Module 9
Risk Estimation; Background Radiation (Natural and Artificial)

- sources of background radiation
- various risk models.
- estimating risk and on the sources of background radiation, both artificial and natural
- response to low-level radiation.
- personal background radiation level.

An Organism's Response to Radiation

- The dose response can be linear or nonlinear and threshold or non-threshold.
- To observe effects due to low dosages, very large numbers of animals need to be irradiated.
- This is necessary to obtain reasonable statistics on these rare events of radiation effects at low dose is based on studies of large numbers of animals at higher doses and extrapolated to the low dose using a linear, non-threshold mode estimate the response at lower doses.
- The Committee on Biological Effects of Ionizing Radiation (BEIR) has found that after reviewing the literature extensively, a quadratic non-threshold behavior described the data better than a linear, nonthreshold response at low energies.
- Since the linear, non-threshold response is a conservative estimate of the response, this has been kept as the standard for estimation of risk at low doses.

Risk Models

(absolute, relative, and time-dependent relative risk models)

- In *absolute risk* model radiation induces a group of cancers above and beyond the natural incidence and is unrelated to it.
- In the *relative risk* model, the effect of radiation is to increase the natural incidence of cancer at all ages subsequent to exposure by a given factor.
- This model predicts a large excess number of cancers appearing late in life after irradiation.
- In the *time-dependent relative-risk* model, it is assumed that the excess incidence of cancer is a function of dose, (dose)2, age at exposure, and time since exposure.
- This model has been useful in understanding epidemiology data from such events as the Hiroshima and Nagasaki atomic bomb exposures and the exposures from the Chernobyl disaster.

Relative Risk

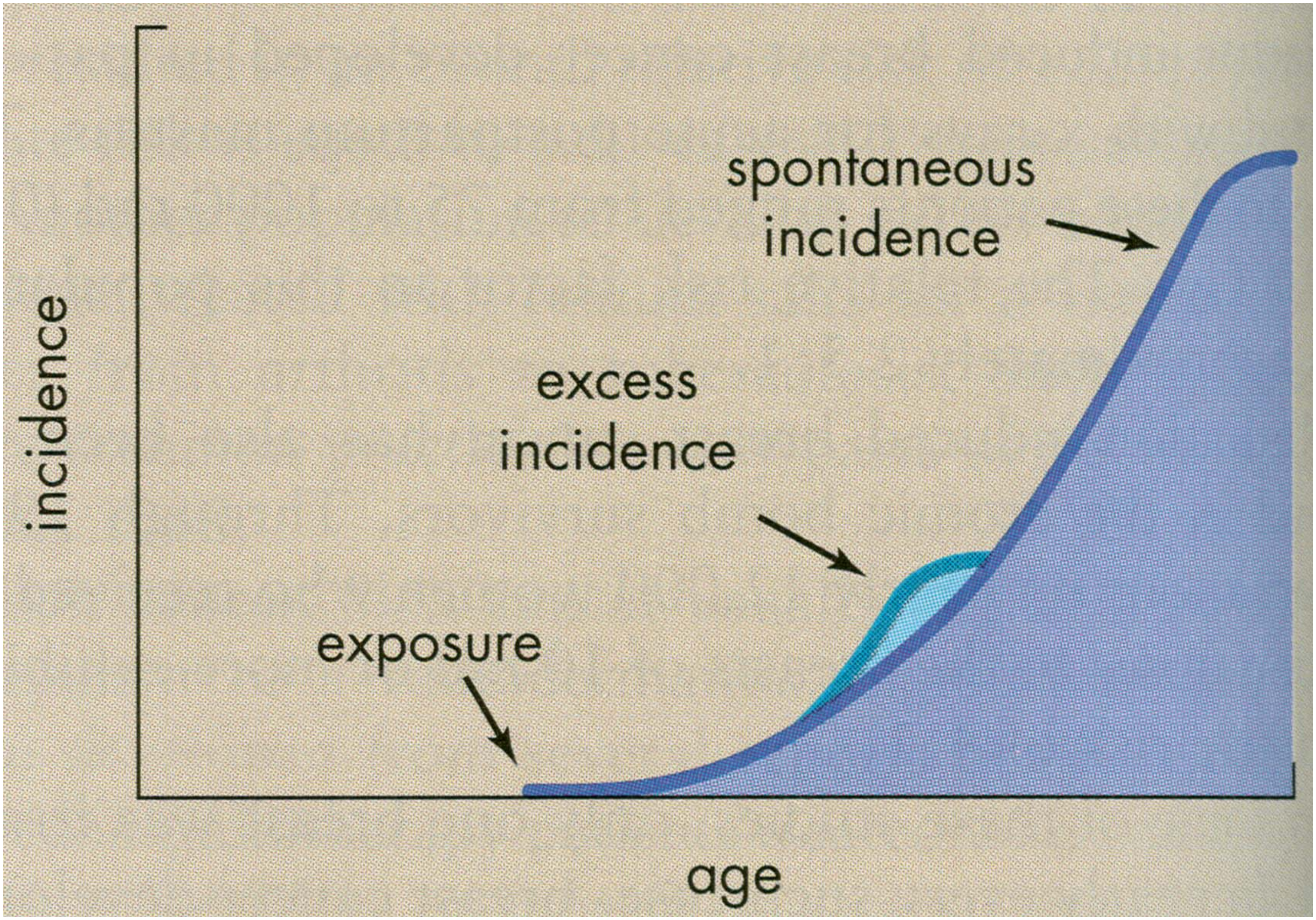
Relative risk = observed cases/expected cases

