How to Get Numbers “Right”

Introduction of LNT in Radiation Protection

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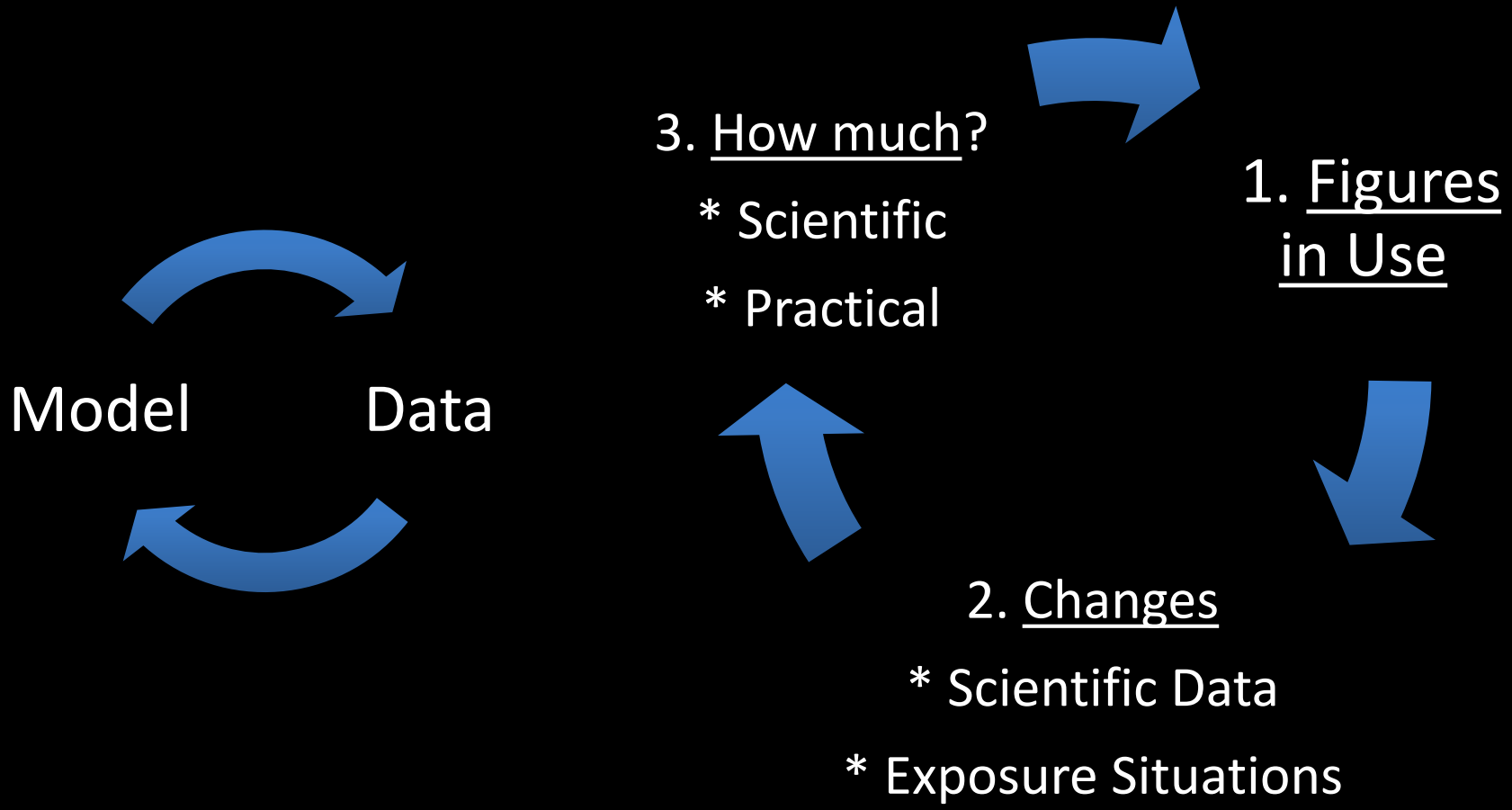
Science | Regulatory Science



Period: 1933-1958

NO LSS (ONLY after 1962) (exc. Leukemia)

No computation of nominal cancer risk coefficients (ONLY after 1977)

1. Figures in Use (1933-1947)

1/100 of an erythema (skin redness) dose per month

(A. Mutscheller, 1925)

… later translated into the physical unit (600 r)

(H. Kustner, 1927)

