The International Framework for Radiation Safety

HISTORY, SCIENCE, PHILOSOPHY AND PRACTICE

PRESENTATION TO THE SYSTEM SAFETY SOCIETY,
EASTERN CANADA CHAPTER

OTTAWA, 2009 JANUARY 15

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Scientific Secretary
International Commission on Radiological Protection

Overview

WHAT IS IONIZING RADIATION?

THE EVOLUTION OF THE SYSTEM OF RADIOLOGICAL PROTECTION

INTERNATIONAL ORGANIZATIONS CENTRAL TO RADIOLOGICAL PROTECTION

What is Ionizing Radiation?

- **Radiation** is emitted energy in the form of waves or particles e.g. visible light, microwaves, and x-rays

- **Ionizing radiation** has enough energy to remove electrons from an atom, causing the atom to become charged or "ionized"

- Common types of ionizing radiation are x-rays and alpha, beta and gamma radiation; these occur in nature, but can also be man-made

The Evolution of the System of Radiological Protection

HISTORY

SCIENCE

PHILOSOPHY / ETHICS

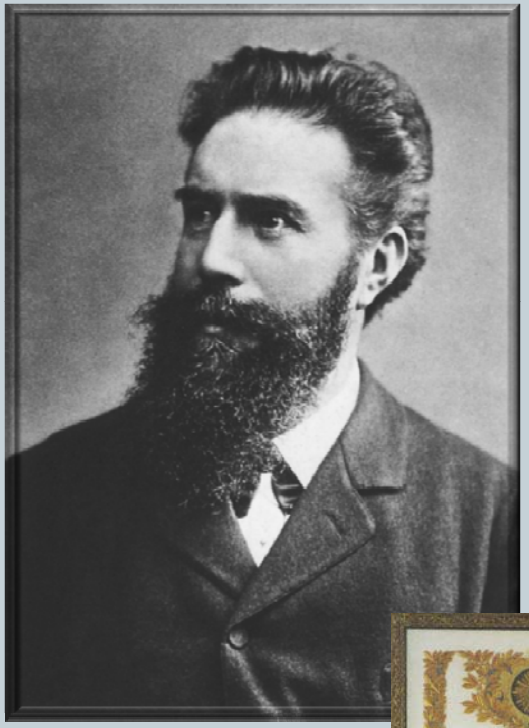
&

THE SYSTEM OF RADIOLOGICAL PROTECTION

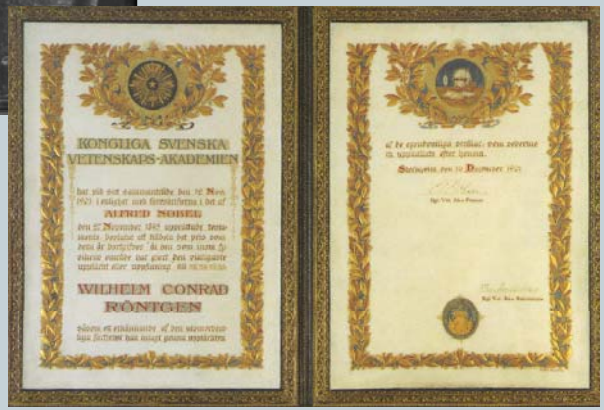
Radiological Protection

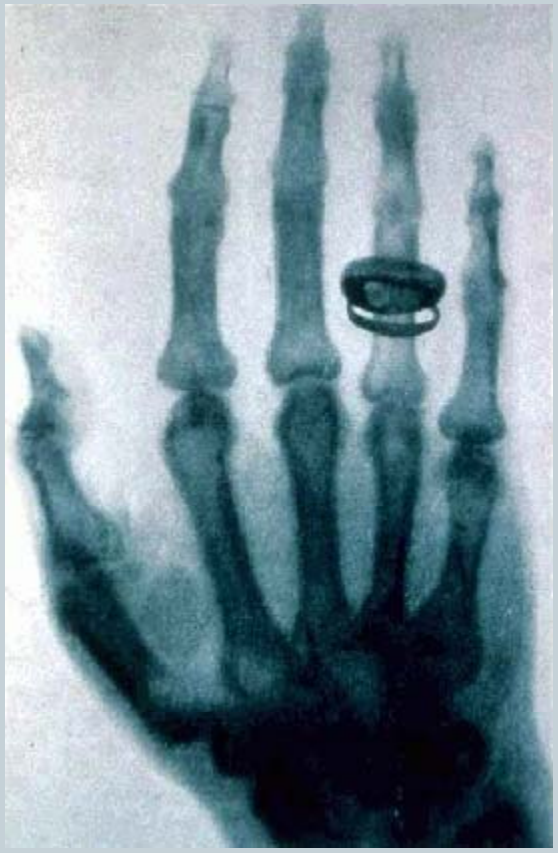
AS WE TRACE THE HISTORY OF RADIOLOGICAL PROTECTION
Circumstances of exposure considered
Who / what is being protected
Known effects of radiation exposure
The ethical basis of protection
Protection methods

