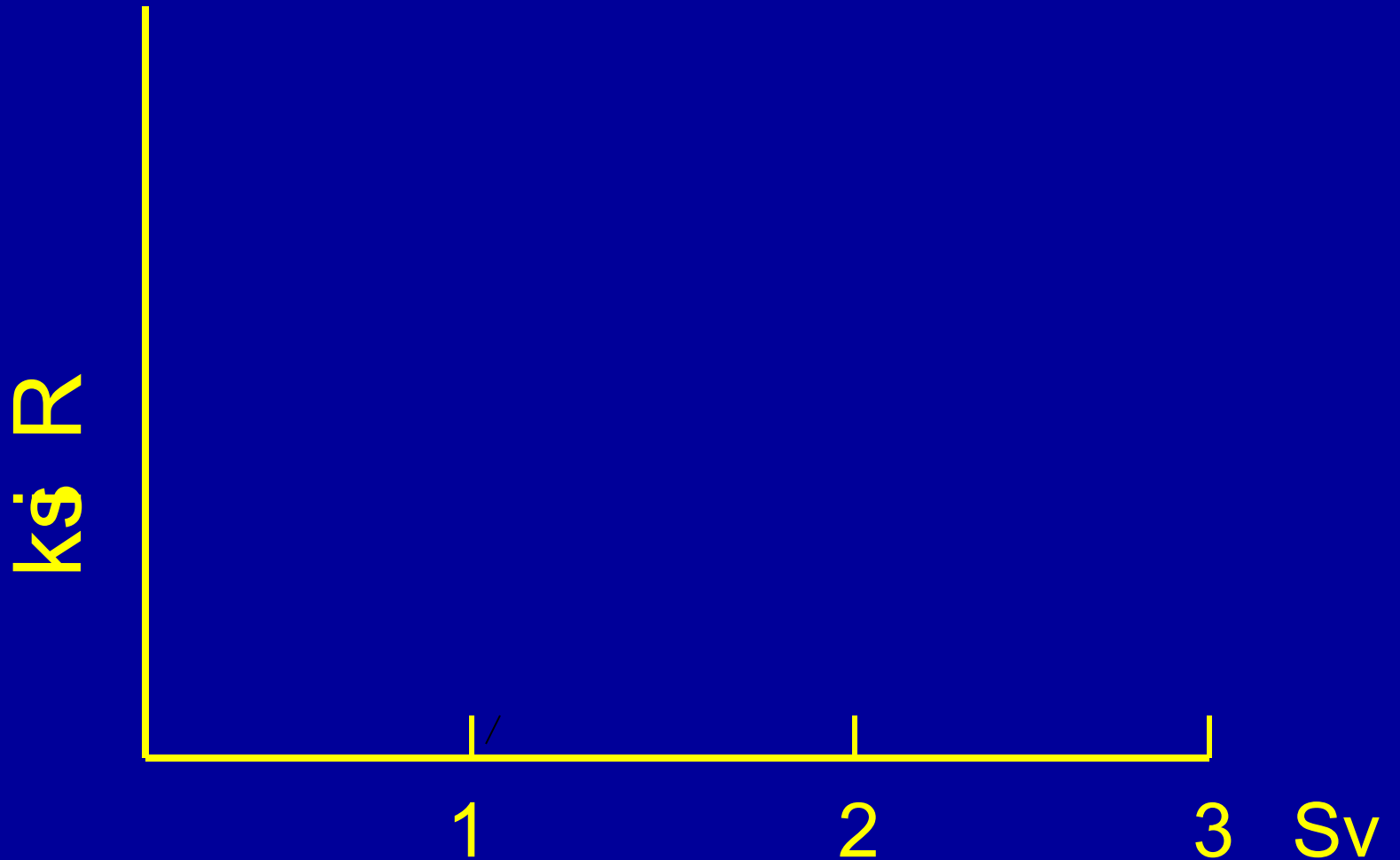
Genetic disorders

# Paradoxes

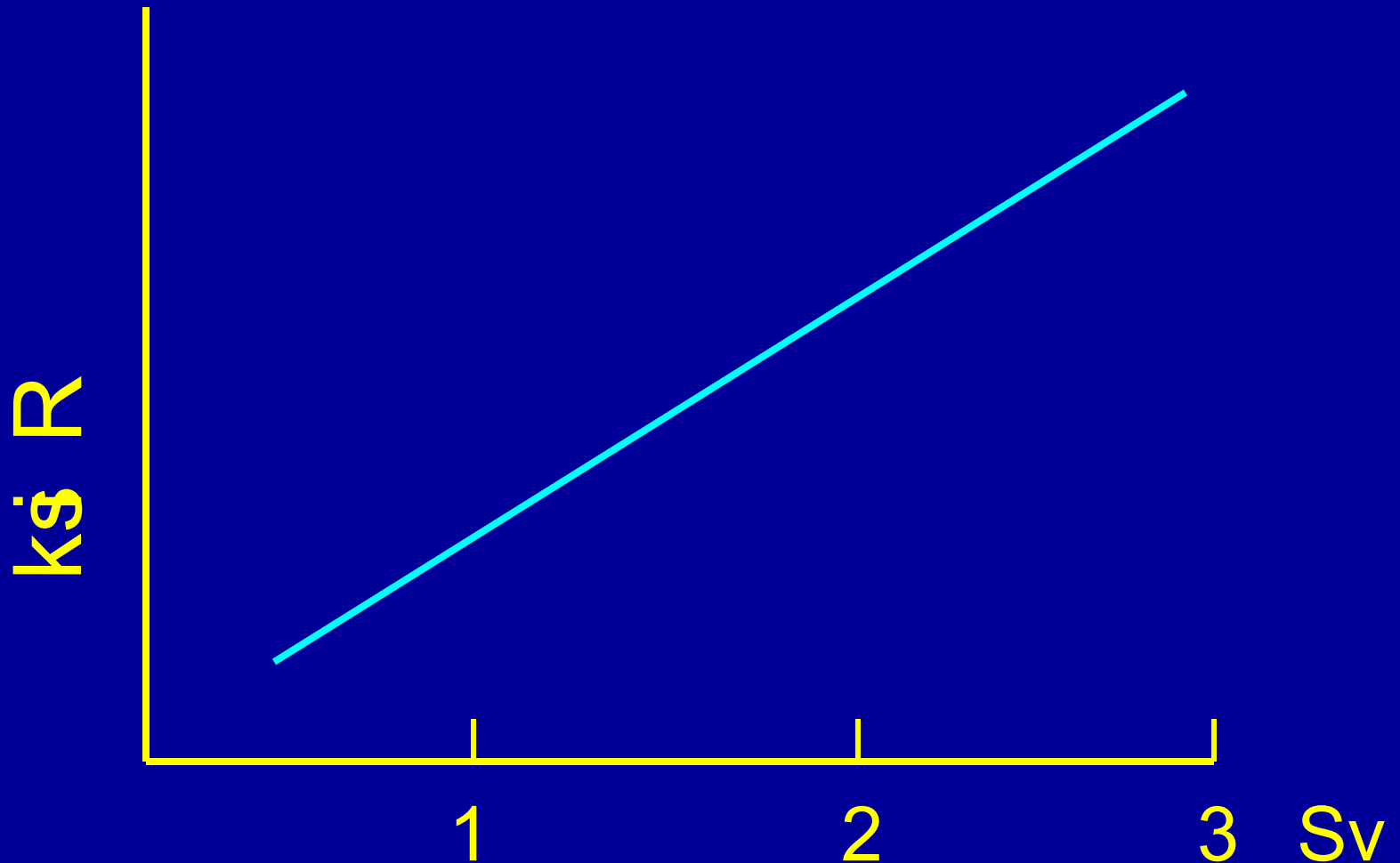
The default safety assumption is a linear no threshold relationship between exposure to ionizing radiations and cancer. This cannot be proved.

Humans are exposed to a 5-10-fold difference in background radiation with no detectable difference in cancer risk