→ 0.2 r per day measured on surface; 0.1 r in air

2. Change in Scientific Data

- Effects at the figure in use: The number of sperm decreased in dogs with exposure to 0.1 r per day for one to two years

- Non-threshold (life-span): Experiments with rodents to whole-body radiation showing measurements of life-span shortening in the neighborhood of 0.1 r per day (H. Blair)

2. Change in Exposure Situations

Medical and industrial uses of X-rays and radium

↓

Atomic energy use

BUT

1. Still confined to occupational settings
2. Concerning a small portion of the general population (i.e. 300,000 in the UK)

→LNT noted (“permissible dose”) but not adopted

Genetics | Cancer

"If only a small proportion of the population, less than 1%, were exposed either 0.05 or 0.1 r per day, the slightly increased incidence of hereditary abnormalities in the population as a whole would probably not be a serious problem. If a substantial proportion or the whole of the population were exposed, then genetic effect[s] would almost certainly be serious."

(JS Mitchell on talks b/w G. Failla and DG Catcheside, April/May 1948)

On the permissible concentrations for bone-seeking elements: then extrapolated from those for radium (0.1.µg) based on 24 cases of radium poisoning.

"A 1% probable incidence of osteogenic sarcoma may possibly be regarded as an insignificant industrial hazard but it would seem to be inadmissible as a hazard to which a large section of the population might be exposed."

(LH Gray, n.d., FD1/465)

3. How? Change in Terms

"Since it seems well established that there is no threshold dose for the production of gene mutations by radiation, it follows that strictly speaking there is no such thing as a tolerance dose when all possible effects of radiation on the individual and future generations are included. …"

Definition of "permissible dose": Not expected to cause "any appreciable bodily injury to a person at any time during his lifetime." (NBS 59, p. 27)

3. How much?

Lower, but integrated
over a longer period of time

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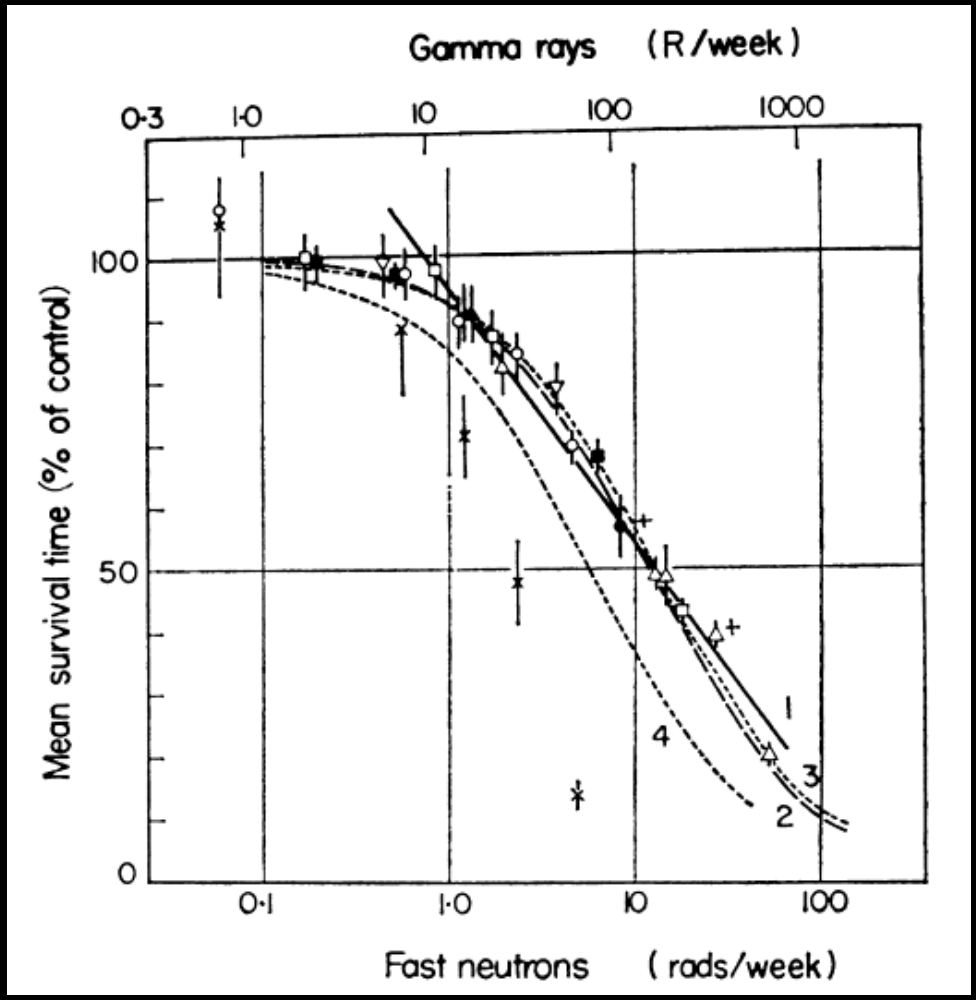
Lower, but integrated
over a longer period of time