The Discovery of Ionizing Radiation



X-rays were discovered by Wilhelm Roentgen in 1895, for which he received the first Nobel prize in physics in 1901

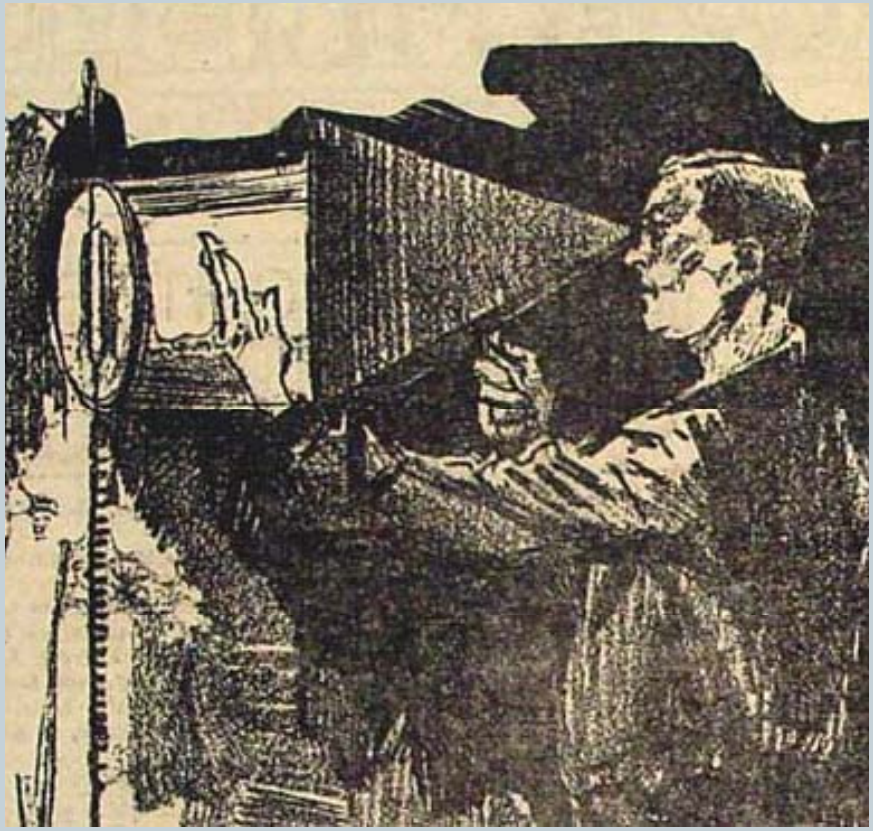




X-ray of the hand of Bertha Roentgen (1895)

Early Radiation Safety Concerns

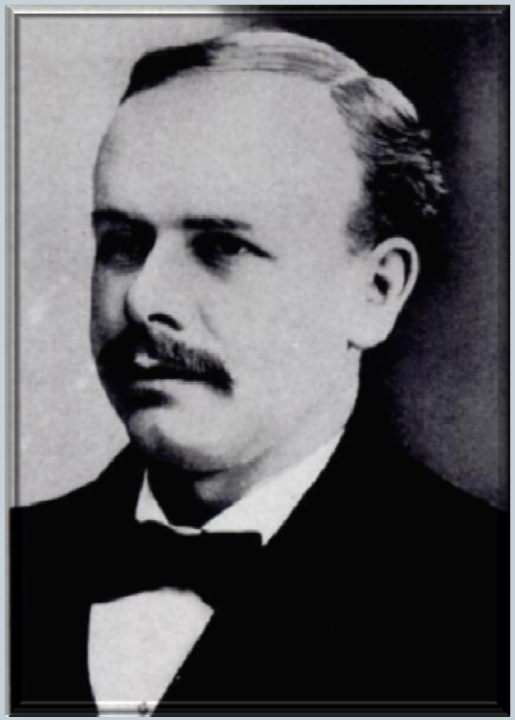
- X-ray dermatitis of the hands was observed in the U.S. by Grubbe
- Drury described radiation damage to the skin of the hands and fingers of early experimental investigators in the UK



The First Radiological Protection Advice

In December 1896 Wolfram Fuchs gave the first protection advice:

