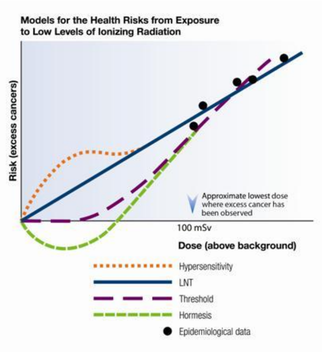
국제방사선방호체계와 LNT



한국원자력학회 2025년 춘계대회 방사선방호 연구부회 워크숍
제주국제컨벤션센터, 2층 202A호

21 May 2025

조건우 Kunwoo Cho
ICRP Main Commission Member
nrsmgp@kaist.ac.kr
한국과학기술원 KAIST

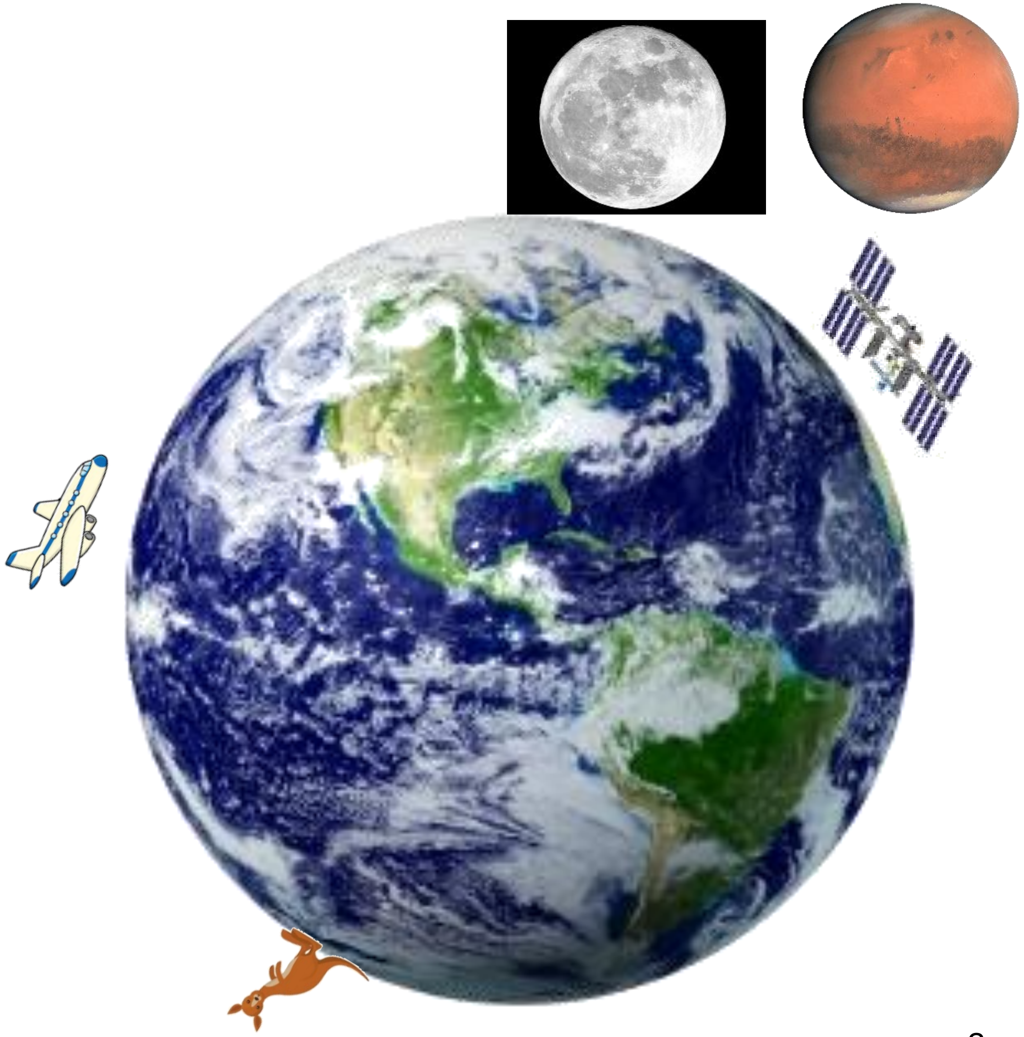
국제방사선방호체계
System of Radiological Protection, ICRP