From day to week

- “For practical reasons it is desirable to express the limit in terms of one week [3 mSv] rather than one day (for one thing, the film monitoring method indicates only the total exposure over a period of one week or more)." (06/04/48, 7-034)
- “When the exposure extends to a period of many years, variation of fractional doses and dosage rates occurring within one week may be assumed to be unimportant, especially when they are within the limits of radiological experience.” (NBS 59, p. 27)

From week to 13 weeks (1/4 year)

- Practice initiated by AEC to prevent personnel shortage due to technical overexposures relating nuclear weapons testing
- “In exceptional cases in which it is necessary for a person to receive in 1 week more than the basic permissible weekly organ doses, the unit of time may be extended to 13 weeks” provided that any one week dose does not exceed by more than a factor of 3, and with a penalty (30 mSv instead of 39)

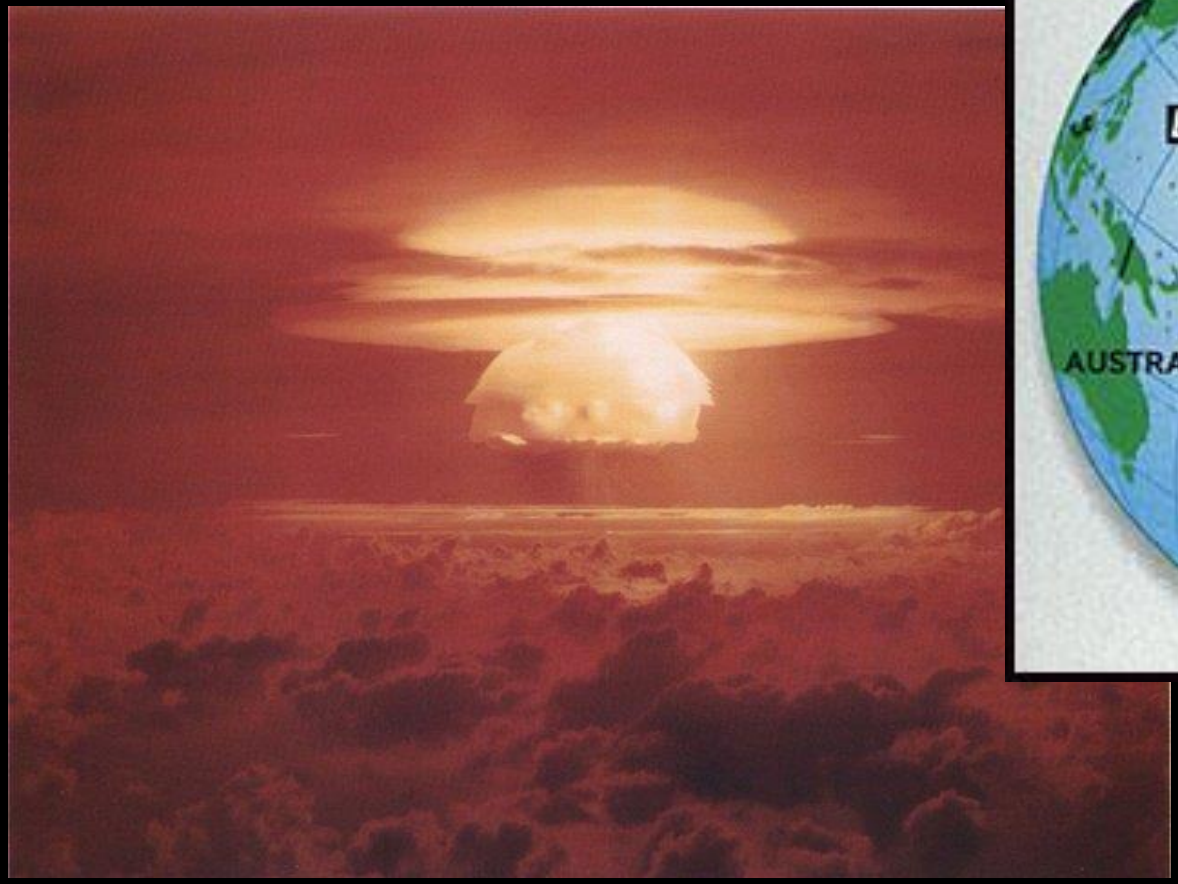


Survival time (expressed as fraction of control) of mice exposed continuously to gamma rays (top scale) and to fast neutrons throughout life.