- The relative risk is computed by comparing the number of persons in the exposed population showing a late effect with the number who developed the same late effect in an unexposed population.
- A relative risk of 1 indicates no risk at all.
- A relative risk of 1.75 would indicate the frequency of the late response is 75% higher in the irradiated population.
- A relative risk of less than 1 indicates a protective benefit.

Risk Comparison

- In a study of radiation-induced leukemia following diagnostic levels of radiation, 237 cases were observed in 100,000 people.
- The normal incidence of leukemia in the United States is 150 cases per 100,000. What is the relative risk of the radiation-induced leukemia?
- Answer: Relative Risk = Observed/Expected = 237/150
- =1.58 (i.e., 58% higher in irradiated population)
- Excess risk can also be calculated. *Excess risk* is the difference between the observed cases and the expected cases.
- The excess cases found are assumed to be radiation induced.
- Excess risk = 237-150 = 87

Time Dependent Risk



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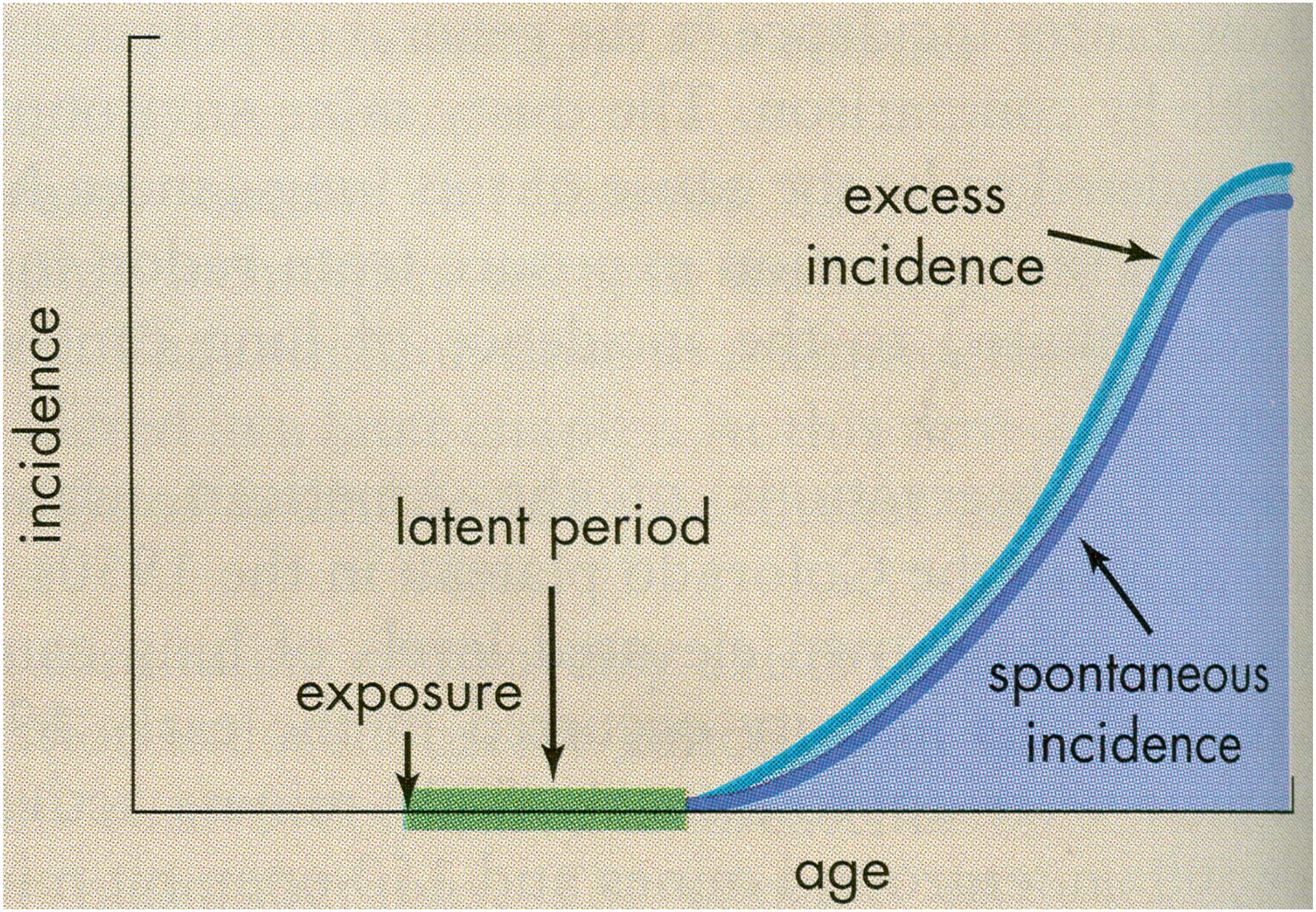
Absolute Risk Model