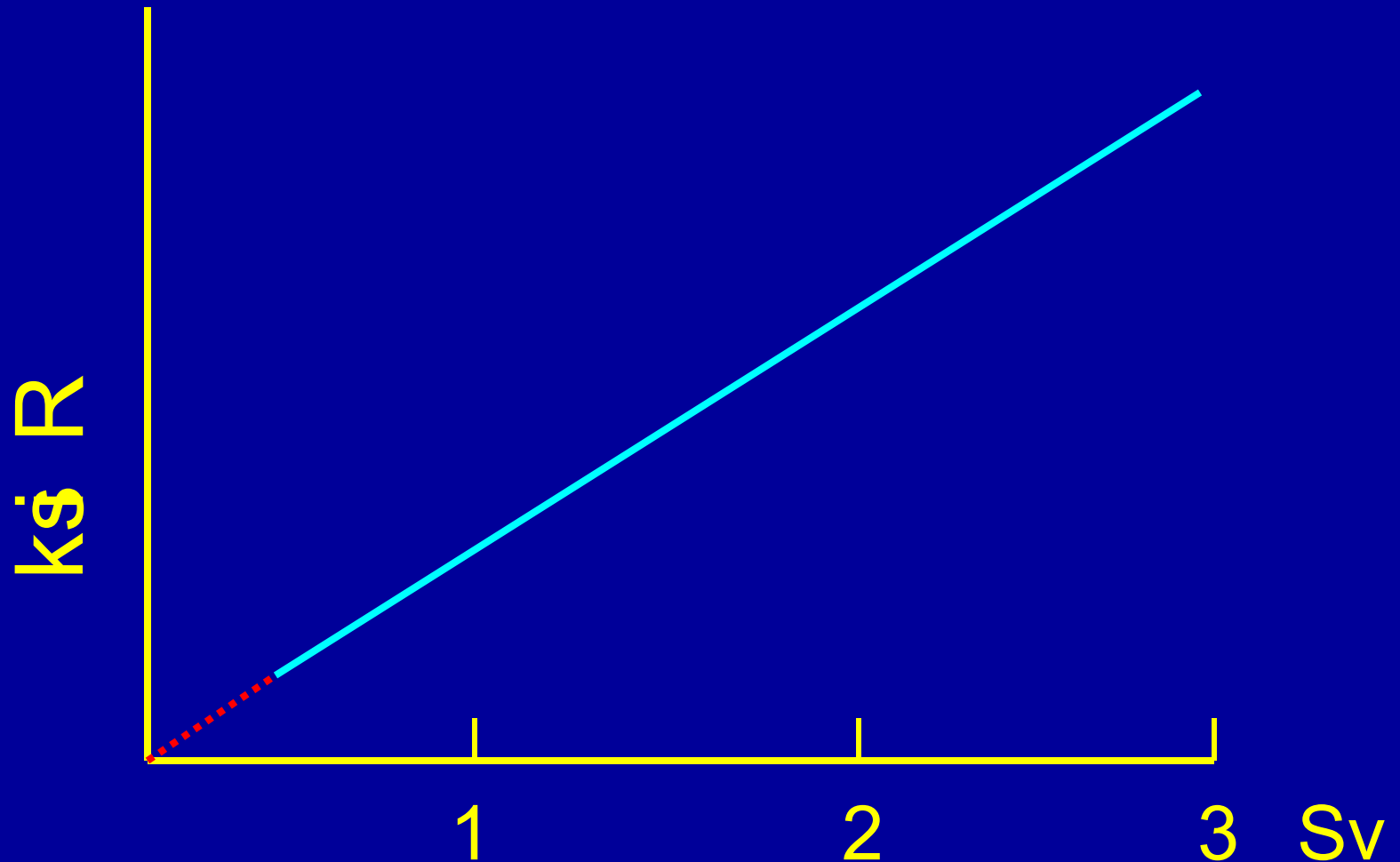
# Dose vs Cancer-Risk



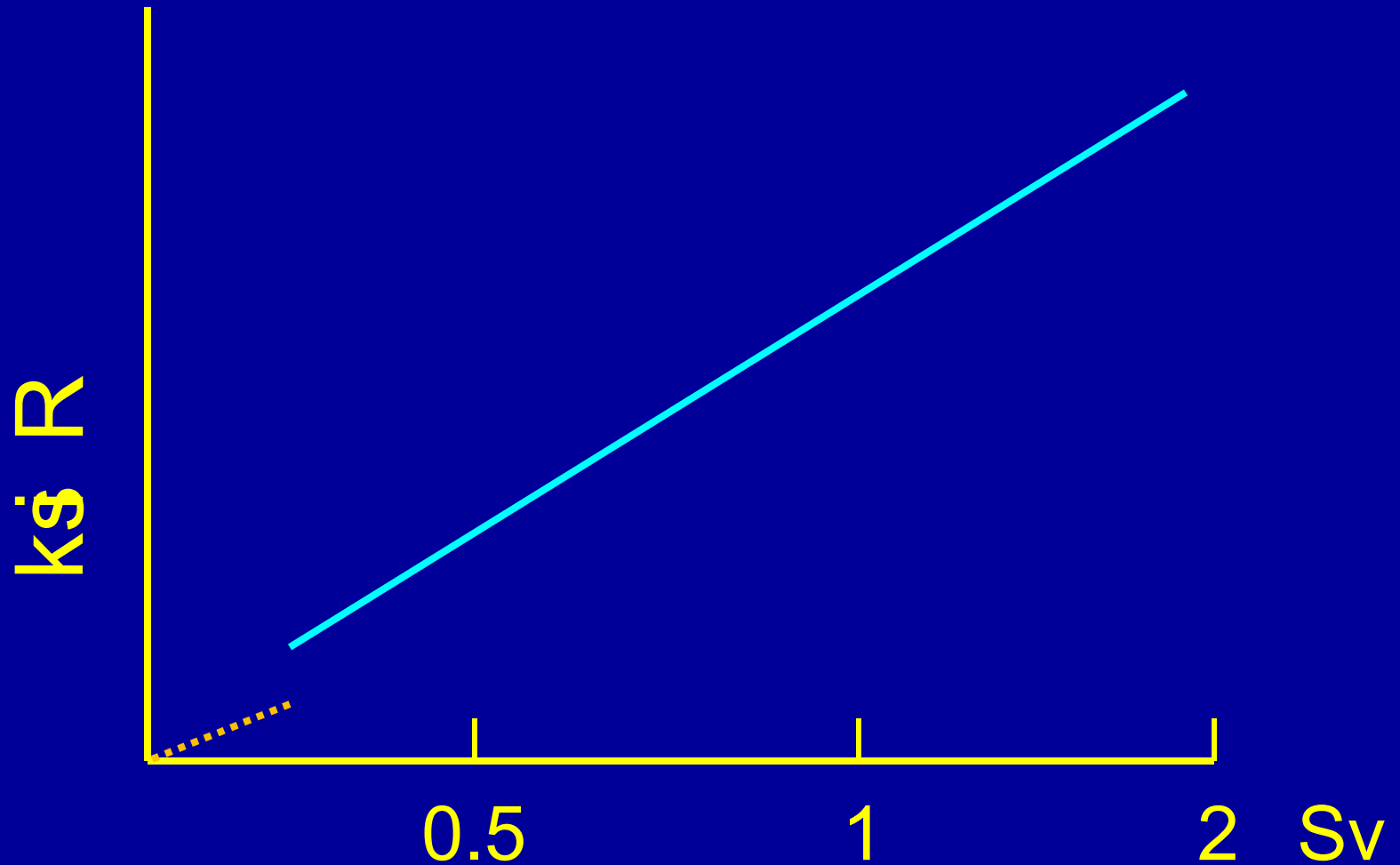
# Dose & Cancer-Risk



# Dose & Cancer-Risk

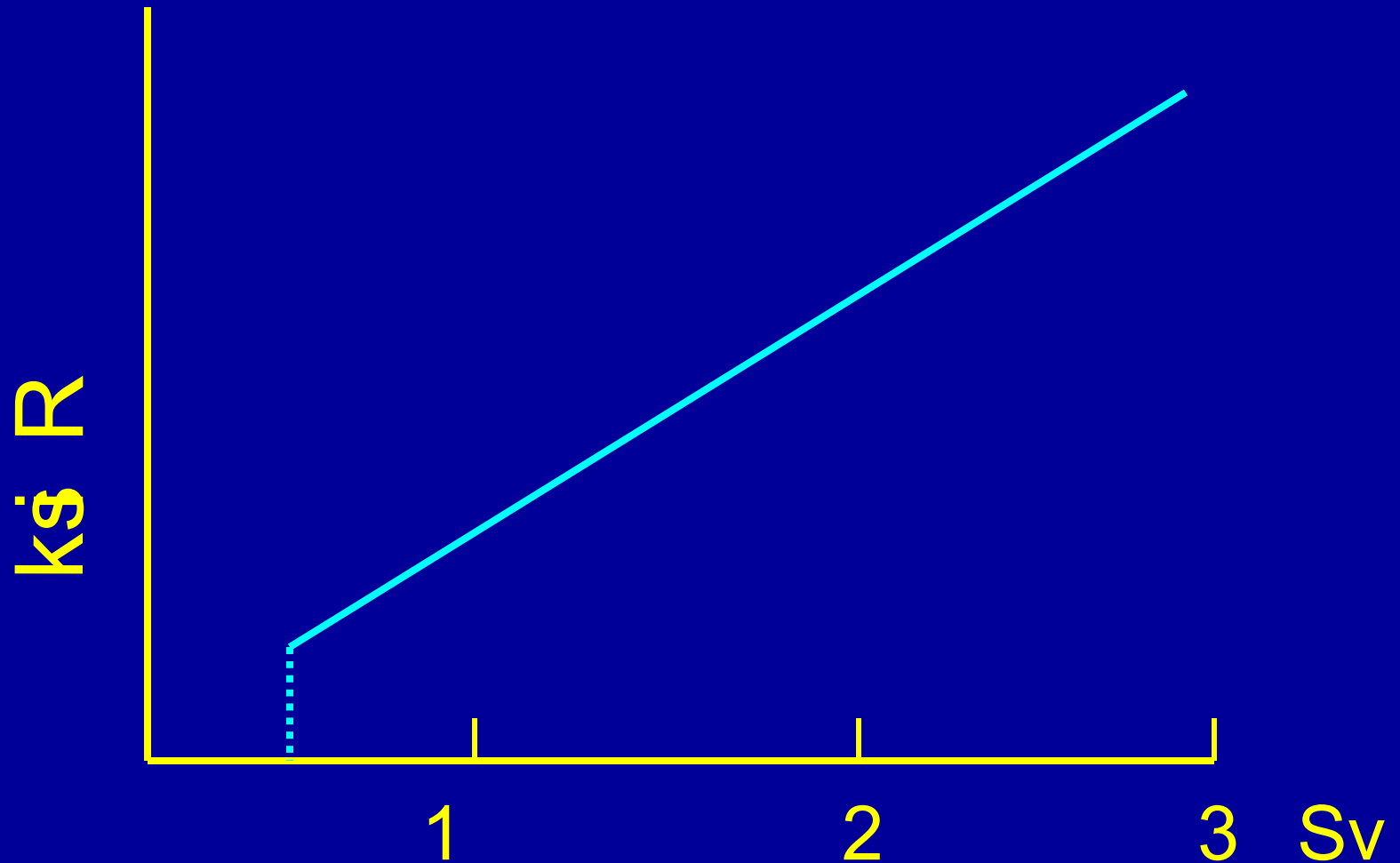


# Dose & Cancer-Risk

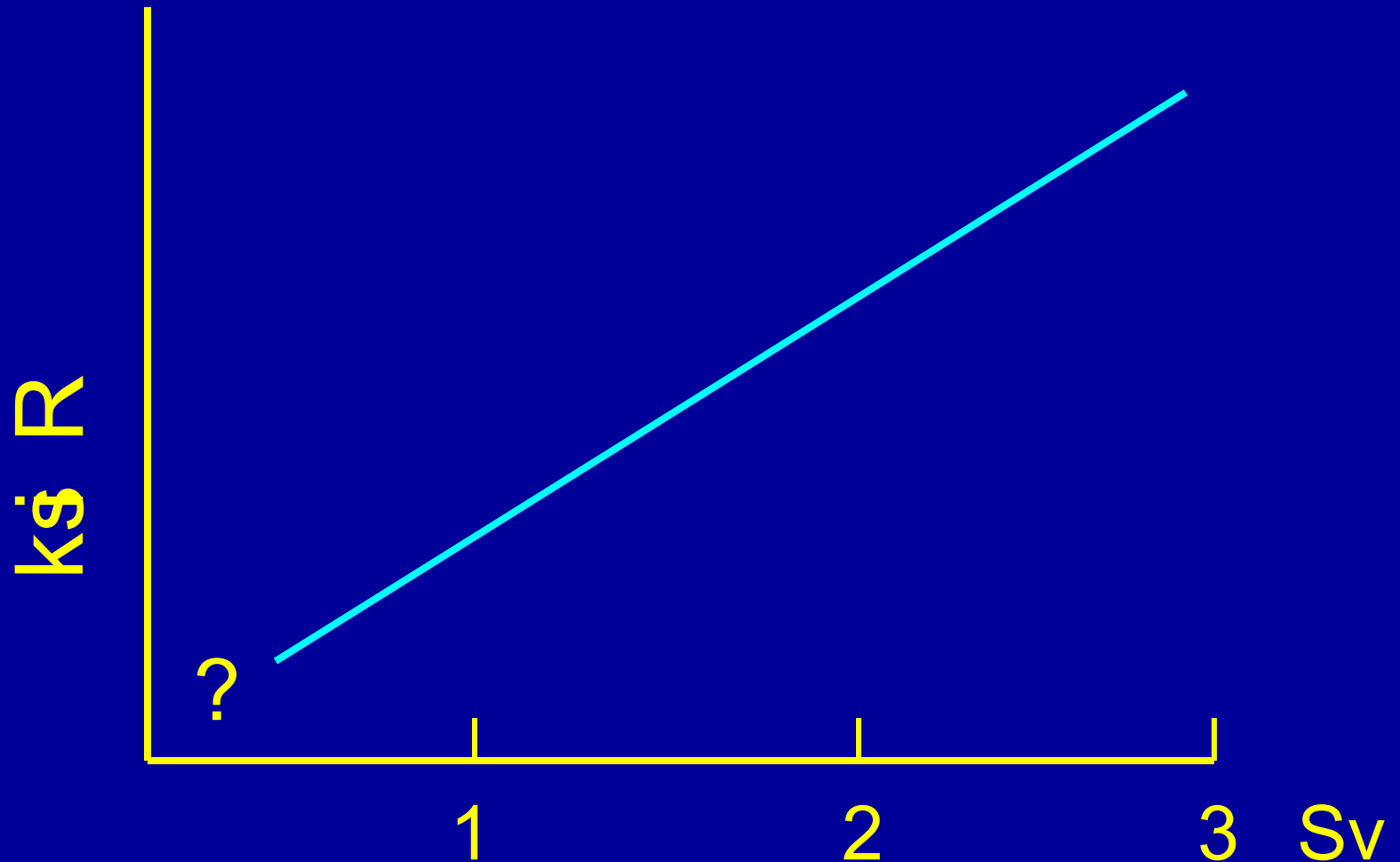




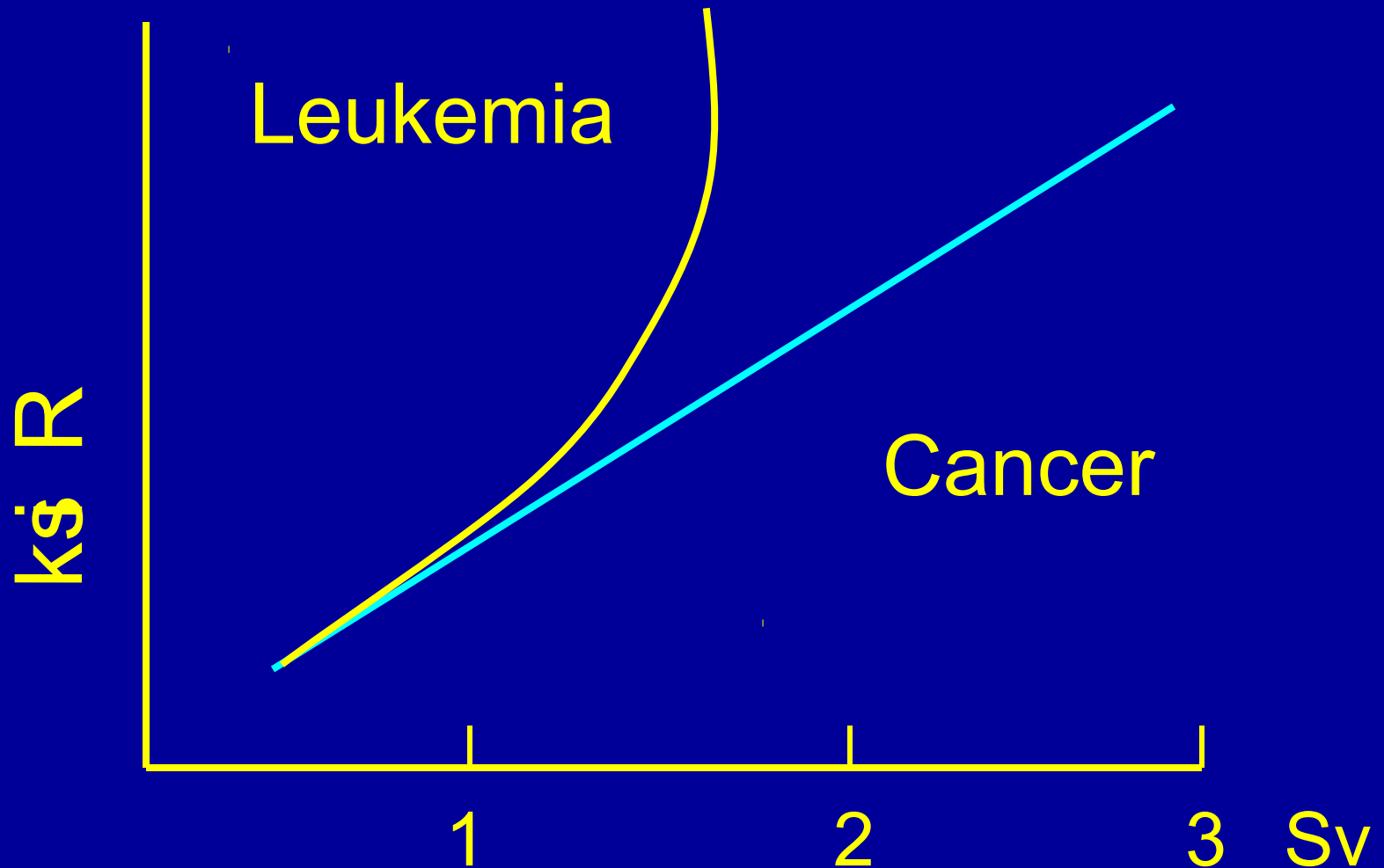
# Dose & Cancer-Risk



# Dose & Cancer-Risk



# Dose vs Cancer-Risk



# Paradoxes

The default safety assumption is a linear, no threshold relationship between exposure to ionizing radiations and cancer. This cannot be proved.