The International Commission on Radiological Protection (ICRP) - Mission

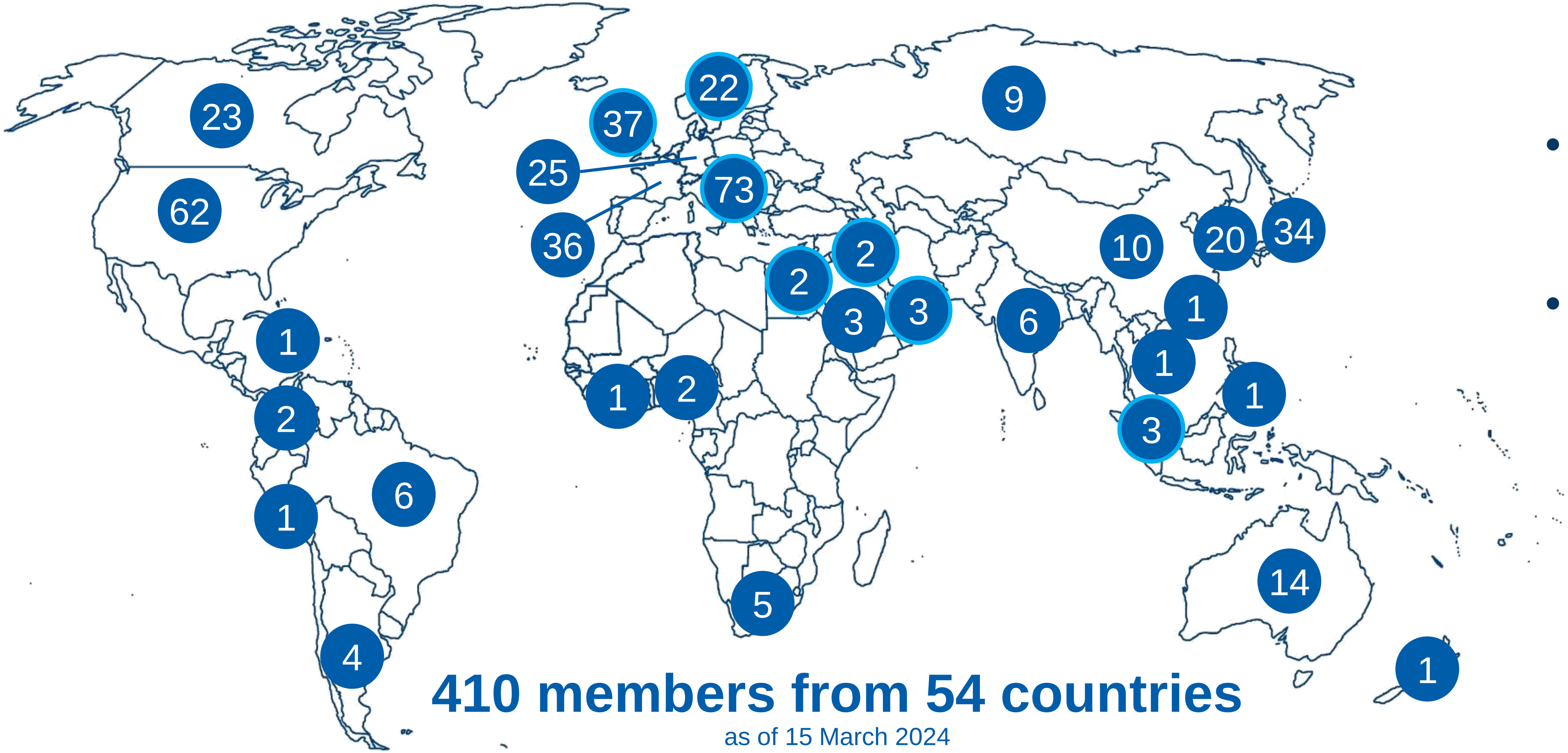
Our Mission

- **Protecting patients, workers, the public, and the environment against detrimental effects of radiation exposure world-wide (and beyond!) …**
- **… without unduly limiting the benefits associated with the use of ionizing radiation.**

The **recommendations** developed by ICRP are the basis of **standards, regulations, guidance**, and **practice** … **everywhere**



The International Commission on Radiological Protection (ICRP)