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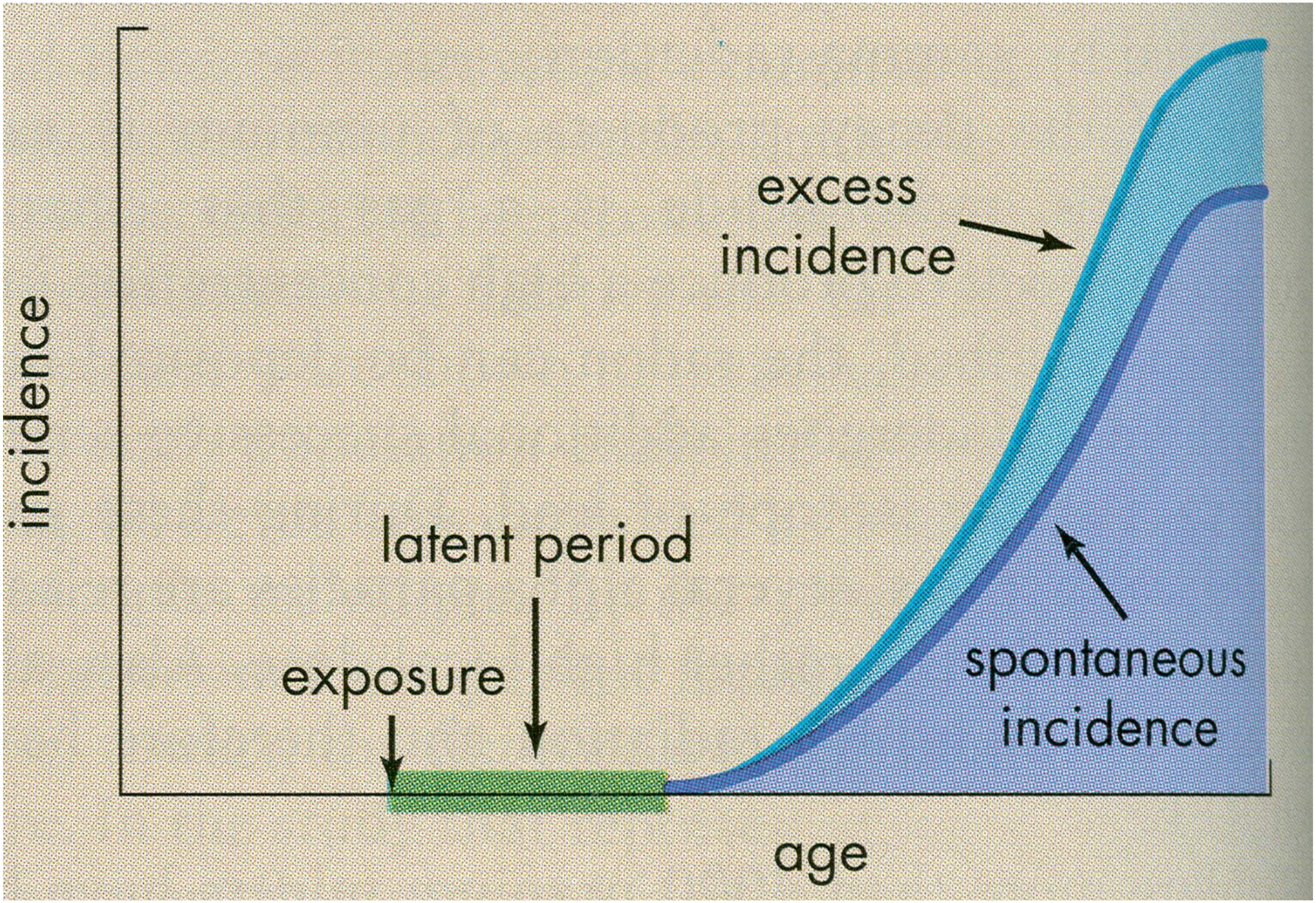
Relative Risk Model