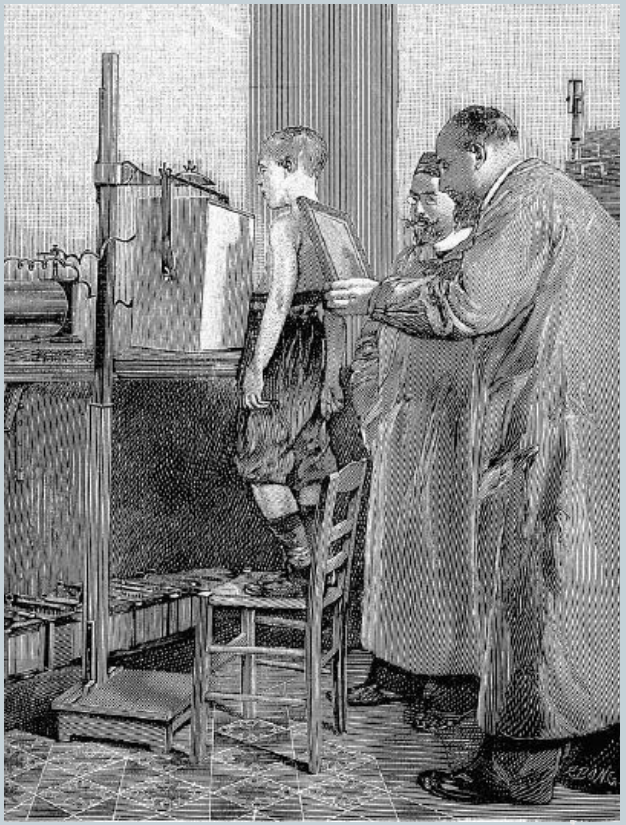
- make the exposure as short as possible
- do not stand within 12 inches (30 cm) of the x-ray tube
- coat the skin with Vaseline and leave an extra layer on the area most exposed

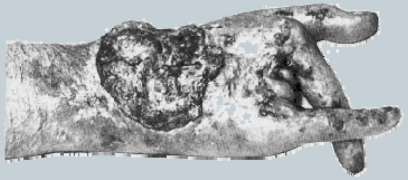


Wolfram Fuchs

Escalating Radiation Safety Concerns

In the first decades of the 20th century ignorance about the risks of exposure to radiation caused numerous injuries despite the many papers published on tissue damage caused by radiation



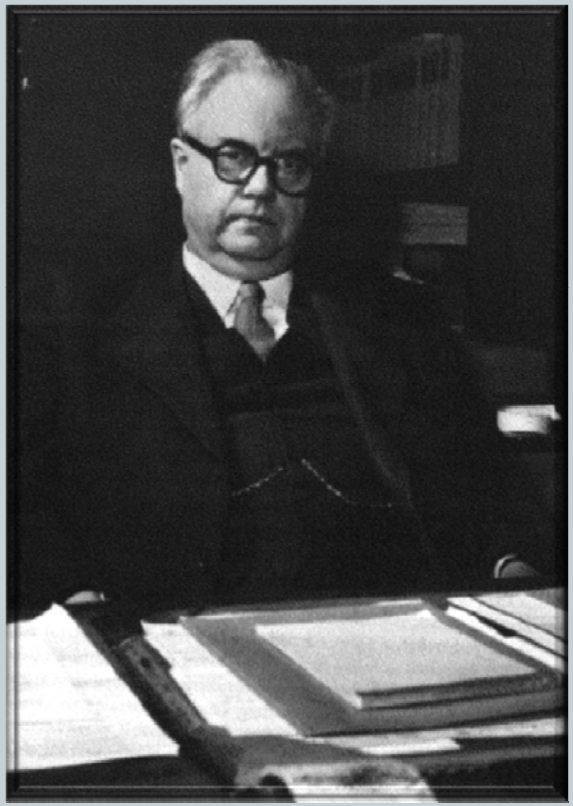


International Congress of Radiology

- Encouraged by growing radiation safety concerns, the first International Congress of Radiology was held in London in 1925

- The most pressing issue was that of quantifying measurements of radiation, so the **International Commission on Radiation Units and Measurements** (ICRU) was created

International X-Ray and Radium Protection Committee



Rolf Sievert

- The second International Congress of Radiology was held in Stockholm in 1928
- The International X-Ray and Radium Protection Committee, precursor to the **International Commission on Radiological Protection** (ICRP), was established, and Rolf Sievert named chairman

Radiological Protection: 1928

Effects / Science

- Concerned with occupational exposure in medicine
- Concerns are threshold (deterministic) effects
- "The effects to be guarded against are (a) injuries to superficial tissues, (b) derangements of internal organs and changes in the blood"