Humans are exposed to a 3-fold difference in background radiation with no detectable difference in cancer risk

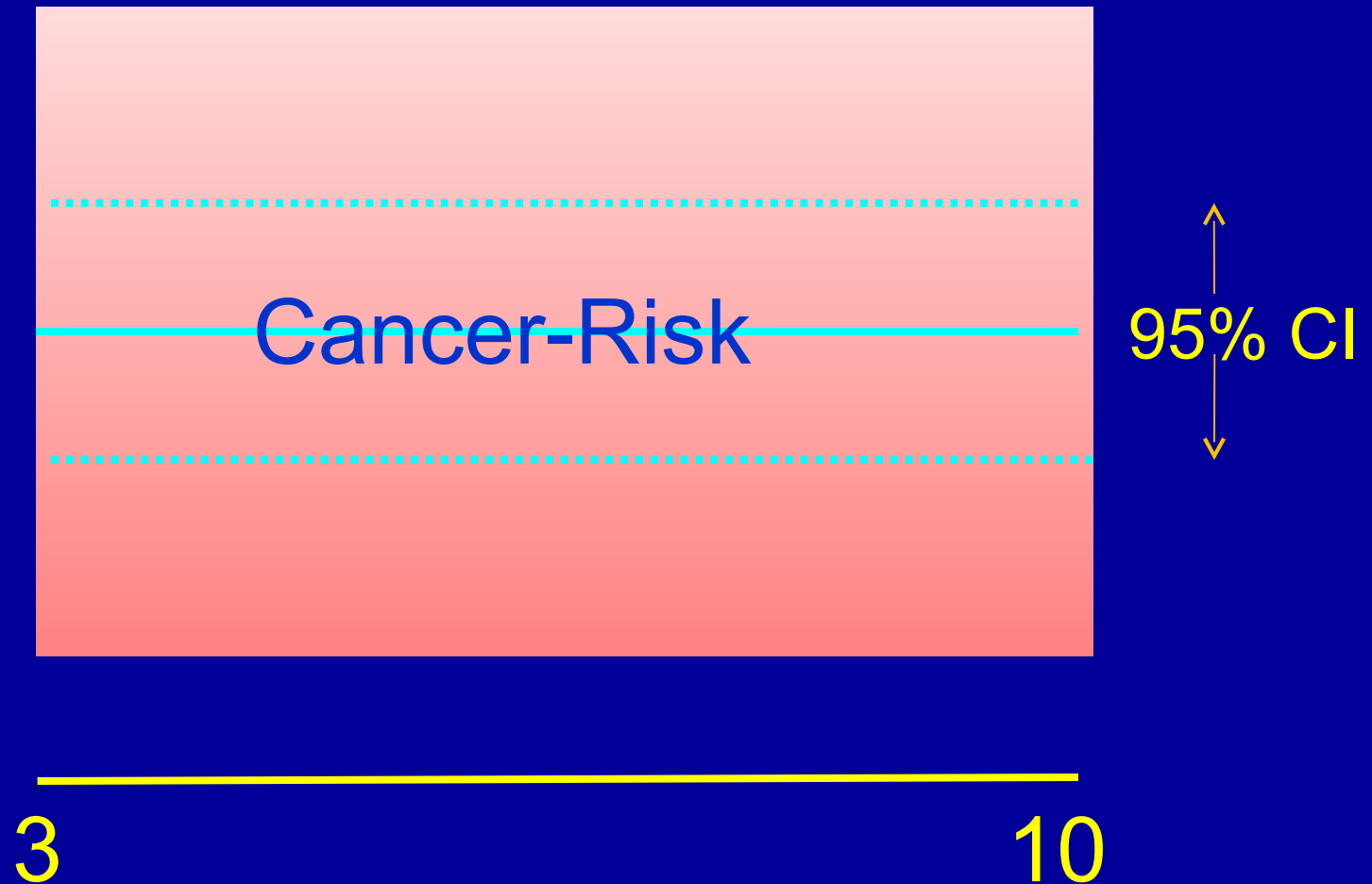
# Background Dose vs Cancer-Risk (mSv)



3

10

# Background Dose vs Cancer-Risk (mSv)



# Nuclear Accidents: Chernobyl & Fukushima

# Similarities and Differences



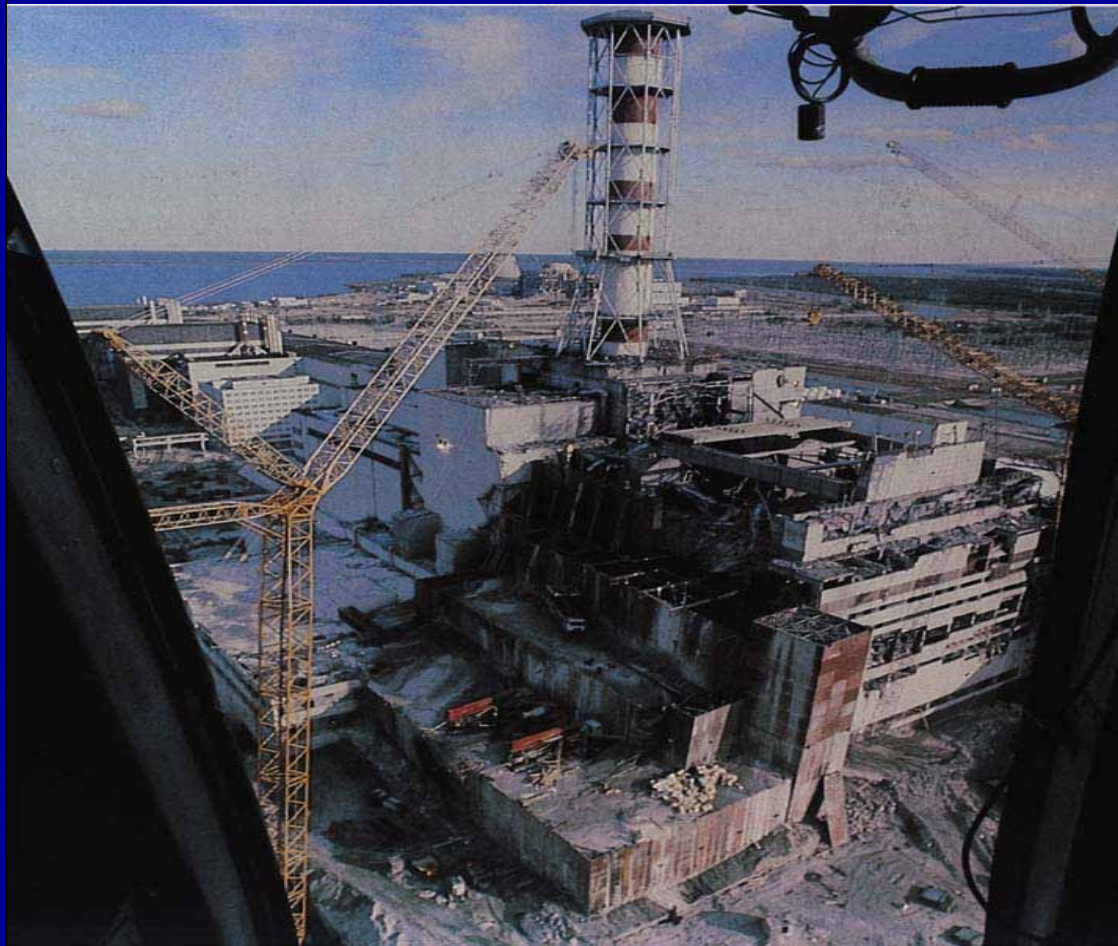
# Similarities and Differences

# Chernobyl NPS (1985)



# Chernobyl NPS Accident

(26 April 1986)