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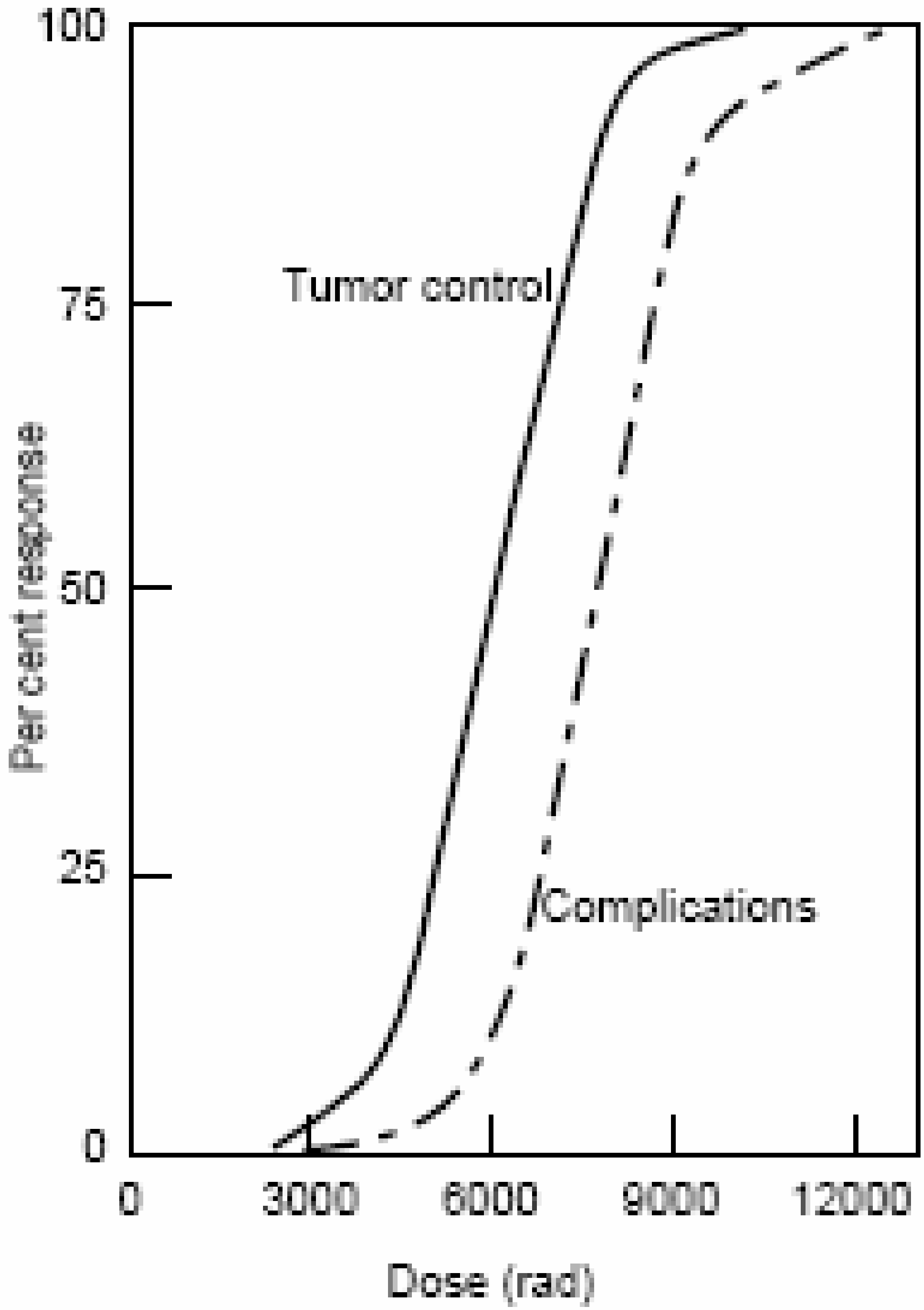
Relative contribution of individual tissues and organs to the probability of fatal cancer and total detriment.