H. Wade Patterson, Accelerator Health Physics (1973), p. 188

Further Change in Exposure Situations

Bikini Incident (March 1, 1954)

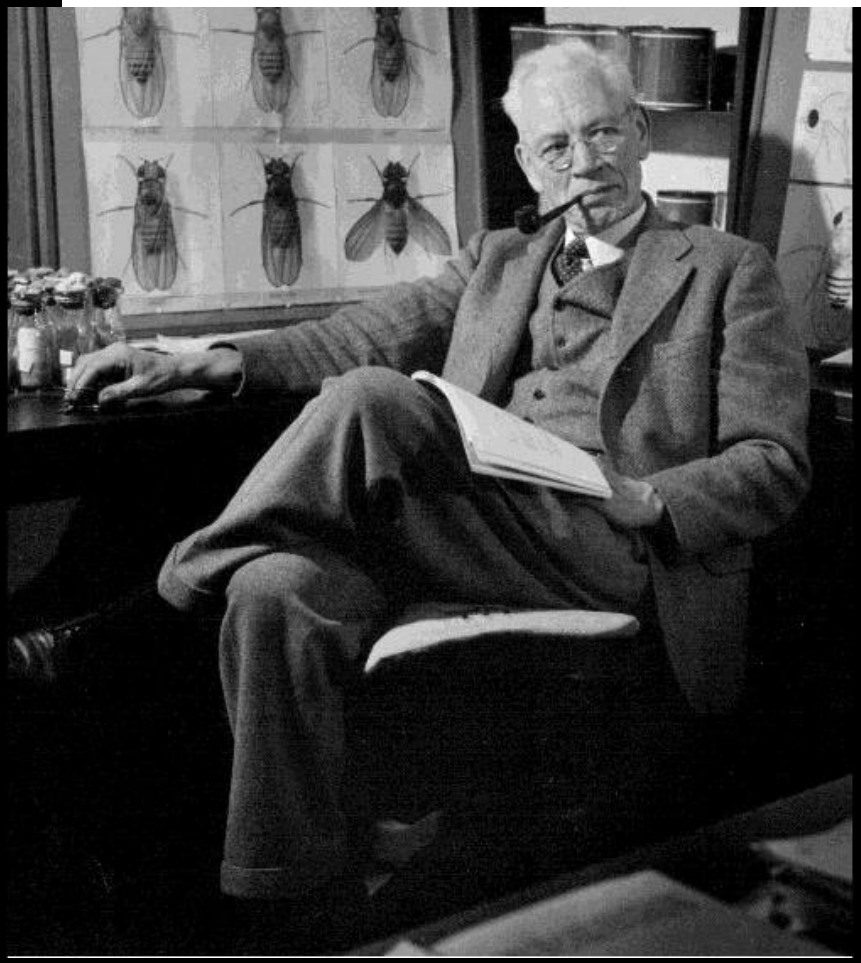


Shot BRAVO, 15 MT

Social Implications of the Genetics of Man*

A. H. Sturtevant

California Institute of Technology, Pasadena



"The probability of an effect on the germ cells of any one individual may be very low; but when many millions of people are being exposed, it becomes certain that some of them will be affected. … Some such defectives would be present if the bombs had never been invented; the point is that the number due to the bombs will be added to this irreducible minimum."

SCIENTISTS URGE U. N. TO SIFT PERIL FROM ATOM TESTS

Their Federation Calls for Air Poisoning Study and Setting Up of Controls

By PETER KIHSS

A United Nations study of how much the atomic and hydrogen bomb tests may be poisoning the world's atmosphere was urged yesterday by the Federation of American Scientists.