# Chernobyl NPS (LandSat)



# Fukushima





# Fukushima (02/23/11)

Nov. 15, 2009



# Fukushima (03/28/11)





# Fukushima

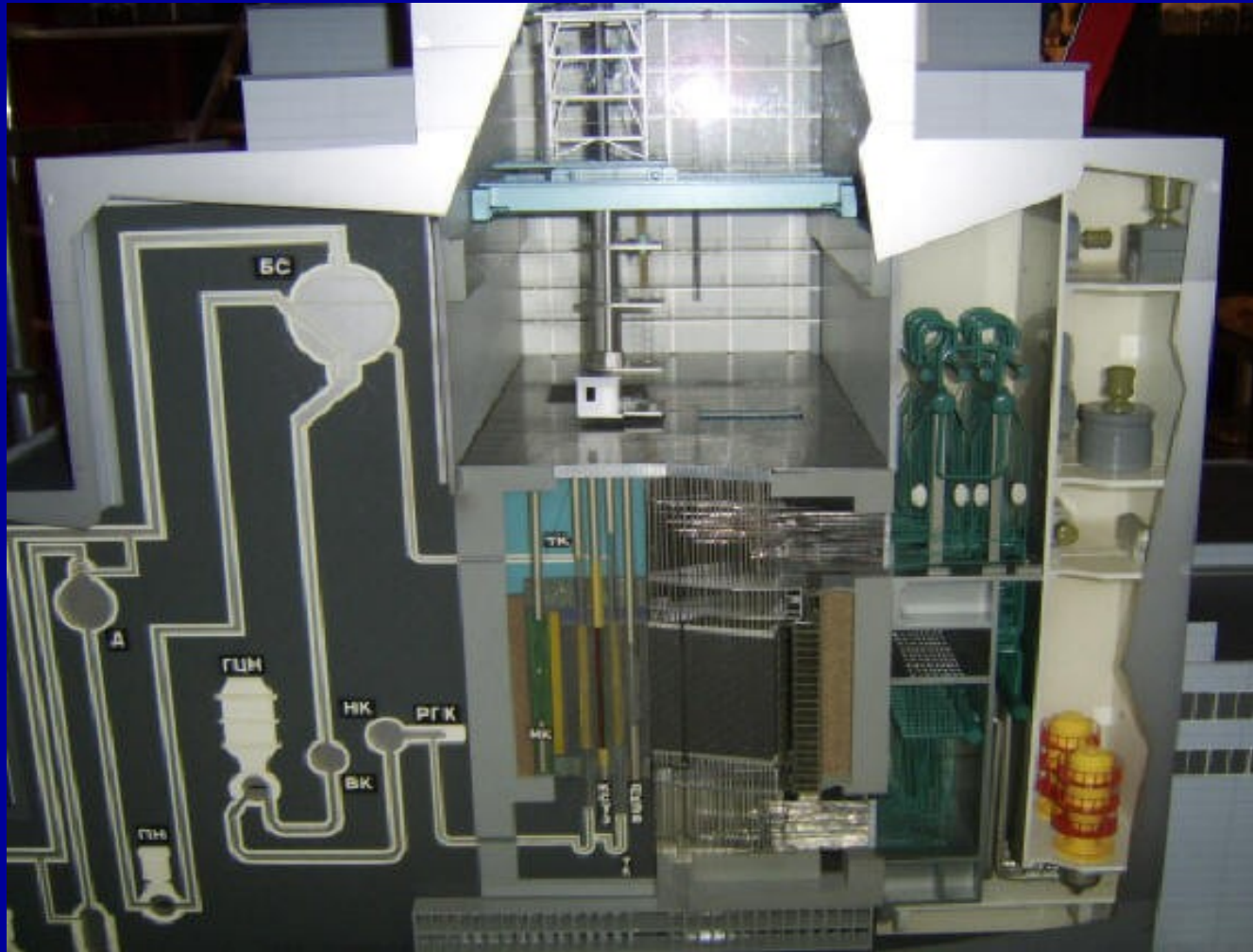




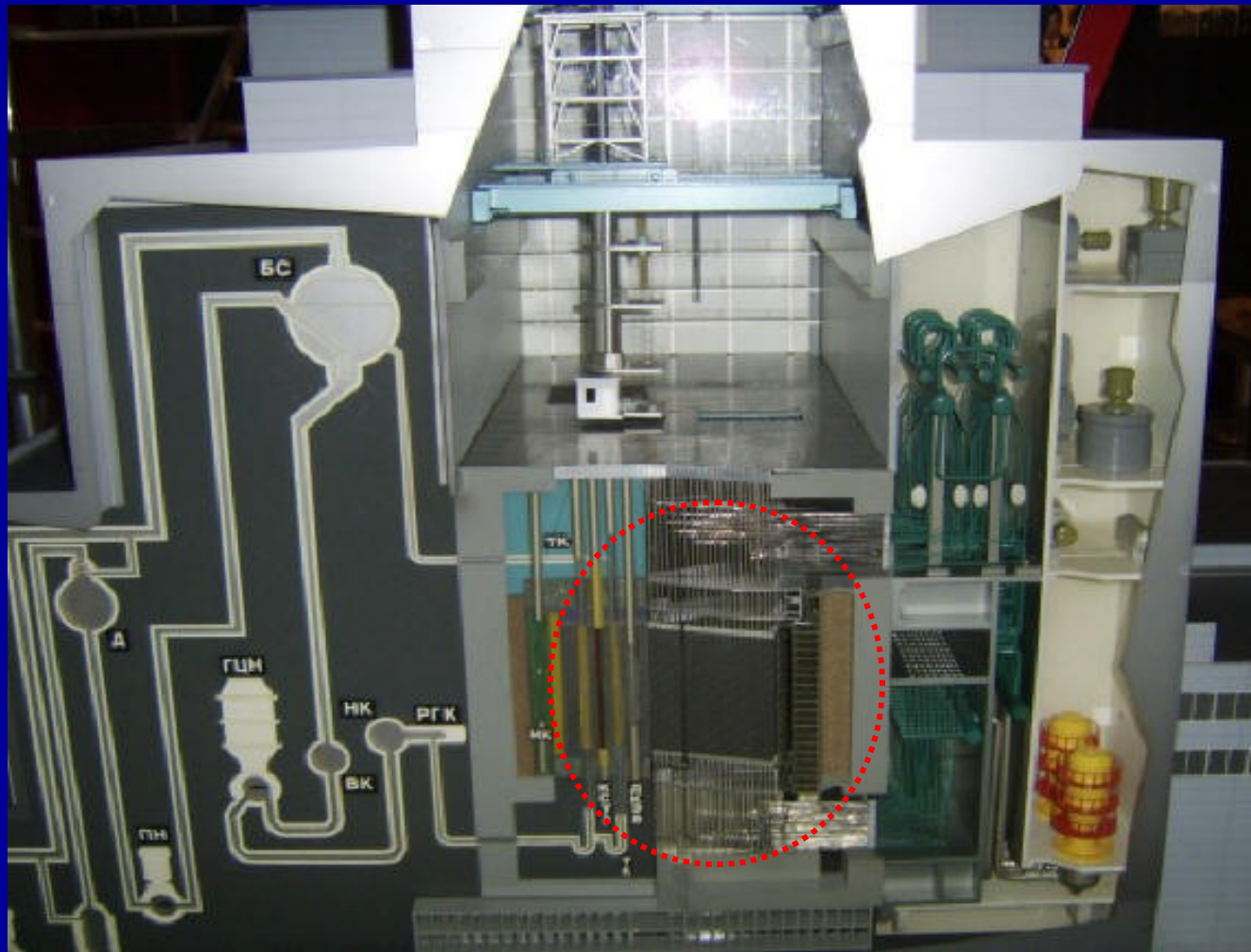
# Similarities and Differences

# Containment

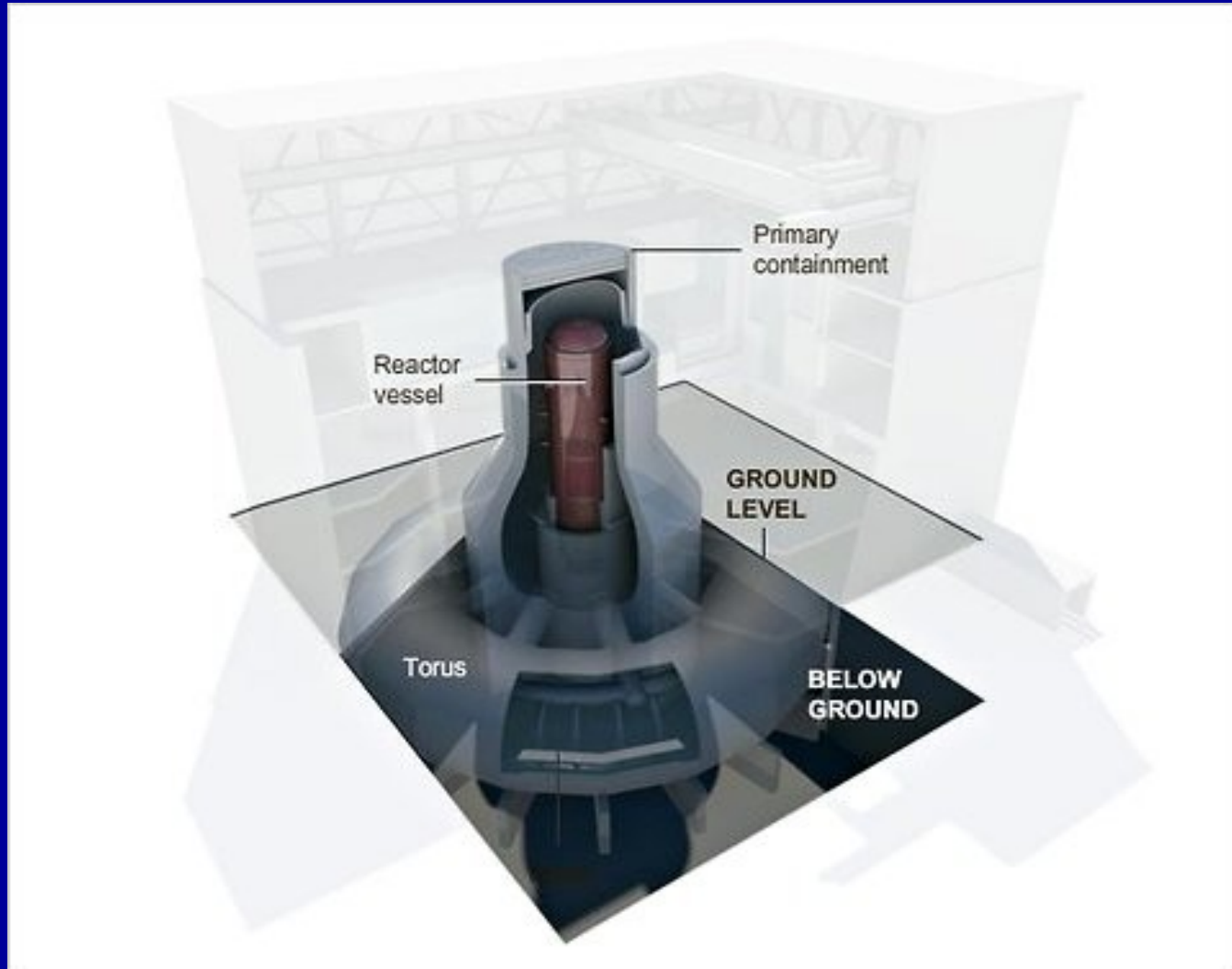
# Chernobyl



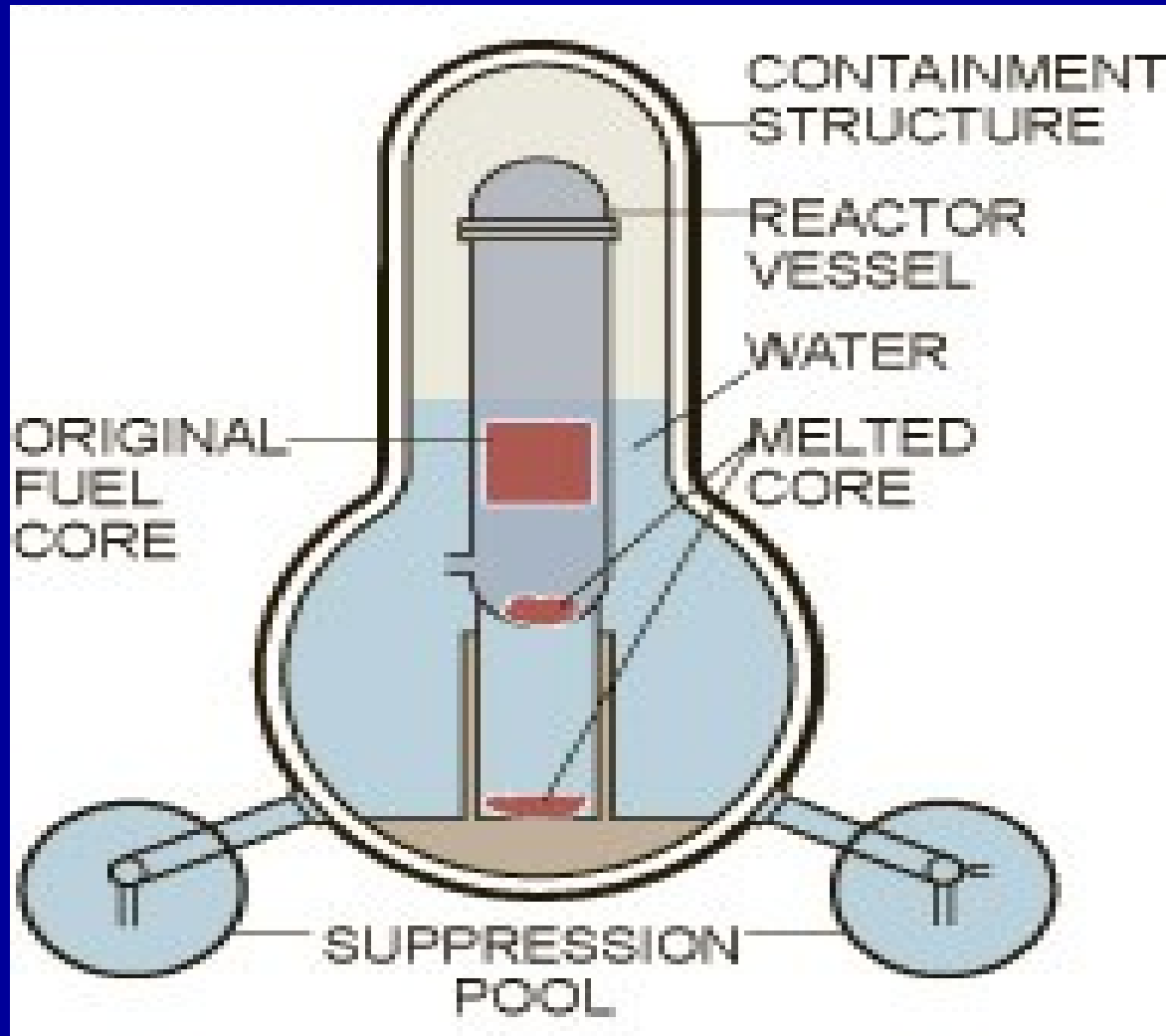
# Chernobyl



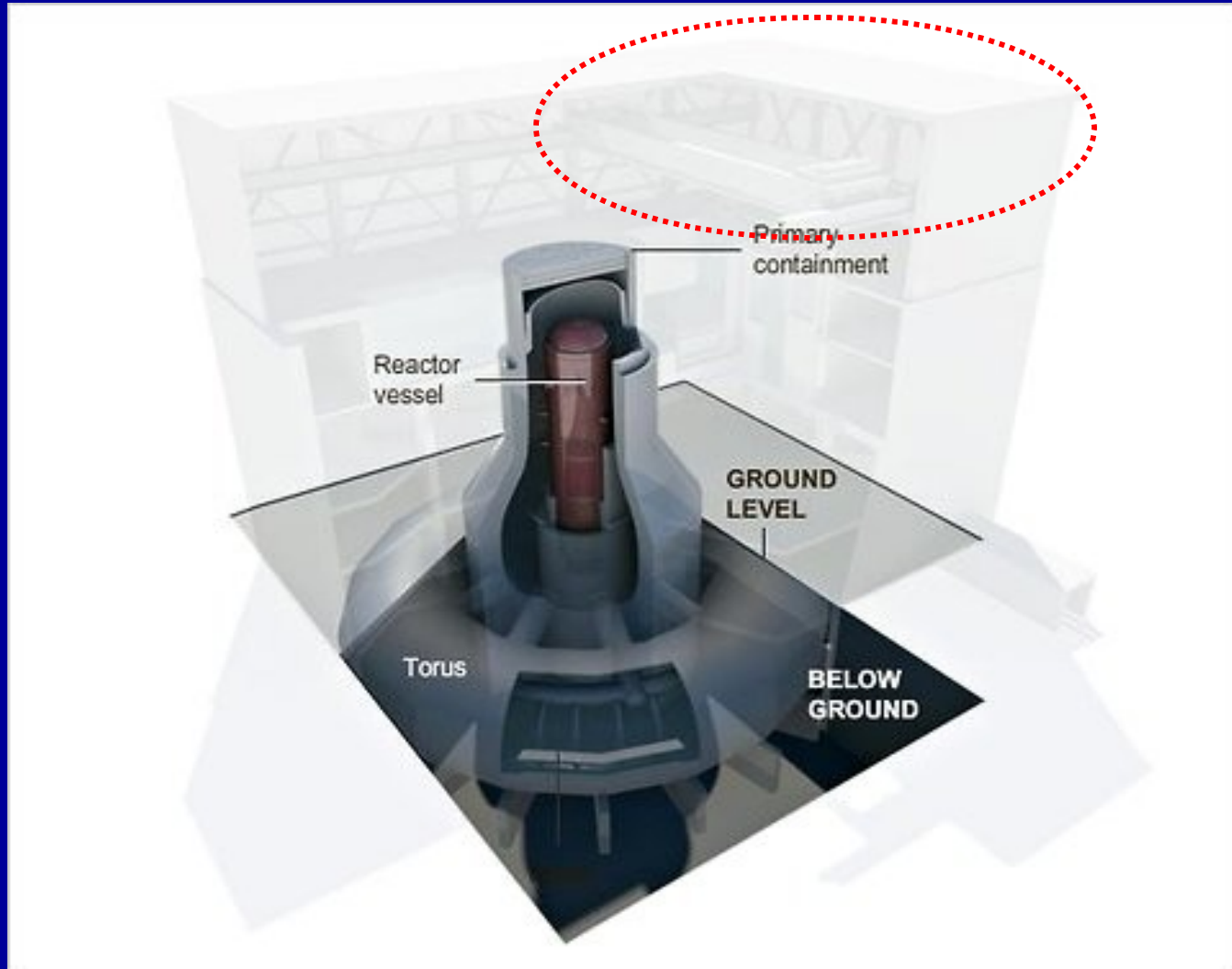
# Fukushima

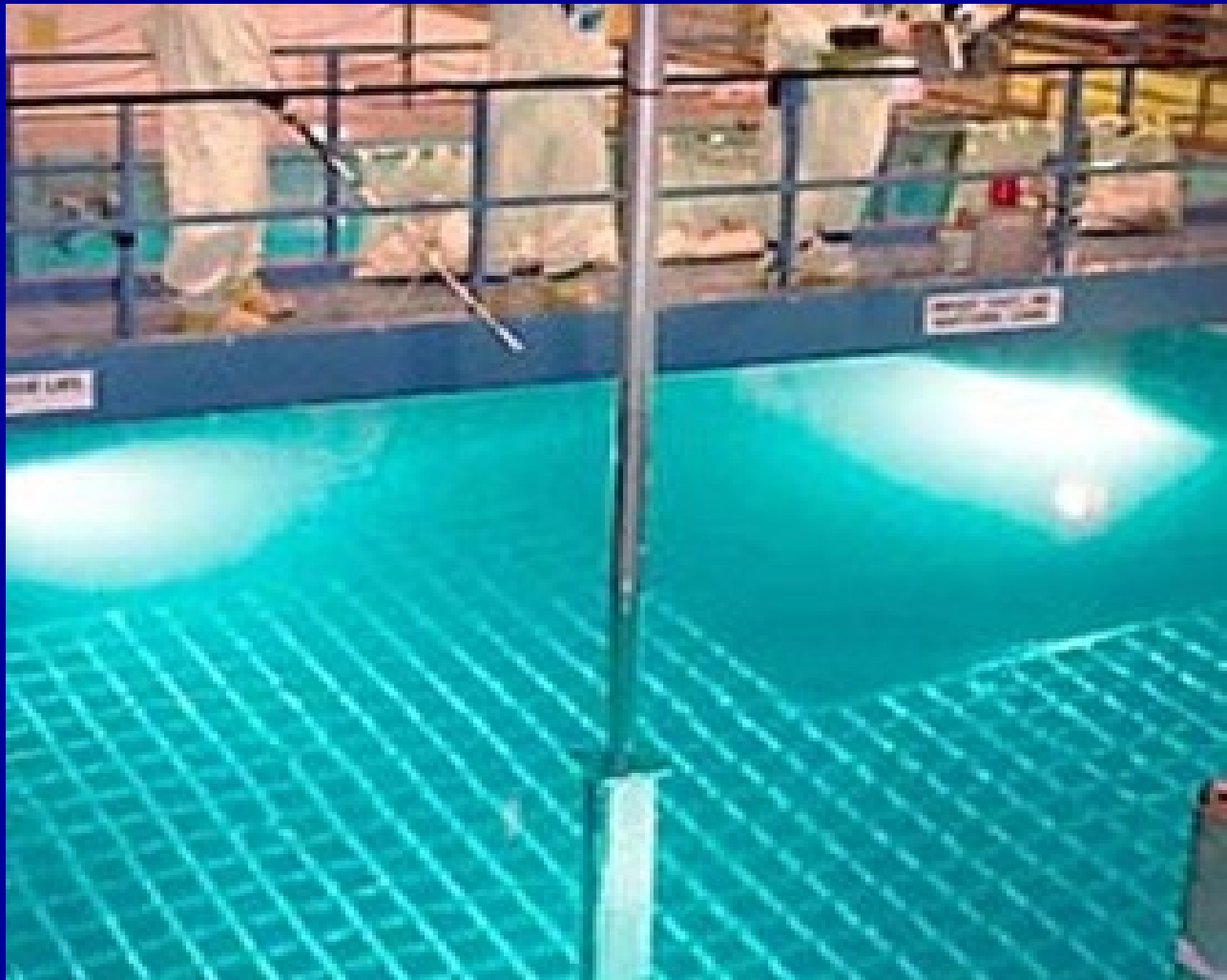


# Fukushima



# Fukushima







# Similarities and Differences

# Radionuclide Release

# Chernobyl Radionuclide Releases (PBq)

	$t_{1/2}$	Activity