Tissues and organs	Probability of a fatal cancer (10^{-4} rem-1)		Total Detriment x10^{-4} /rem^{-1}	
	Whole Population	Radiation Workers	Whole Population	Radiation Workers
Bladder	0.30	0.24	0.29	0.23
Bone Marrow	0.50	0.40	1.04	0.83
Bone Surface	0.05	0.04	0.07	0.06
Breast	0.20	0.16	0.36	0.29
Esophagus	0.30	0.24	0.24	0.19
Colon	0.85	0.68	1.03	0.82
Liver	0.15	0.12	0.16	0.13
Lung	0.85	0.68	0.80	0.64
Ovary	0.10	0.08	0.15	0.12
Skin	0.02	0.02	0.04	0.04
Stomach	1.10	0.88	1.00	0.80

Risk Factor of Life Shortening

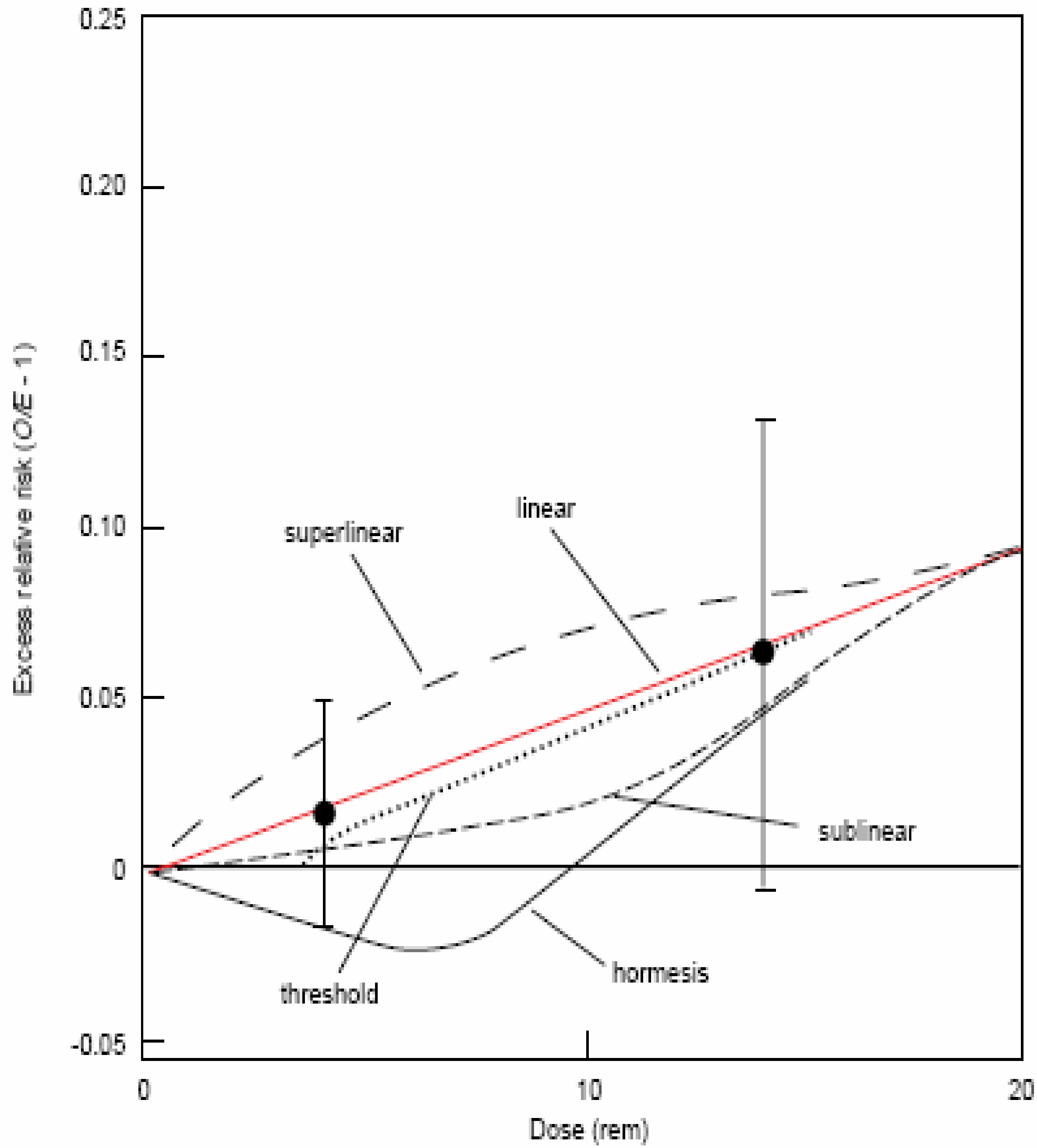
Risk Factor	**Expected days of life lost**
Being Male rather than Female	2800
Heart Disease	2100
Being Single	2000
One pack of cigarettes a day	1600
Working as a Coal Miner	1100
Cancer	980
Stroke	900
All accidents	435
Service in Vietnam	400
Motor Vehicle Accident	200
Speed limit increase from 55 to 65	40
Radiation Worker	12
Airplane Crashes	1