UNITED STATES MISSION TO THE UNITED NATIONS

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Memorandum of Conversation

DATE: May 20, 1955

SUBJECT: US Initiative in UN on Radiation Effects

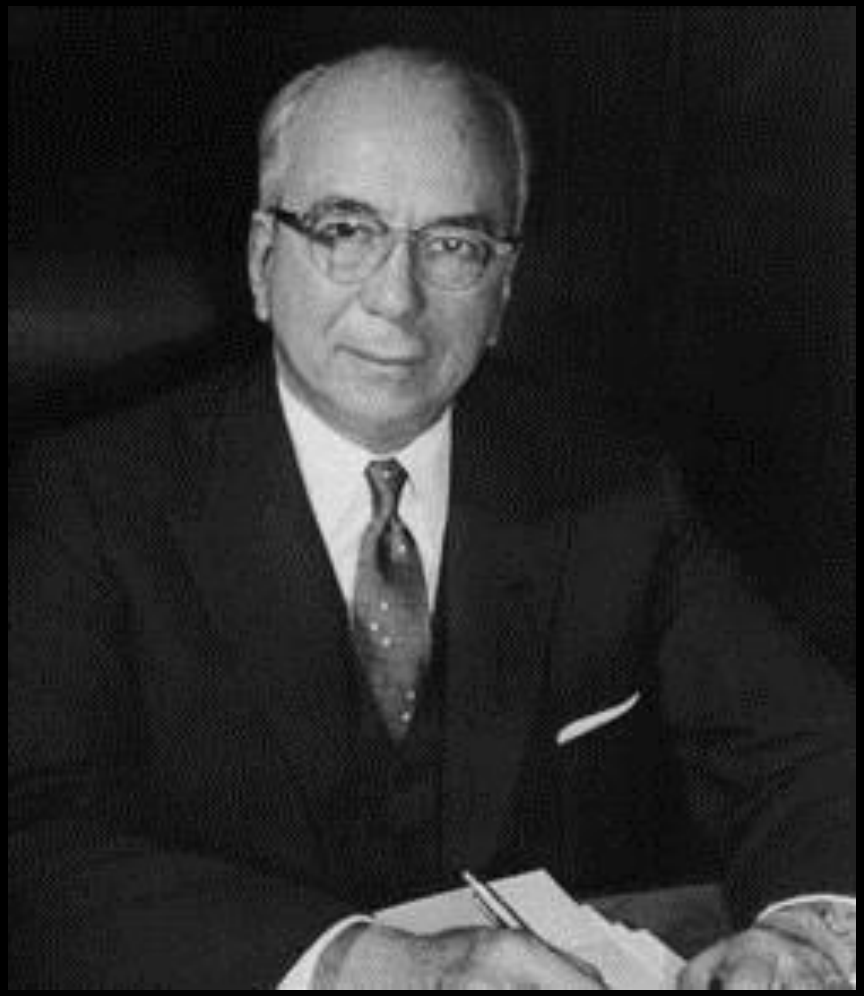
PARTICIPANTS: The Secretary of State
Under Secretary Herbert Hoover, Jr.
Assistant Secretary David McK. Key
Deputy Asst. Secretary D. W. Wainhouse
S/AE - Mr. Gerard C. Smith

AEC - Admiral Lewis L. Strauss

USUN - Amb. Henry Cabot Lodge, J
Brig Gen C. S. Babcock
Mr. James W. Barco

COPIES TO: The Secretary
The Under Secretary
Mr. Key
Mr. Smith
UNP - Mr. Popper
Ambassador Lodge
Ambassador Wadsworth
General Babcock
EXEC/Reference
Mr. Cook

Lewis Strauss (AEC Chairman)



Henry Cabot Lodge, Jr (US Amb. to UN)

Admiral Strauss said that he did see objection and that he would like to explain why. Any report by an international body would be considered by a packed jury and, if it were adopted, the finding would undoubtedly be adverse to our possession of nuclear weapons. Admiral Strauss said, to avoid this, he would rather accept the onus of opposing anything introduced by Sweden, India or others. Admiral Strauss explained further that investigation of the effects of radiation on human genetics would probably not reveal anything for a long period of time, possibly for hundreds of years. Tests that have been conducted during the last seven years with higher animal life had produced no conclusions. He pointed out that the use of antibiotics in modern medicine might be producing mutations more serious than radiation, inasmuch as bacterial strains were being produced which are resistant to antibiotics, ~~but we would not know the results for many years~~. Admiral Strauss felt that not only would the results of investigation prove inconclusive but he feared that to make an investigation on an international scale would lead us into dangerous paths where demands for cessation of nuclear tests and the disclosure of information concerning our weapons would possibly result. We could not afford to be put in a position where we would have to agree either to cease tests as the result of political pressures or disclose information concerning our weapons to the danger of our national security.