$^{131}\text{I}$	8 d	1760
$^{137}\text{Cs}$	30 y	85
$^{133}\text{Xe}$	5 d	6500
$^{90}\text{Sr}$	29 y	10
$^{239}\text{Pu}$	24 y	0.013

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$^{239}\text{Pu}$	24 y	0.013

# Estimated Radionuclide Releases (PBq)

	$^{131}\text{I}$	$^{137}\text{Cs}$
Chernobyl	1760	85

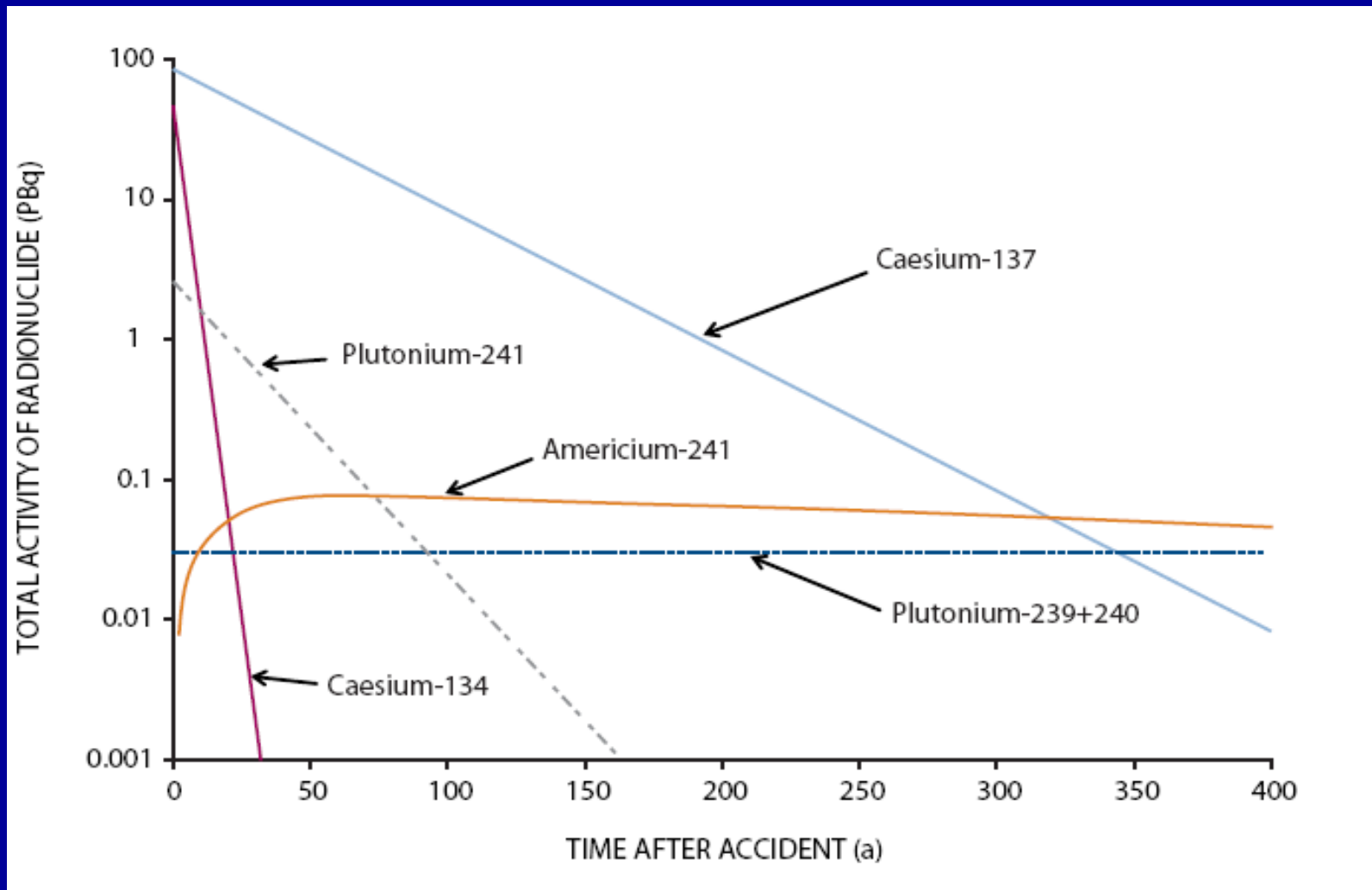
# Estimated Radionuclide Releases (PBq)

	$^{131}\text{I}$	$^{137}\text{Cs}$
Chernobyl	1760	85
Fukushima*	180	9

# Estimated Radionuclide Releases (PBq)

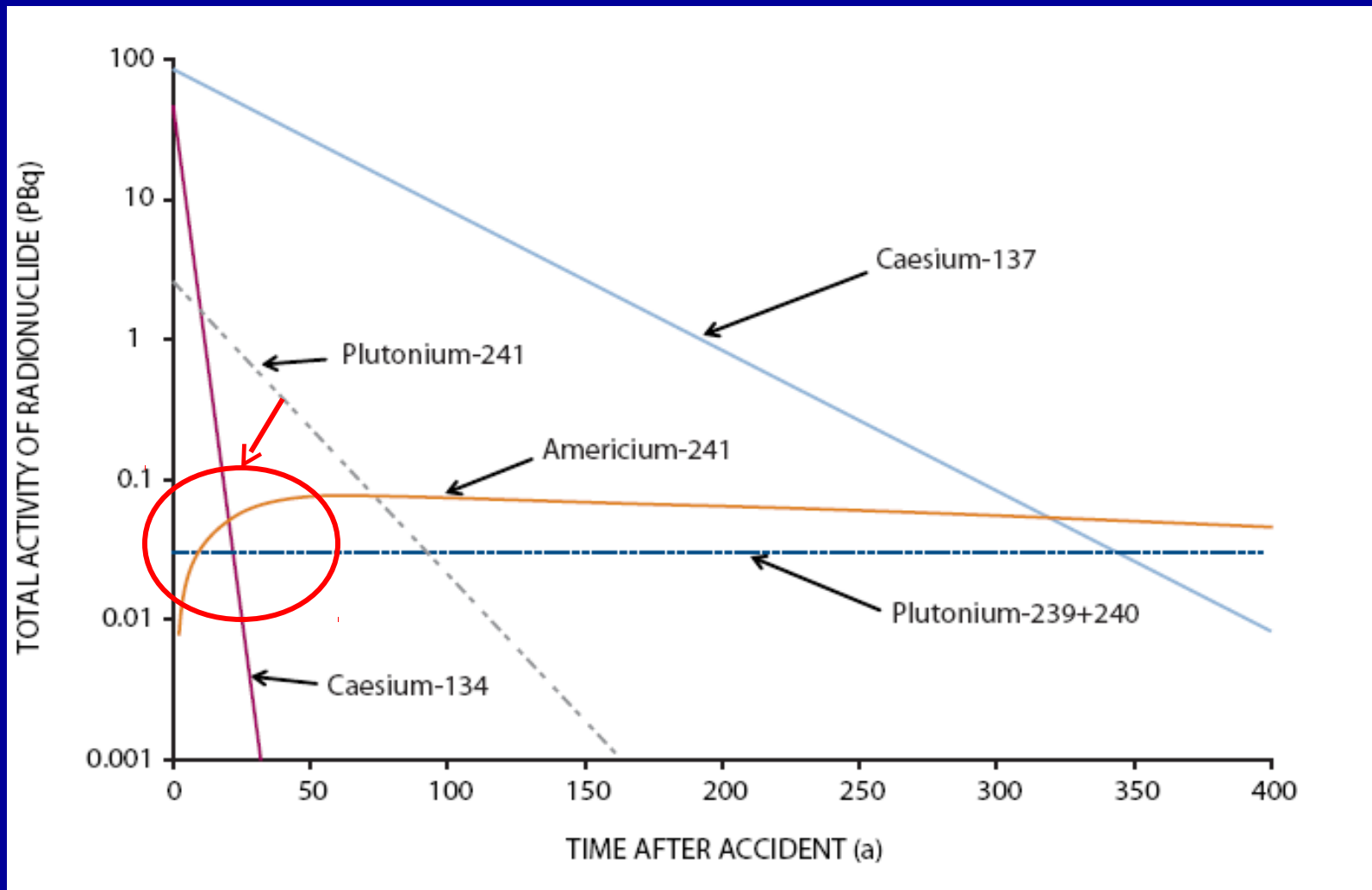
	$^{131}\text{I}$	$^{137}\text{Cs}$
Chernobyl	1760	85
Fukushima*	180	9
A-Bomb Tests	675,000	948