100
75
50
25
0
Per cent response
Tumor control
Complications
0
3000
6000
9000
12000
Dose (rad)

Extrapolation Methods

- Linear-dose response, no threshold hypothesis (LNT)
- Threshold
- Sublinear
- Superlinear
- Adaptative Response (Radiation Hormesis)



0.25
0.20
0.15
0.10
0.05
0
-0.05
Excess relative risk (O/E - 1)
superlinear
linear
sublinear
threshold
hormesis
0
10
20
Dose (rem)

Exposure Limits

- The risk models are used to aid the various regulatory committees in imposing limits.
- The earliest limits on radiation were based on preventing the onset of obvious effects such as skin ulcerations, which appeared after intense exposures to radiation.
- Later limits were based on preventing delayed effects, such as cancer.
- In 1902, the first dose limit of 10 rad was recommended.
- In1924, a "tolerance dose rate," a dose that could be tolerated indefinitely, was determined.
- Essentially, early limits were a judgment call based on the absence of observed biological harm.

Occupational Exposure limits

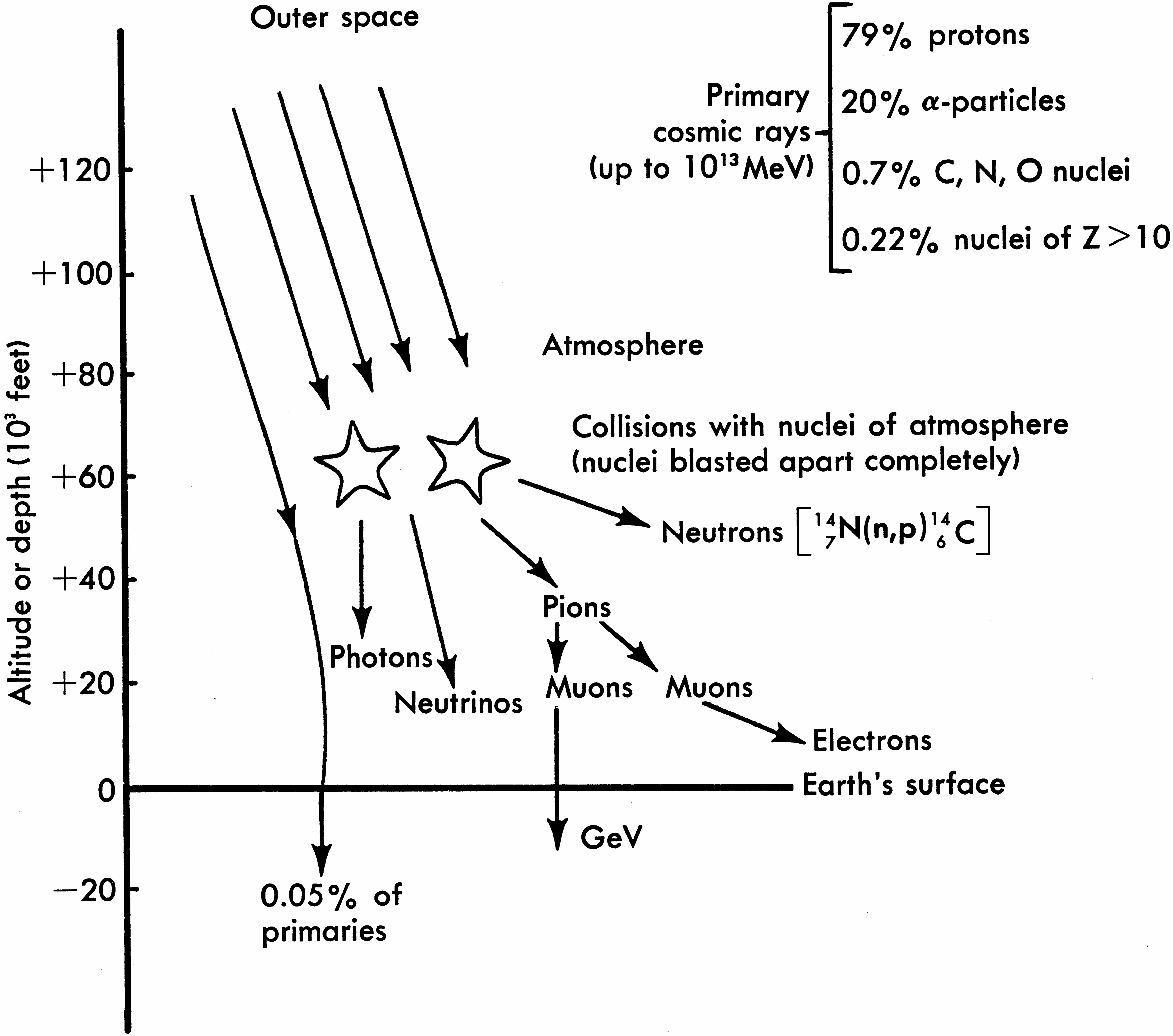
- 5 rem (0.05 Sv) for stochastic effects
- 15 rem (0.15 Sv) for the lens of the eye
- 5 rem (0.05 Sv) for all other organs