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Ambassador Lodge asked Admiral Strauss if he would object to making the report of the National Academy of Sciences available to the UN. Admiral Strauss said that he would have no objection to doing this. Ambassador Lodge said that this was all we were proposing, that is, that States with experience in the atomic field should make reports to a UN body such as the Disarmament Commission which would collate these reports and disseminate them. This left the determination of what was to be included in the report in the hands of the national Governments, in our own case, in the hands of the Atomic Energy Commission. He felt if Admiral Strauss had no objection to this, we were in fact in agreement on what should be done. Admiral Strauss said that he objected to any international investigation. Ambassador Lodge said that we did not propose an investigation by an international body. The investigations would be in the hands of the Governments and they would report what they saw fit on the basis of their own findings. They could in fact do this anyway. In reply to the Secretary's question, Admiral Strauss said he felt he could live with such an arrangement.

Biological Effects of Atomic Radiation (BEAR) Committee

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

Warren Weaver (Chair: Math)

Gioacchino Failla (NCRP/ICRP)

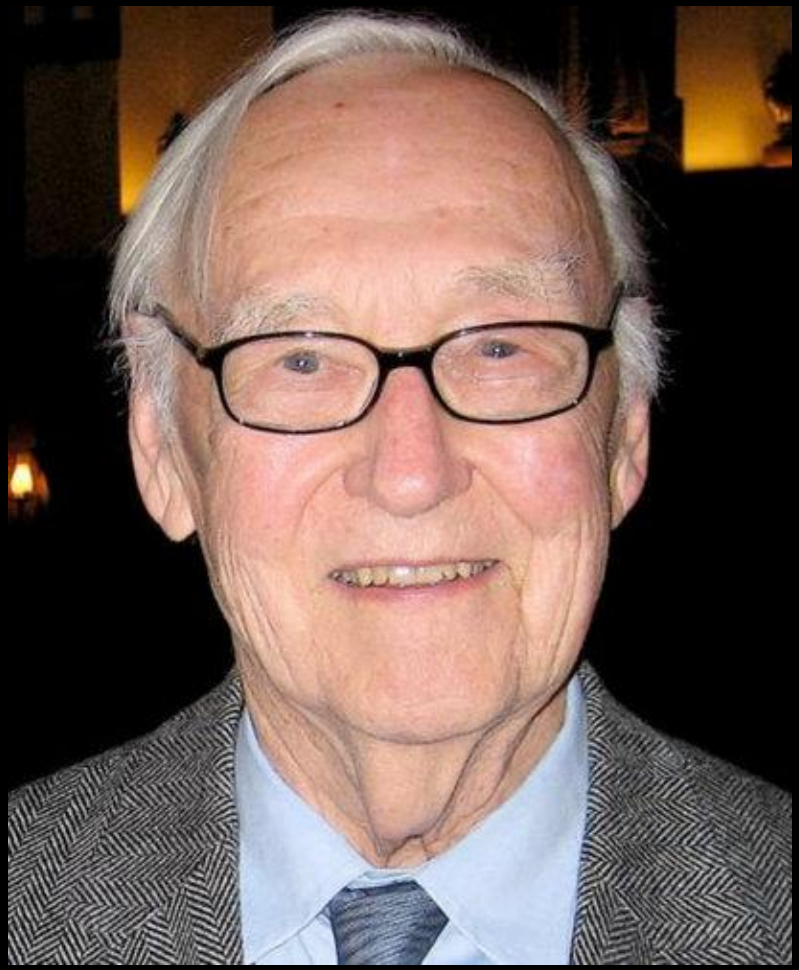
Need of a concrete figure to be taken into radiation protection

Weaver: There is the practical problem that goes beyond general principles. We have to face the question: "What are proper safeguards?" It won't be sufficient to say: "As little as possible." That kind of statement won't be helpful.

Failla: I am assuming that this panel will set a figure for the general population. If it doesn't, some other group will. There is pressure because of the coming meeting of the International Committee on Radiation Protection. Unfortunately, someone has suggested 10 per cent of the exposure of occupational workers as the limit for the general population. No geneticist would agree to that - it's too high, for the permissible dose for occupational workers is about 450 r in 30 years (.3 per week).