# Environmental Long-Lived Radionuclides





# Environmental Long-Lived Radionuclides



# Temporal Delivery of Dose

50% in the 1<sup>st</sup> 3 months

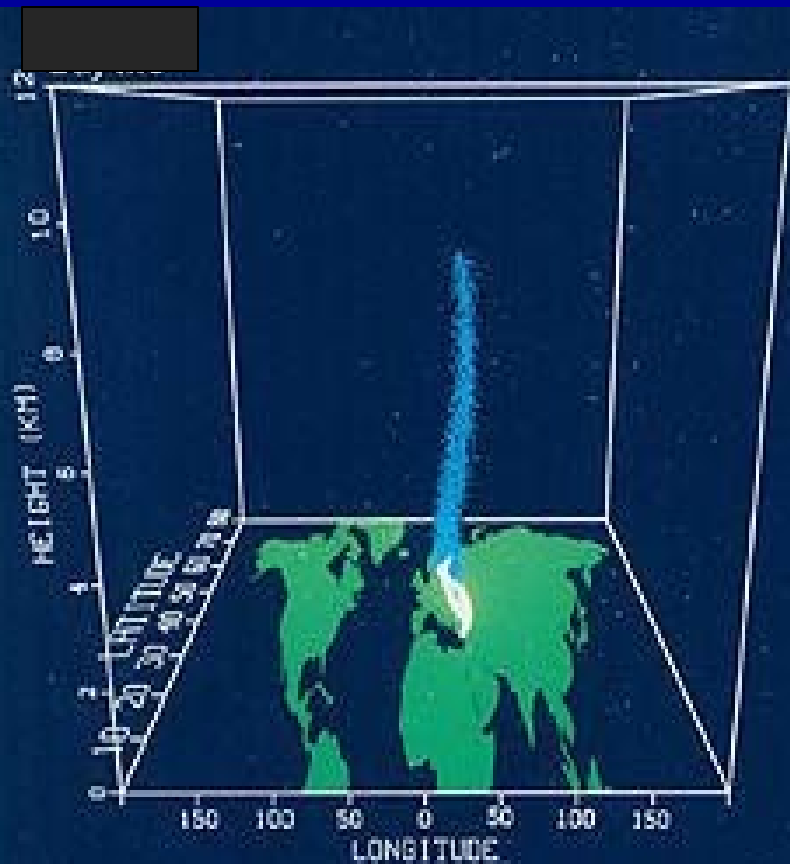
40% over the next 2 years

10% over the next 50 years

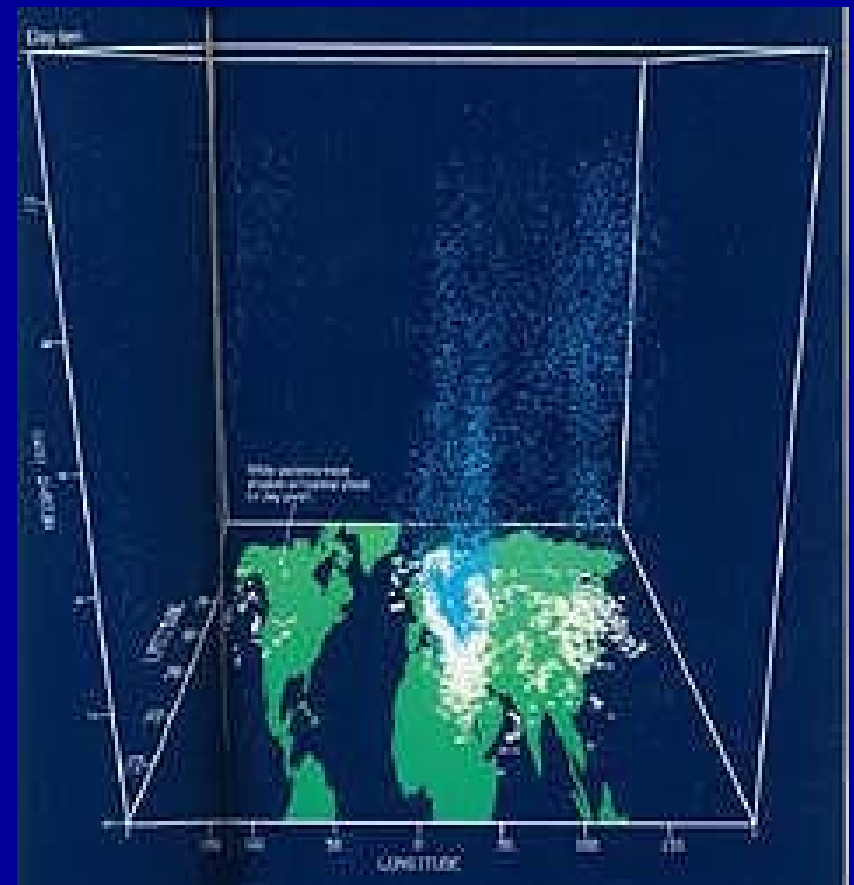
# Similarities and Differences

# Radionuclide Dispersion

# Chernobyl Dispersion of Radioactivity



Day 2

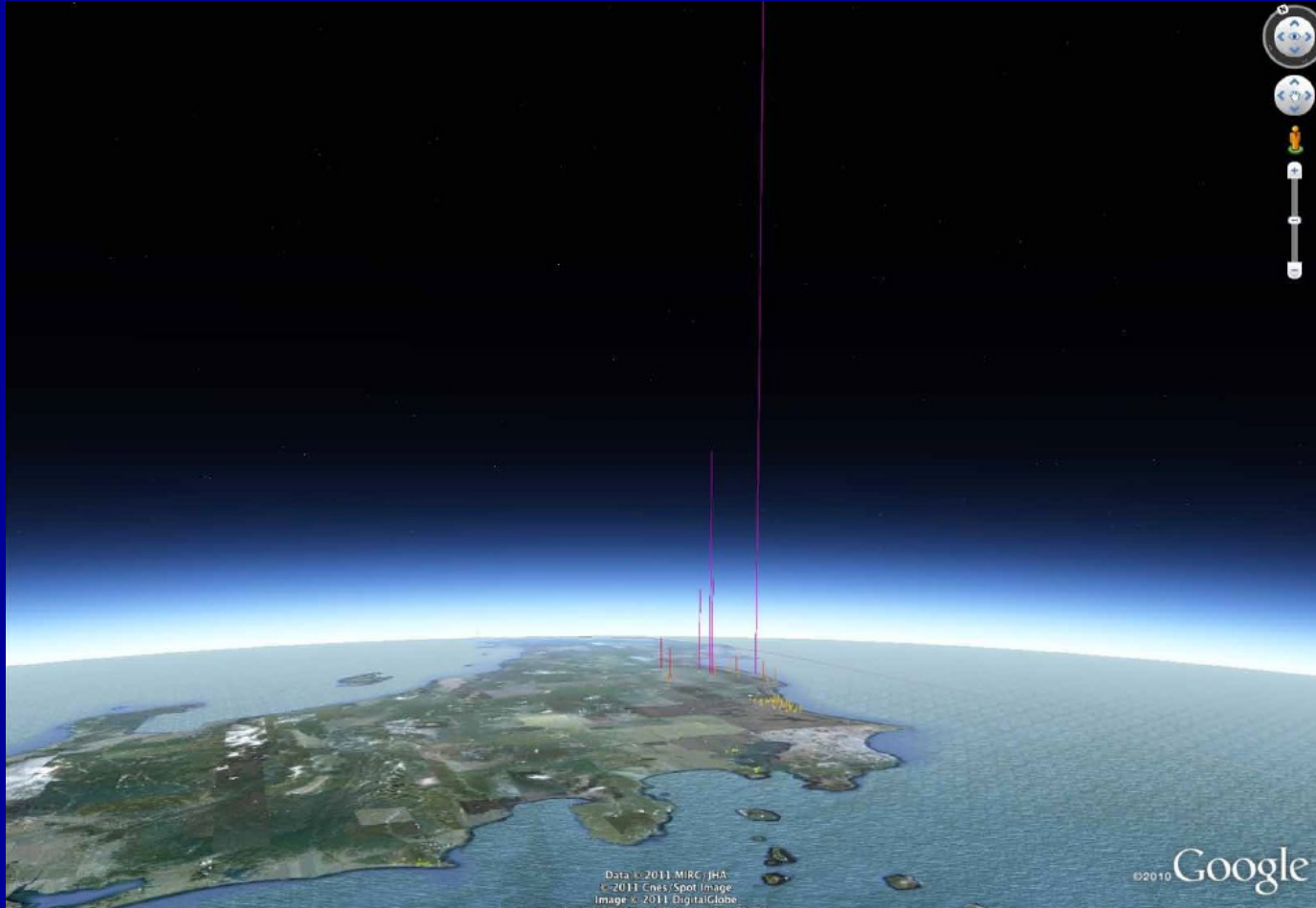


Day 10

# Fukushima



# Fukushima



# Fukushima

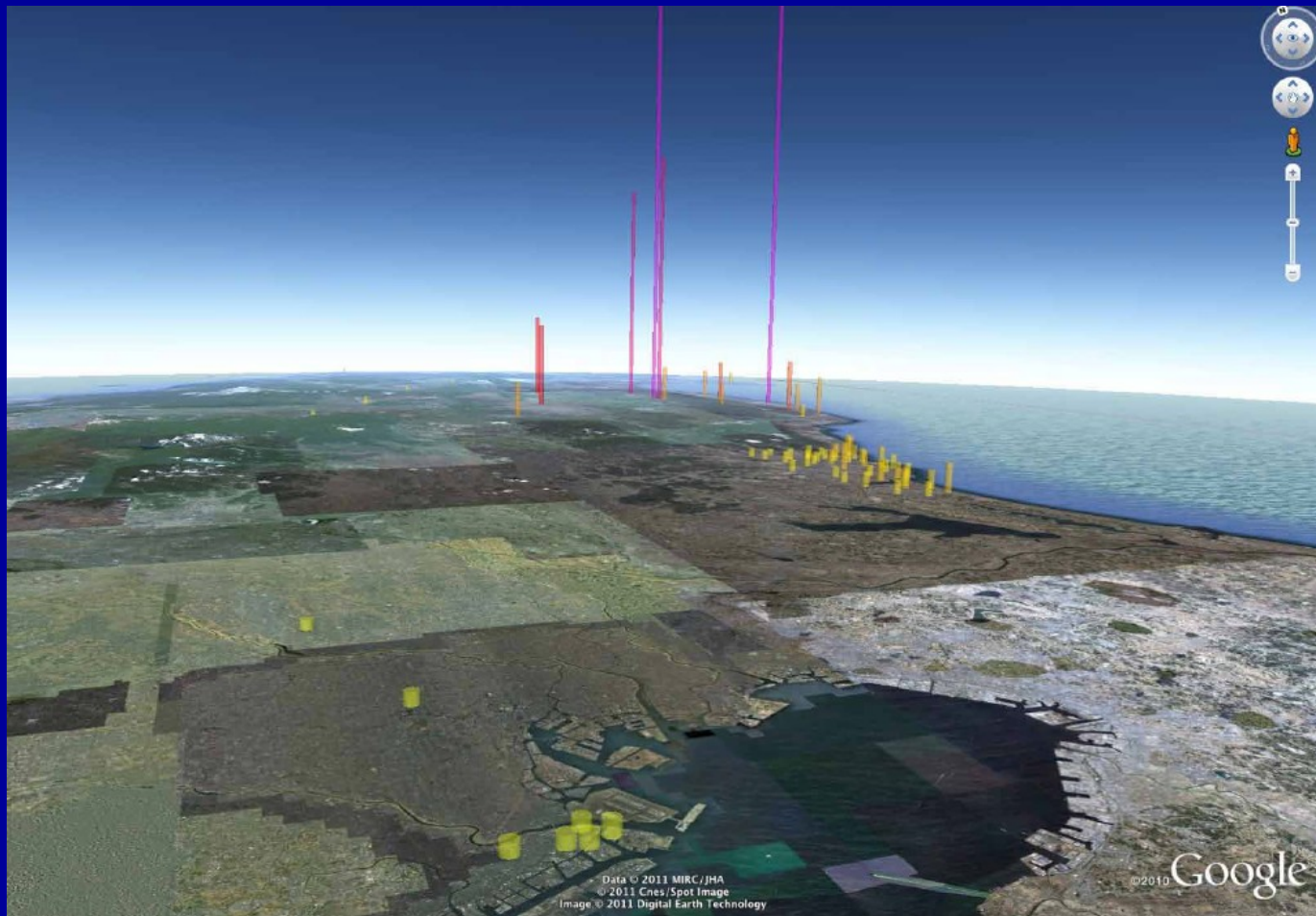


Data © 2011 MIRC/JHA  
© 2011 Cnes/Spot Image  
Image © 2011 DigitalGlobe

©2010 Google

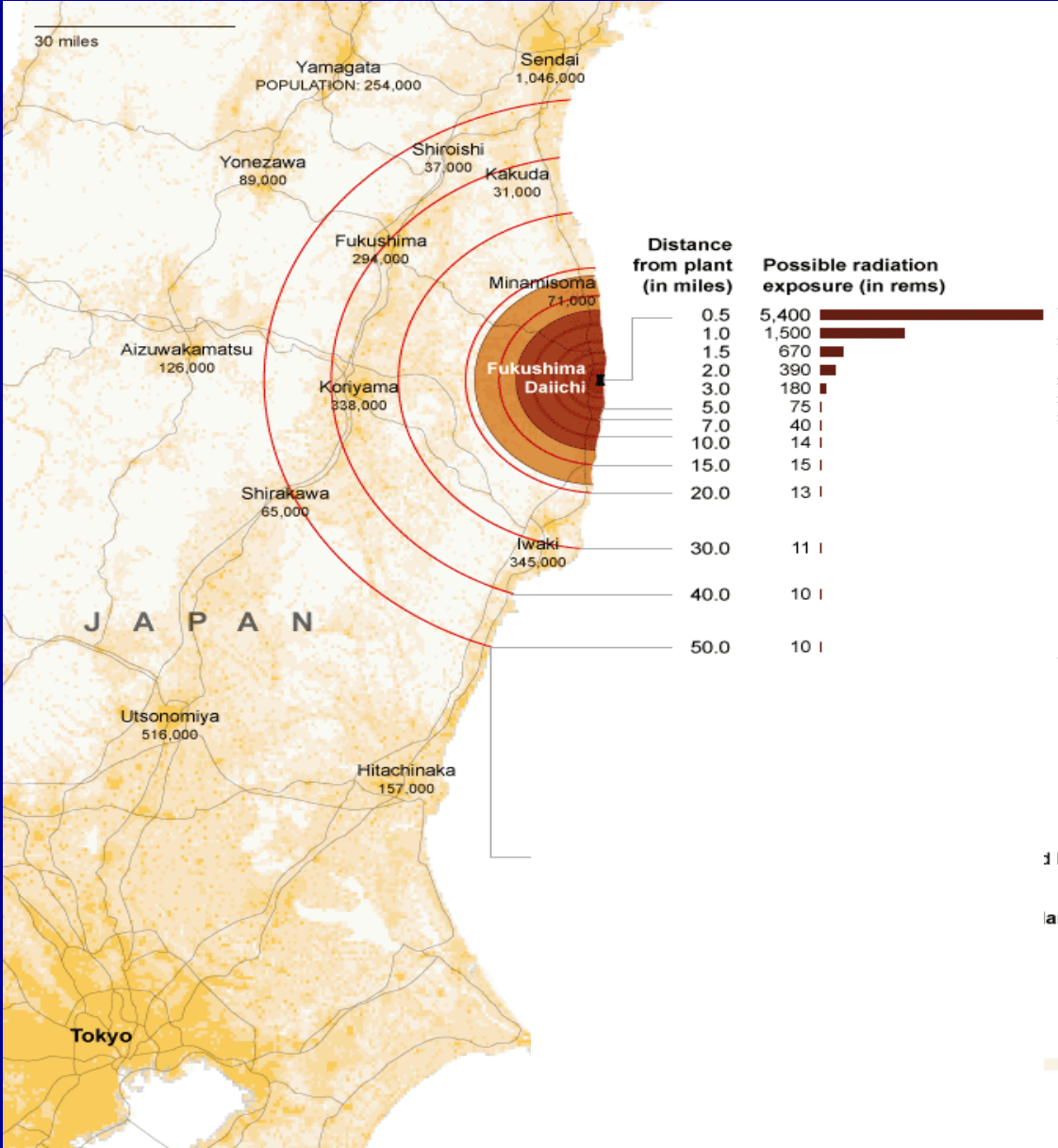


# Fukushima









# Evacuation





# Decontamination



# Decontamination



# Similarities and Differences

# Acute Radiation Syndrome



# Acute Radiation Syndrome

Chernobyl 204

Fukushima 0

# Fukushima



# Consequences of a NPS Accident

Health

Environmental

Social

Economic

Energy Policy

# Consequences of a NPS Accident

Health