General population Limits

- whole body less than 0.5 rem (5 mSv) per year
- 0.1 rem/year (1 mSv/year) above the background radiation level (2.2mSv/ year)
- A basic principle of radiation protection is to keep radiation exposure <u>a</u>s <u>l</u>ow <u>a</u>s <u>r</u>easonably <u>a</u>chievable (ALARA)

Background Radiation: Natural and Artificial

- Natural Sources
  - cosmic radiation
  - external terrestrial radiation
  - internal terrestrial radiation



Outer space
Primary
cosmic rays
(up to 10^13 MeV)
79% protons
20% α-particles
0.7% C, N, O nuclei
0.22% nuclei of Z > 10
+120
+100
+80
+60
+40
+20
0
−20
Altitude or depth (10^3 feet)
Atmosphere
Collisions with nuclei of atmosphere
(nuclei blasted apart completely)
Neutrons [14/7N(n,p)14/6C]
Pions
Photons
Neutrinos
Muons
Muons
Electrons
Earth's surface
GeV
0.05% of
primaries

Artificial Background

- Medical X-Rays
- Nuclear Medicine
- Consumer Products

Radiation Source Annual Dose	
Man Made	mRem
Diagnostic X-Rays	40
Nuclear Medicine	14
Consumer Products	10
Other	1
Subtotal	65
Natural Background	
Internal Dose	40
Terrestrial Nuclides	29
Cosmic Rays	29
Radon	197
Subtotal	295
Total	360

Background Radiation Sources