Herman Muller

James Crow



Public: 100 mSv (30-year per capita average)

Weaver: I would like to know what led to the choice of these particular figures.

Crow: Well, Muller had once suggested 20 r and Stern 5 r. We arrived at 10 r as the geometric mean.

Muller: My rather high value was based on a doubling dose of 80 r rather than one of 40 r, which now seems more probable. I was trying to stay well below the doubling dose in my recommendation. I admit the damage would be the same regardless of the spontaneous mutation rate, but we have empirical knowledge of the consequences of the spontaneous rate and that should help us to visualize what a doubling or a fifty per cent rise might do. There are some populations (high Andes, Tibet) that probably receive 5 r per generation more than ordinary populations. Yet, after thousands of years, they are getting along all right. So an increase of 5 r per generation for other populations should at least be tolerable.

100 mSv : Practical!

Weaver: Is the economic question the only one relating this figure to future controls?

Muller: No. The present amount of radiation given for medical purposes, according to Stanley Clark in the last issue of the Bulletin of Atomic Scientists, is probably running above 3 r within 30 years. It might be as much as 5 r. If you add fallout, we are getting toward the 10 r limit, but we are still far enough from it to cause no inconvenience to the atomic program or to physicians. This 10 r limit does not include the natural background radiation, but it does include all the artificial radiation, medical, atomic, and fallout.

Beadle: The maximum from fallout, barring all-out atomic war, plus the amount from medical exposure plus the background adds up to about 10 r, so doubling the natural background through waste disposal would make about 10 r above the natural background amount.

Muller: If we had set 5 r as a limit, everyone would have said, "impractical - Utopia." At 10 r many more will strive for protection.

100 mSv : Scientific?

Crow: I dislike giving strong arguments for the value of the figure because it is more likely to represent a voting consensus of a series of opinions arrived at from many different sources and on many different bases than a single logically derived solution.

Weaver: Can we say that the best justification of this figure is that it is roughly one-fourth of the dose which would produce a mutation rate comparable to the spontaneous mutation rate?

Russell: I wouldn't consider that a reason. It isn't an established fact that 10 r represents a dose that will give a quarter of the spontaneous mutation rate. The estimate was based on highly biased loci, certainly as far as the spontaneous rate is concerned.

Muller: Why are they highly biased?

Russell: They will be biased in an upper direction because they are necessarily loci at which spontaneous mutations have occurred in the past.

Occupational: 500 mSv (30-year individual)

= Appx. 1/10 of 4.5 Sv (a 30-year total of 3 mSv per week)

Failla (NCRP/ICRP) opposed:

- Impact on academic research
- Only the average dose to the whole population mattered
- No reliable way to keep records of small doses (<0.3 mGy)
- No consultation with somatic effects

National laboratories and companies opposed:

- No need for the regulation as few workers would have 50 r
- An individual limit would cause serious operational difficulties

From week to year

- Occupational: The maximum accumulated dose at any age, N, equals 5 (N-18) rem (5 rem [50 mSv]/yr) provided no annual increment over 15 rem (3 mSv/wk x 50 weeks)

"All agreed with [Robert] Stone's subsequent statement that it is all right to shift to a yearly concept if it is biologically acceptable, but if it is not we should not make recommendations to suit the convenience of industry." (8-112/113)

- Population: 1/10 of 5 rem/yr [=5 mSv/yr]

"So 1/3 the population can be exposed to that level and still stay within 10 rem [100 mSv] average." (8-071)

Figures Revised

- 1977 Recommendations

  Calculations of the lifetime fatal cancer risk

  – 50 mSv/yr for workers

  – 5 mSv/yr for members of the public

- 1990 Recommendations (2007)

  Revised Estimation of Population Cancer Risk based on DS86

  Elucidation of risk acceptance criteria [<<1 in 1,000 per year for work; <<1 in 10,000 for the public]

  – 20 mSv/yr over 5 years with no more than 50 mSv in a single year [The average annual attributable fata cancer risk: 7 in 10,000]

  – 1 mSv/yr for members of the public [3 in 100,000]

Conclusion:
How to Get Numbers “Right”

Data do not automatically translate into figures

1. Data is used to evaluate whether the existing figures “work”
2. Change in exposure situations is also critical
3. Figures are revised not only to err on the side of caution but also to create room for flexible rules to meet operational demands