Environmental

Social

Economic

Energy Policy

# Exposed Populations

Emergency personnel

Recovery personnel

Evacuated persons

Inhabitants contaminated lands

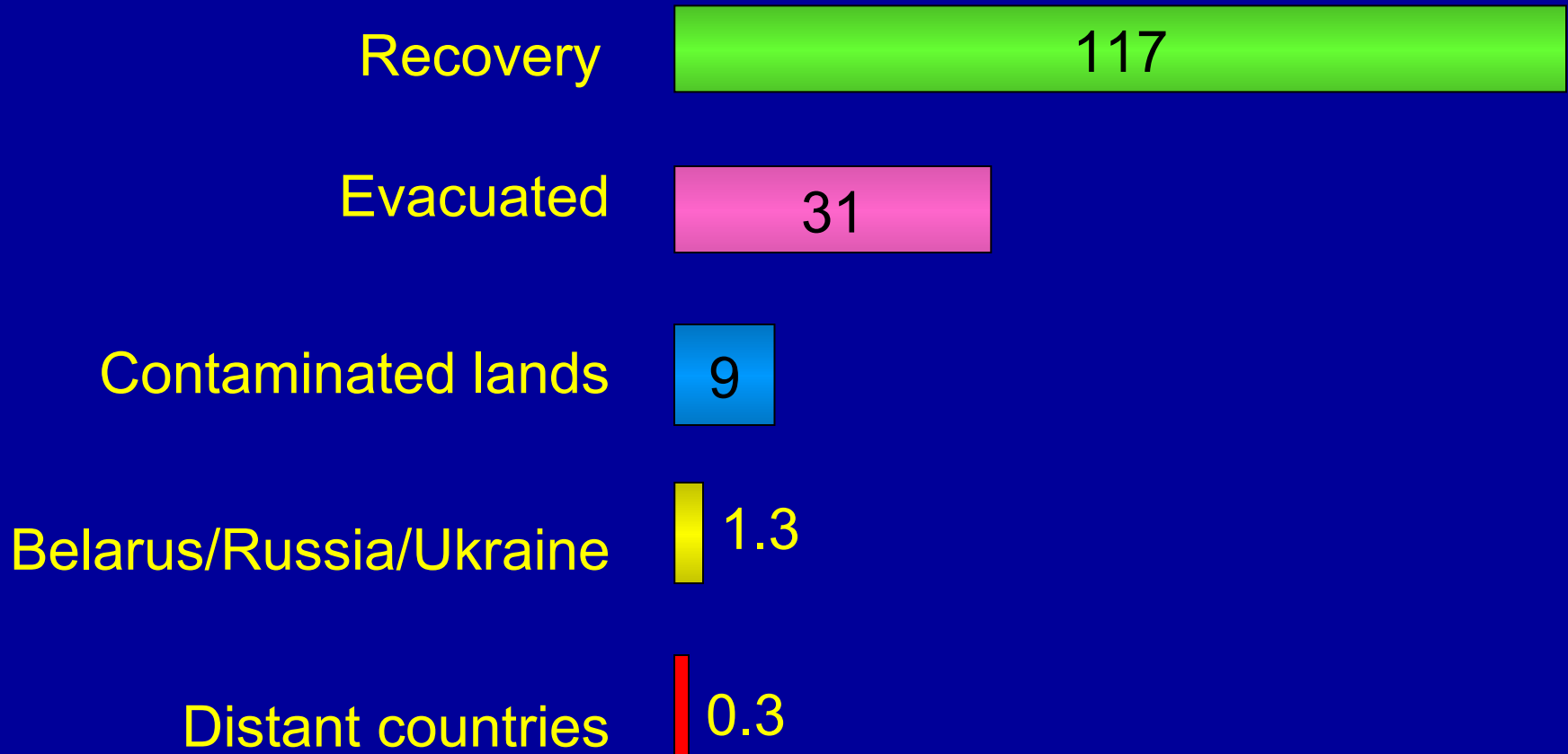
Belarus//Russia/Ukraine

Distant countries

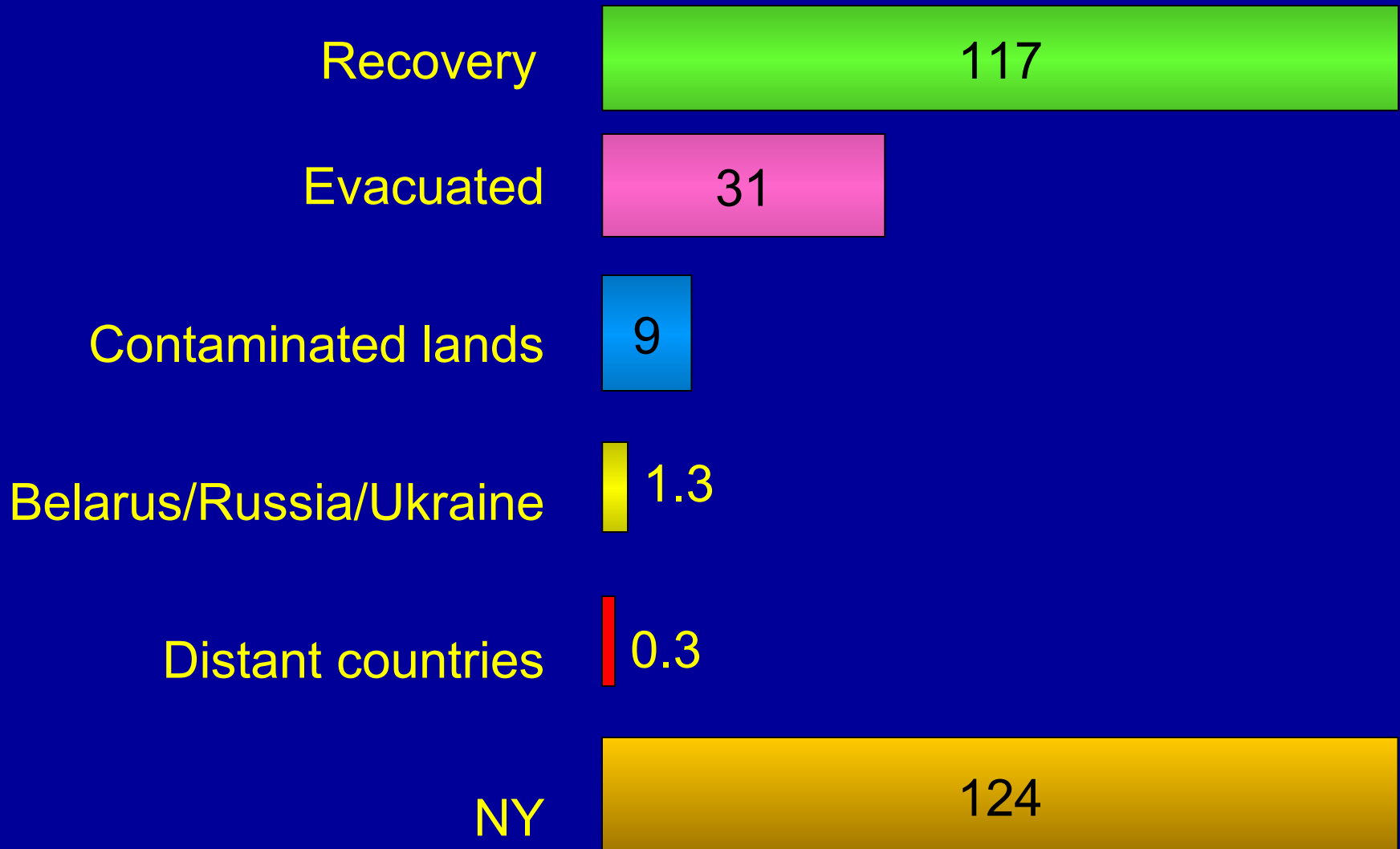
# Exposed Populations

Emergency personnel	1,000
Recovery personnel	530,000
Evacuated persons	115,000
Inhabitants contaminated lands	6.4 M
Belarus/Russia/Ukraine	98 M
Distant countries	500 M

# Dose to Exposed Populations (mSv 1986-2005)



# Dose to Exposed Populations (mSv 1986-2005)





# Chernobyl Collective Effective Dose Estimates (1986-2005 man Sv)

Recovery	61,200
Evacuees	3,600
Contaminated	58,900
B/R/U	125,000
Distant	130,000

# Chernobyl Collective Effective Dose Estimates (1986-2005 man Sv)

Recovery	61,200
Evacuees	3,600
Contaminated	58,900
B/R/U	125,000
Distant	130,000

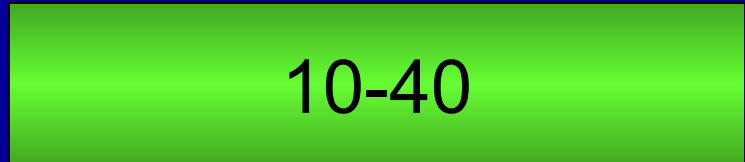
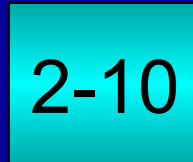
# Latency from Exposure to Cancers from A-Bombs (years)