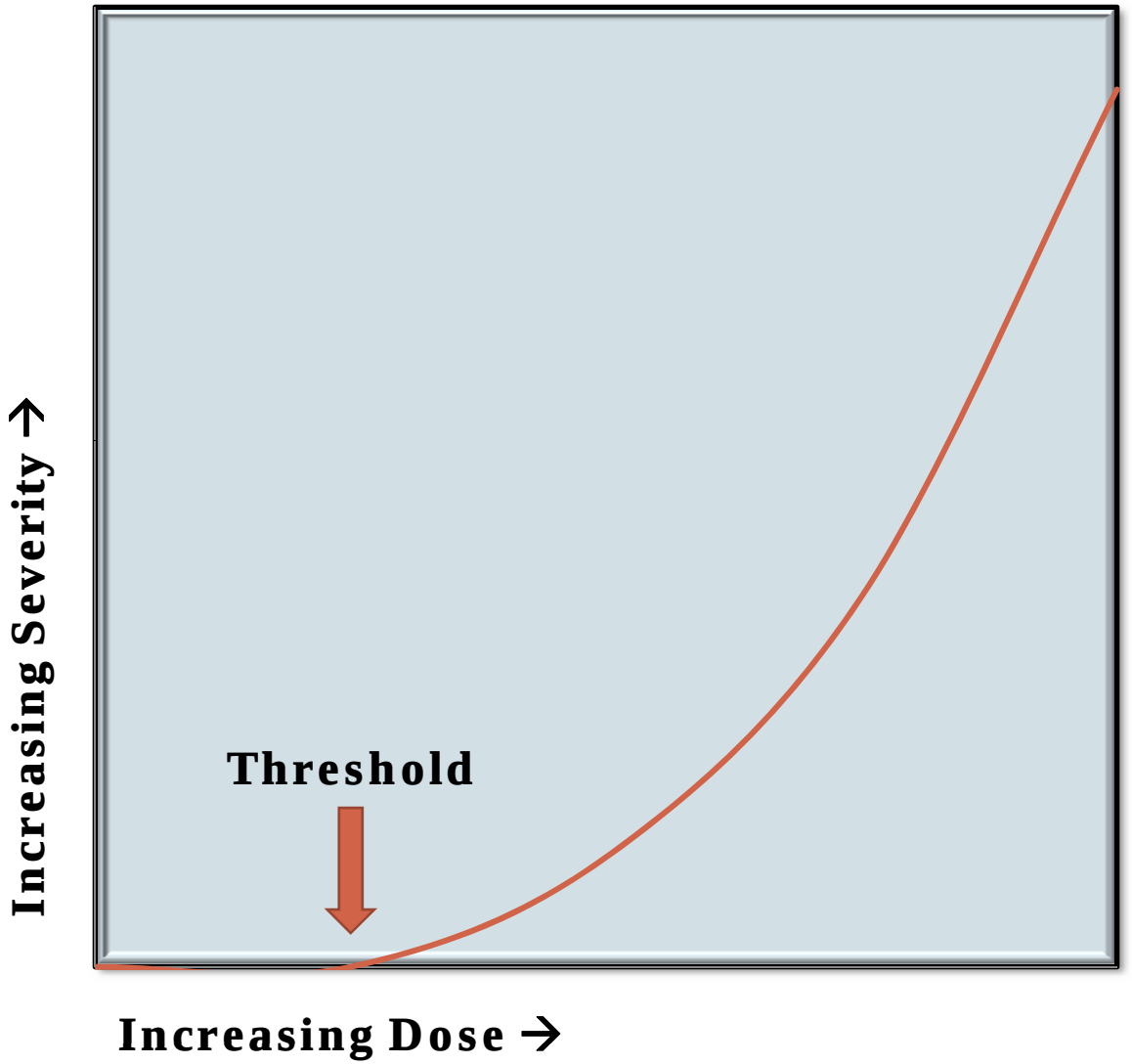
Protection

- "An X-ray operator should on no account expose himself unnecessarily to a direct beam of X-rays"
- "An operator should place himself as remote as practicable from the X-ray tube. It should not be possible for a well rested eye of normal acuity to detect in the dark appreciable fluorescence of a screen placed in the permanent position of the operator."

Deterministic Effects

There are no effects below a **threshold** dose

Above the threshold, the **severity** of the effect increases with dose



Radiological Protection: 1930's – early 1950's

Effects / Science

- Concern expands to all occupational exposures
- Focus continues to be on threshold (deterministic) effects
- Increasing knowledge of dose thresholds for adverse effects

Protection

- 1934: daily tolerance dose introduced (~25x current limits)
- 1951: weekly permissible dose introduced at ~½ previous levels because the earlier value "seems very close to the probable threshold for adverse effects"
- 1951: "every effort be made to reduce exposures to all types of ionizing radiations to the lowest possible level"

Radiological Protection: 1950's

Effects / Science

- Concerned with all occupational exposures
- Emerging science on:
  - Superficial injuries
  - General effects on the body, particularly blood and blood-forming organs, e.g. anaemia and leukaemia
  - Malignant tumour induction
  - Other deleterious effects including cataracts
  - Genetic effects
- By 1955 excess leukaemia is observed in survivors of Hiroshima and Nagasaki

Protection

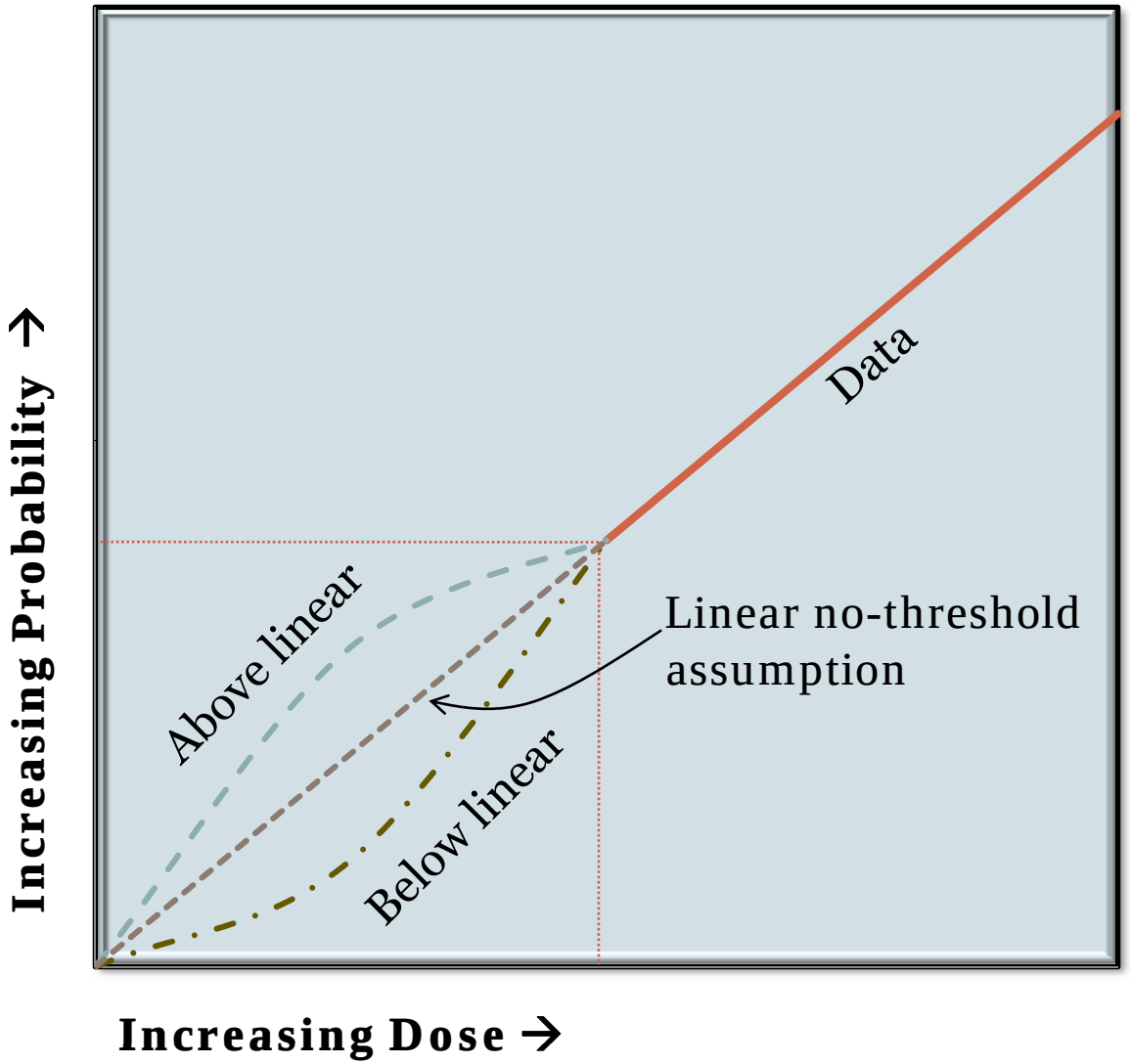
- "In view of the incomplete evidence ... it is strongly recommended that every effort be made to reduce exposure to all types of ionising radiation to the lowest possible level"
- Doses to the public are considered distinct from occupational and medical doses

Stochastic Effects & LNT

The linear no-threshold (LNT) model assumes:

the **probability** of an effect increases linearly with dose

there is **no threshold** dose below which there is no risk



Radiological Protection: 1960's

Effects / Science

- It is clear that some effects (e.g. cancer induction) are stochastic in nature, rather than deterministic
- The probability of a stochastic effect increases with dose (without threshold)
- The severity of a deterministic effect increases with dose (with threshold)