Leukemia

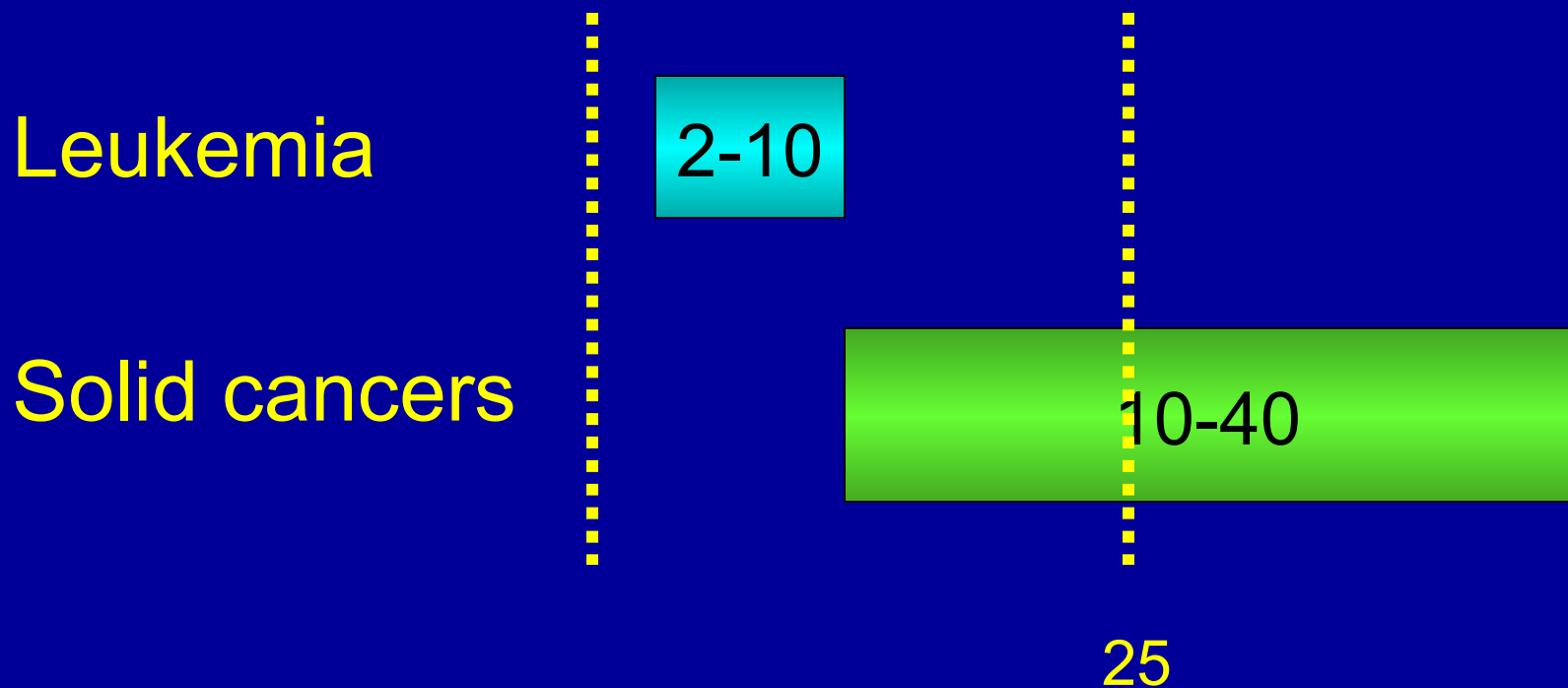
2-10

Solid cancers

10-40



# Latency from Exposure to Cancers from Chernobyl (y)

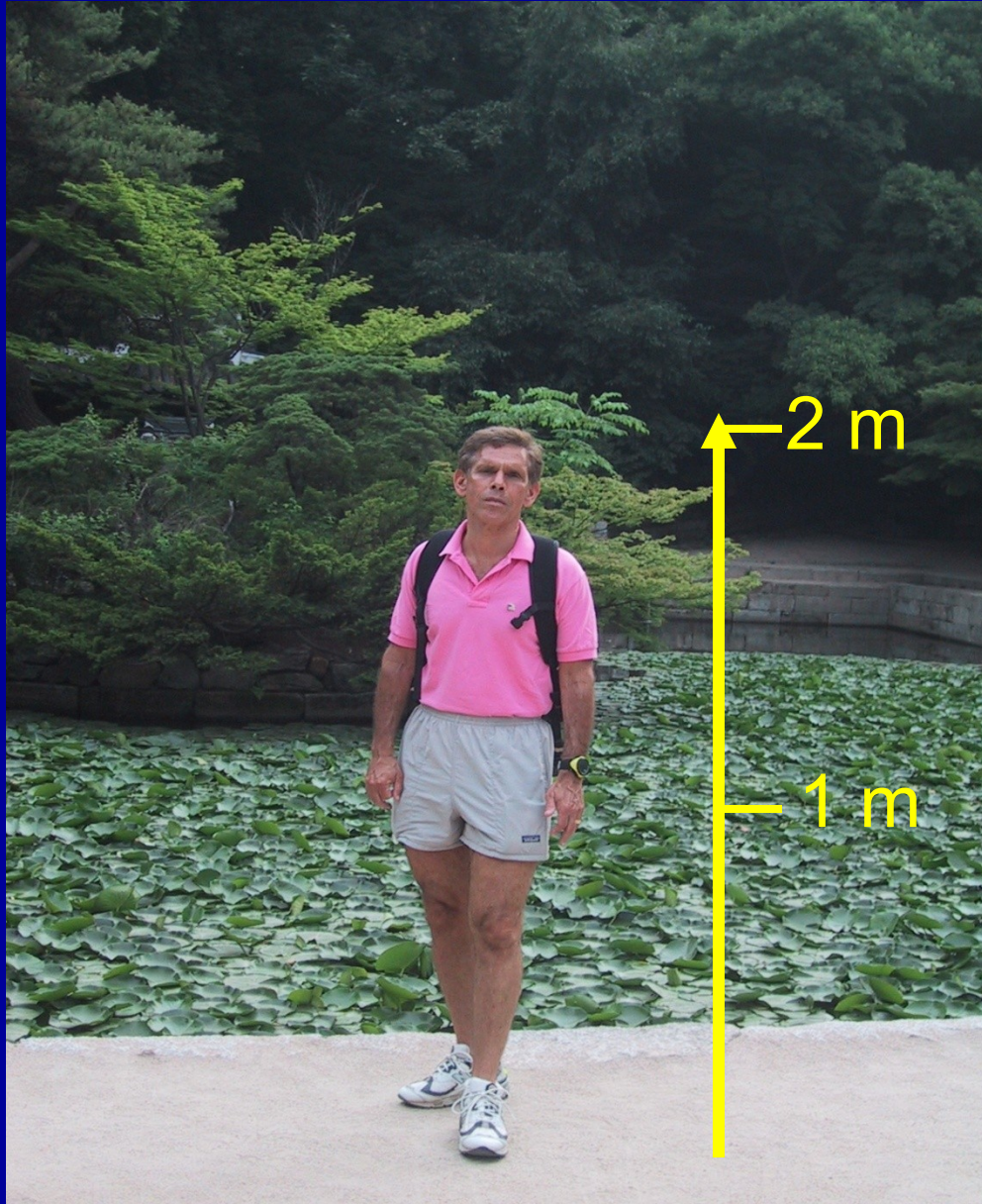


# Chernobyl-Related Cancer Estimates

1986-2005

What is the difference  
between an estimate and a  
guess?

How tall is Bob Gale?





Is Bob Gale's wife beautiful?

Compared to what?

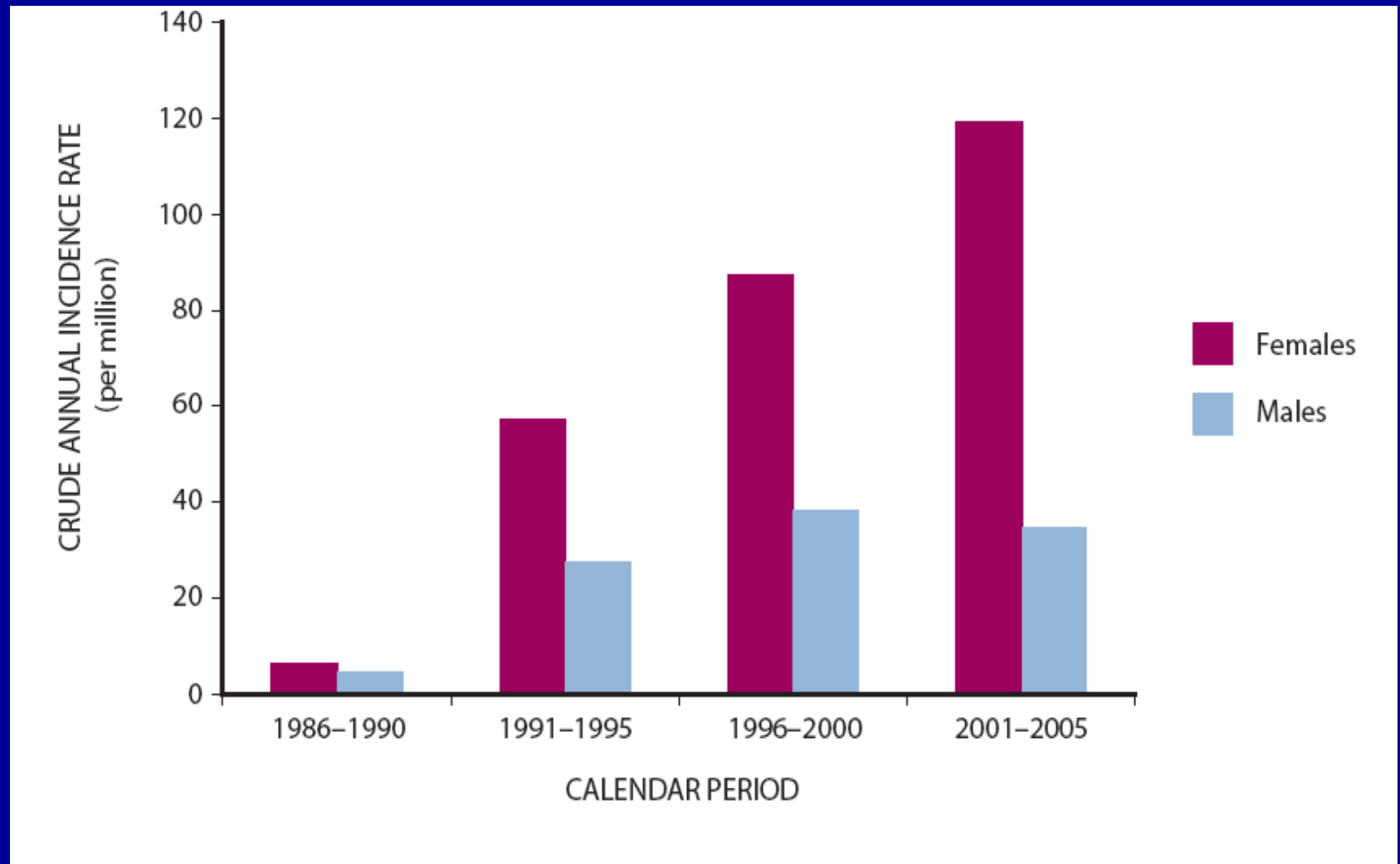
How can I know, I've never  
seen her?



# Chernobyl-Related Cancer Estimates

1986-2005

# Thyroid Cancers in Children



# Cancer Incidences (50 years)

5,000

0-15,000

42,000,000

# Chernobyl Conclusions

Markedly increased thyroid cancers

No convincing increase in leukemia\*

No convincing increase in other cancers

No birth defects

No genetic abnormalities

# Estimated Cancer Incidences Fukushima (50 years)

500

0-1,500

20,000,000



# Fukushima Estimates

Few, if any, thyroid cancers

Few, if any, leukemias

Few, if any, other cancers

No birth defects

No genetic abnormalities



# Energy-Related Deaths 1986-2065

Chernobyl

5,000

Coal

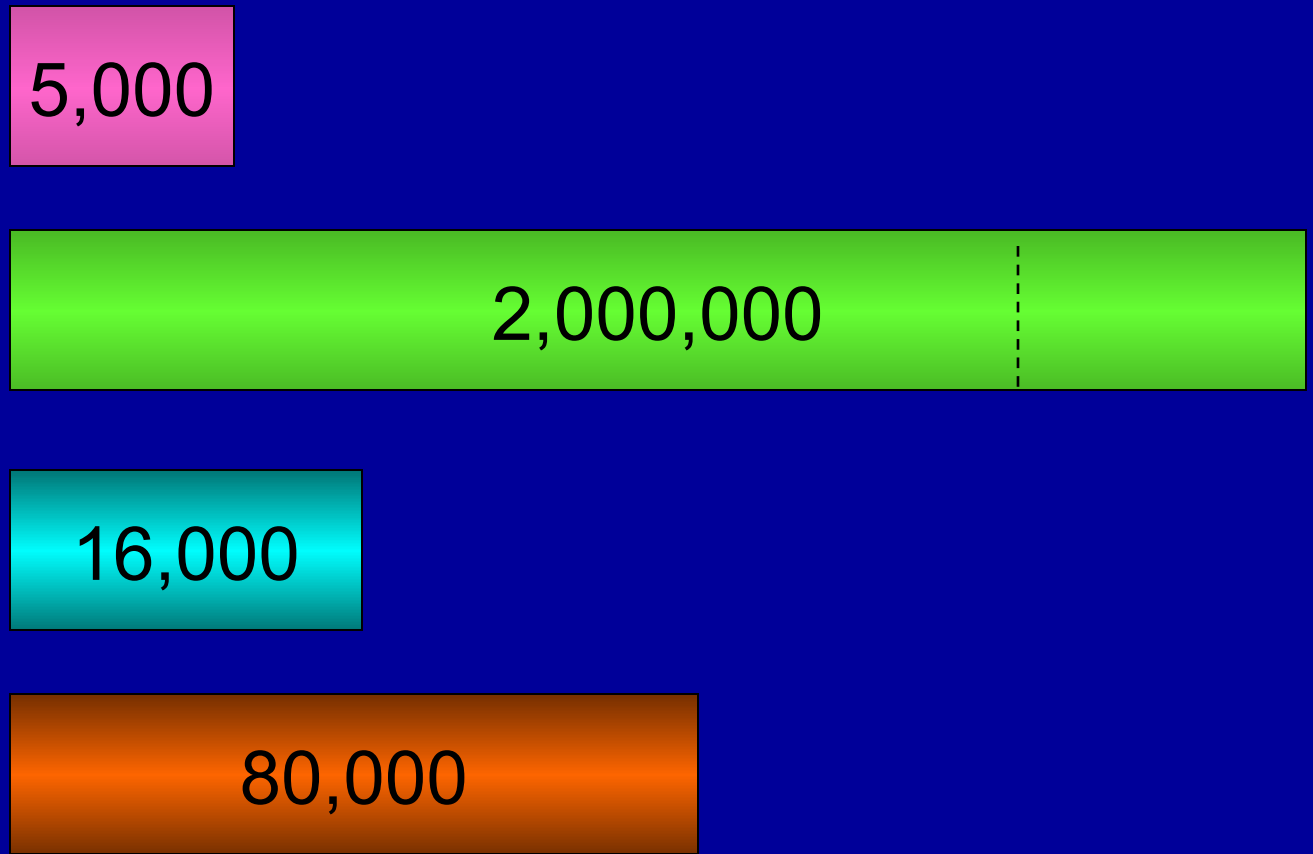
2,000,000

Global Warming

16,000

Wars

80,000



# Collaborators

Alexander Baranov

Angelina Guskova

Andrei Vorobiev

Georgi Selidovkin

Hideke Kodo

Hakumi Oh

Shigetaka Asano

Shigeru Chiba