Protection

- "for the purposes of radiological protection ... [assume] a linear relationship between dose and effect, and that doses act cumulatively"
- This LNT assumption "may be incorrect, but ... unlikely to lead to the underestimation of risks"
- "any exposure may involve some degree of risk"
- "any unnecessary exposure be avoided and that all doses be kept as low as is **readily** achievable, economic and social consequences being taken into account"

Radiological Protection: 1970's – 1990's

Philosophy / Ethics

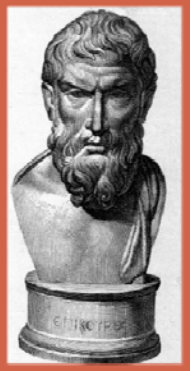
- "Radiation protection is concerned with the protection of individuals, their progeny and mankind as a whole, while still allowing necessary activities from which radiation exposure might result"
- Control the risk from stochastic effects, and avoid deterministic effects
- "if man is adequately protected then other living things are also likely to be sufficiently protected"

Protection

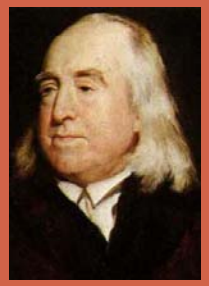
- *Justification*: "no practice shall be adopted unless its introduction produces a positive net benefit"
- *Optimization*: "all exposures shall be kept as low as **reasonably** achievable, economic and social factors being taken into account" (**ALARA**)
- *Individual Dose Limitation*: "doses to individuals shall not exceed the limits"

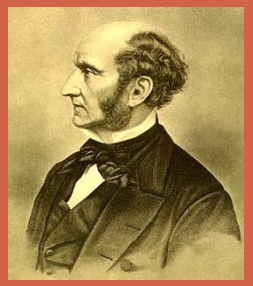
Utilitarian Ethics

Originates ~300 BC in the work of the ancient Greek philosopher Epicurus



Further developed in 19c England by Jeremy Bentham and John Stuart Mill

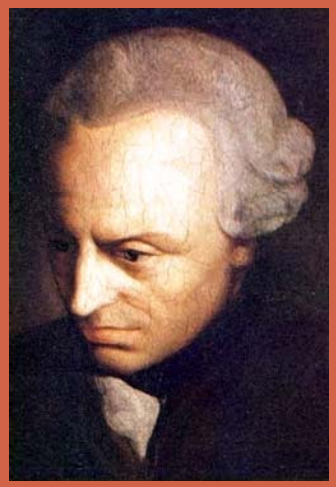




- ***Actions are judged by their consequences***
- **Consequentialism**: An action is morally right if the consequences of that action are more favourable than unfavourable
- **Utilitarianism**: An action is morally right if the consequences of that action are more favourable than unfavourable <u>to everyone</u>
- Maximize net benefit to society

"The needs of the many outweigh the needs of the few"

Deontological Ethics



Immanuel Kant, an 18th century German philosopher, the father of modern deontological ethics

- ***Actions are based on duty or obligation***
- Focus on the moral rightness, or intrinsic goodness, of an action
- Some actions are right (or wrong), irrespective of the consequences that might follow
- Kant argued there is a single self-evident principle of duty, the "categorical imperative"
- Act according to rules that you would apply universally
- "the needs of the one outweigh the needs of the many"

Value Judgements in Radiological Protection

Utilitarian ethics

- *Actions are judged by their consequences*

- Justification
  - Do more good than harm
- Optimization
  - Maximize good vs. harm

Deontological ethics

- *Actions are based on duty or obligation*

- Dose Limitation
  - No individual is unduly harmed

Radiological Protection Today

Philosophy / Ethics

- "an appropriate level of protection for people and the environment against the detrimental effects of radiation exposure without unduly limiting the desirable human actions that may be associated with such exposure"
  - Increased focus on deontological ethics i.e. concern for the individual
  - Increased focus on protection of the environment

Protection

- *Justification*, *Optimization* and *Individual Dose Limitation* remain cornerstones of the system of protection
- Dose constraints aid in optimization while effectively increasing dose equity
- The environment seems to be adequately protected, but there is a greater need to demonstrate this

Value Judgements in Radiological Protection

Utilitarian ethics

- *Actions are judged by their consequences*

- Justification
  - Do more good than harm
- Optimization
  - Maximize good vs. harm

Deontological ethics

- *Actions are based on duty or obligation*

- Dose Limitation
  - No individual is unduly harmed
- Dose Constraints
  - Aid optimization & increase equity

Radiological Protection Then and Now

THEN		NOW
Occupational exposure in medicine	→ All occupational exposure →	All exposure
Protection of man	→ Assume protection of the environment →	Demonstrate protection of the environment
Deterministic effects only	→ Recognition of stochastic effects →	Stochastic and deterministic effects
Avoid all harm	→ Main focus on utilitarian ethics →	Increased focus on deontological ethics
Practical advice	→ Dose limits →	Optimization and limits

International Organizations Central to Radiological Protection

WHO THEY ARE, WHAT THEY DO, AND HOW THEY INTERACT

ICRP, UNSCEAR, IAEA AND OTHERS

International Commission on Radiological Protection

- Established in 1928 to advance for the public benefit the science of radiological protection, in particular by providing recommendations and guidance on all aspects of protection against ionising radiation

- Produces recommendations on radiological protection adopted world-wide, based on science and value judgements

UNSCEAR

United Nations Scientific Committee on the Effects of Atomic Radiation

- Established by the UN in 1955 to assess and report levels and effects of exposure to ionizing radiation
- Provides the scientific basis for evaluating radiation risk and for establishing protective measures

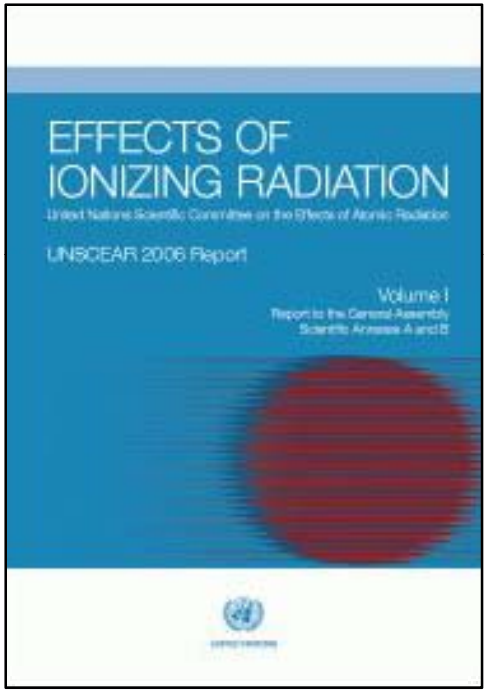
IAEA

International Atomic Energy Agency

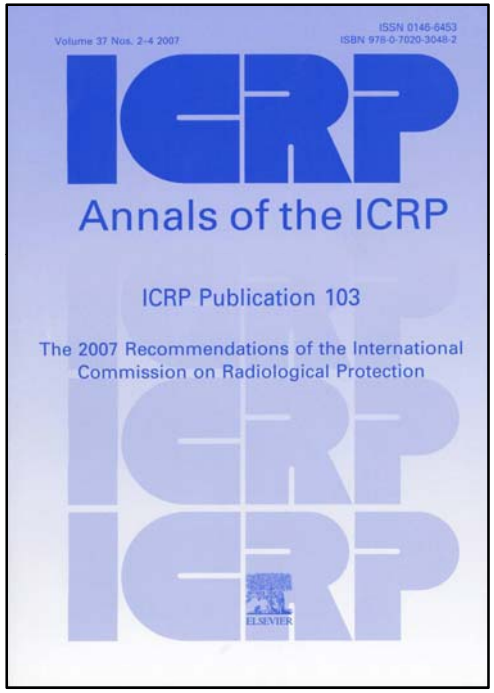
- Established within the UN family in 1959 as the world's "Atoms for Peace" organization to promote safe, secure and peaceful nuclear technologies

- Wide range of programmes, including development of Safety Standards in regulatory language

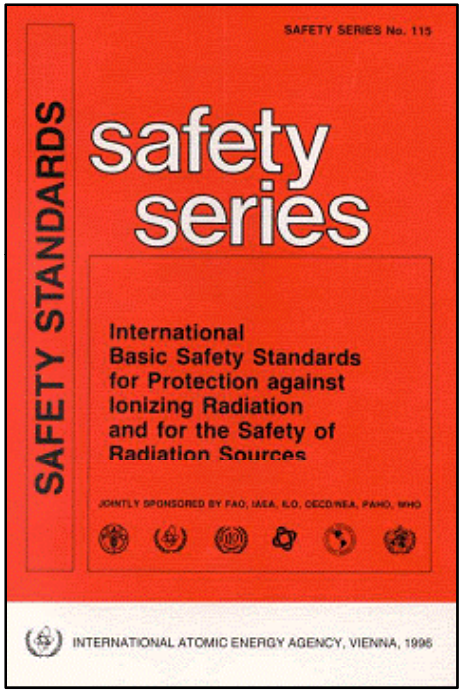
UNSCEAR, ICRP, IAEA



UNSCEAR Reports
on doses and effects

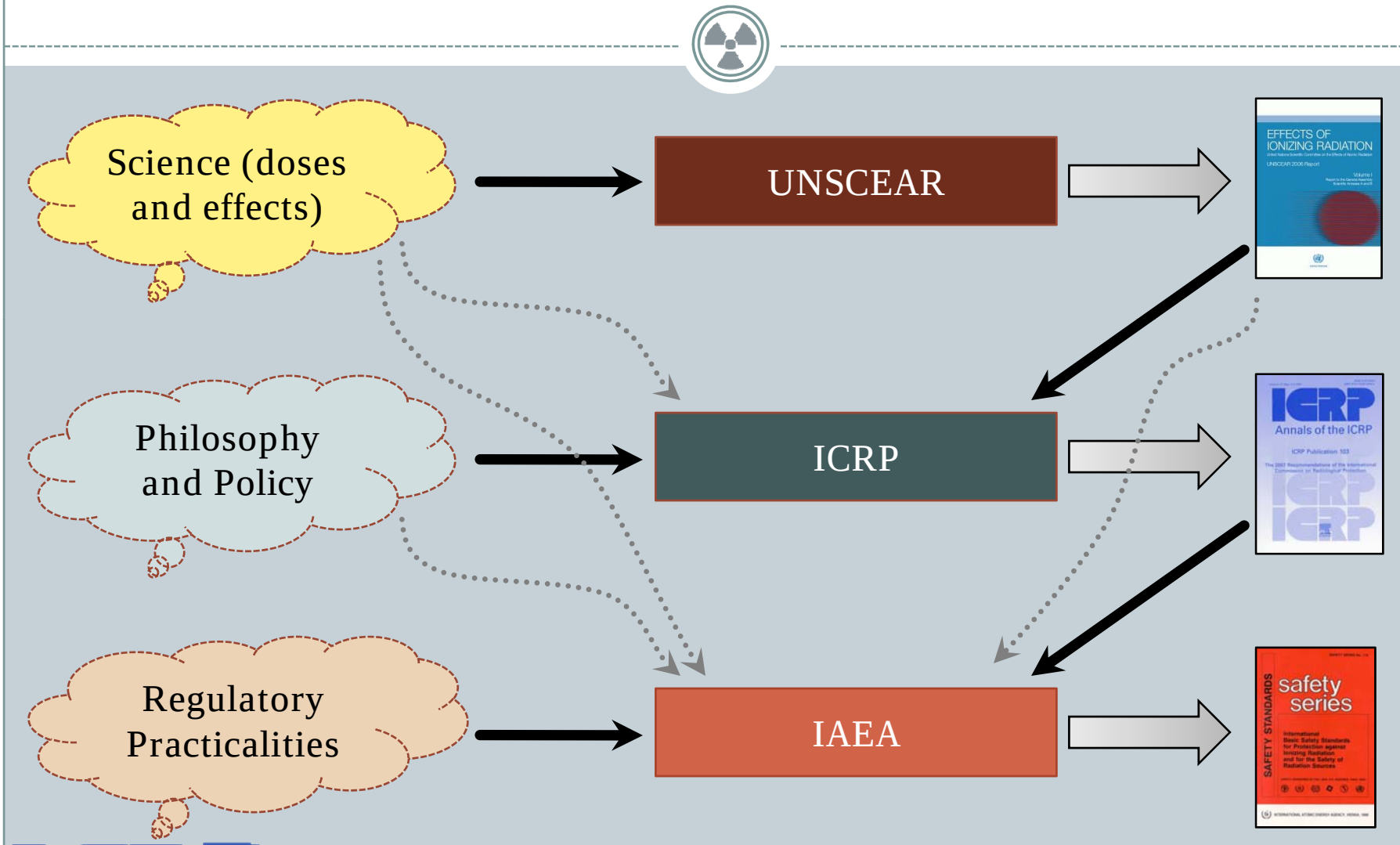


ICRP
Recommendations



IAEA Safety
Standards

UNSCEAR → ICRP → IAEA



Other International Organizations

- International Commission on Radiation Units and Measurement (ICRU)
- OECD Nuclear Energy Agency (NEA)
- CEC Euratom
- International Radiation Protection Association (IRPA)
- International Commission on Non-Ionizing Radiation Protection (ICNRP)
- ILO, WHO, PAHO, FAO, ISO, IEC, IARC, etc.

Canadian Framework

- Other scientific reports
- Canadian considerations
- Public consultation
- Lessons from other regulators

Canadian Regulatory System

- Canadian Nuclear Safety Commission
  - *Nuclear Safety and Control Act* & regulations
- Health Canada
  - *Radiation Emitting Devices Act* etc.
- Director General Nuclear Safety (DND)
- Provincial/Territorial Agencies

Acknowledgements

Roger Clarke, former ICRP Chair

&

Jack Valentin, “former” ICRP Scientific Secretary

- A History of the International Radiation Protection Association (Health Physics **88** (April 2005))

David Sowby, former ICRP Scientific Secretary

- Forty years on: how radiological protection has evolved internationally (J. Radiol. Prot. **23** (2003))

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