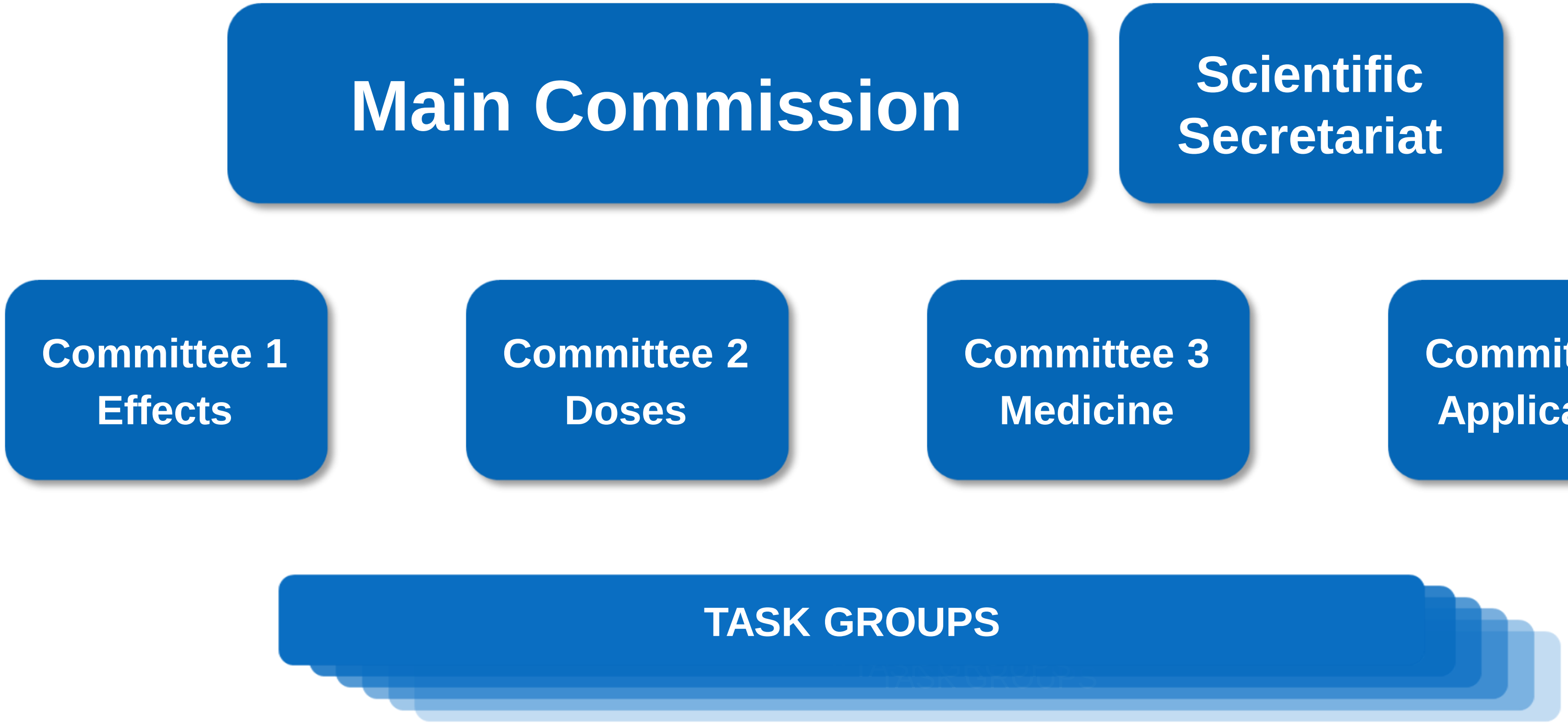


410 members from 54 countries

as of 15 March 2024

- Members are selected based on their expertise
- Members do not represent their country
- Members do not represent their employer

ICRP Structure



ICRP Main Commission


Werner Rühm
Chair


Simon Bouffler
Vice-Chair


Christopher Clement
Scientific Secretary


Dominique Laurier
C1 Chair


François Bochud
C2 Chair


Kimberly Applegate
C3 Chair


Thierry Schneider
C4 Chair


Kun-Woo Cho
Member


Gillian Hirth
Member


Michiaki Kai
Member


Senlin Liu
Member


Sergey Romanov
Member


Andrzej Wojcik
Member

ICRP Committees

Committee 1 Effects

considers the effects of radiation action from the subcellular to population and ecosystem levels, including the induction of cancer, hereditary, and other diseases, impairment of tissue/organ function and developmental defects, and assesses implications for protection of people and the environment

Chair: Dominique Laurier, France

Committee 2 Doses

develops dosimetric methodology for the assessment of internal and external radiation exposures, including reference biokinetic and dosimetric models and reference data and dose coefficients, for use in the protection of people and the environment

Chair: François Bochud, Switzerland

Committee 3 RP in Medicine

addresses protection of persons and unborn children when ionising radiation is used in medical diagnosis, therapy, and biomedical research, as well as protection in veterinary medicine

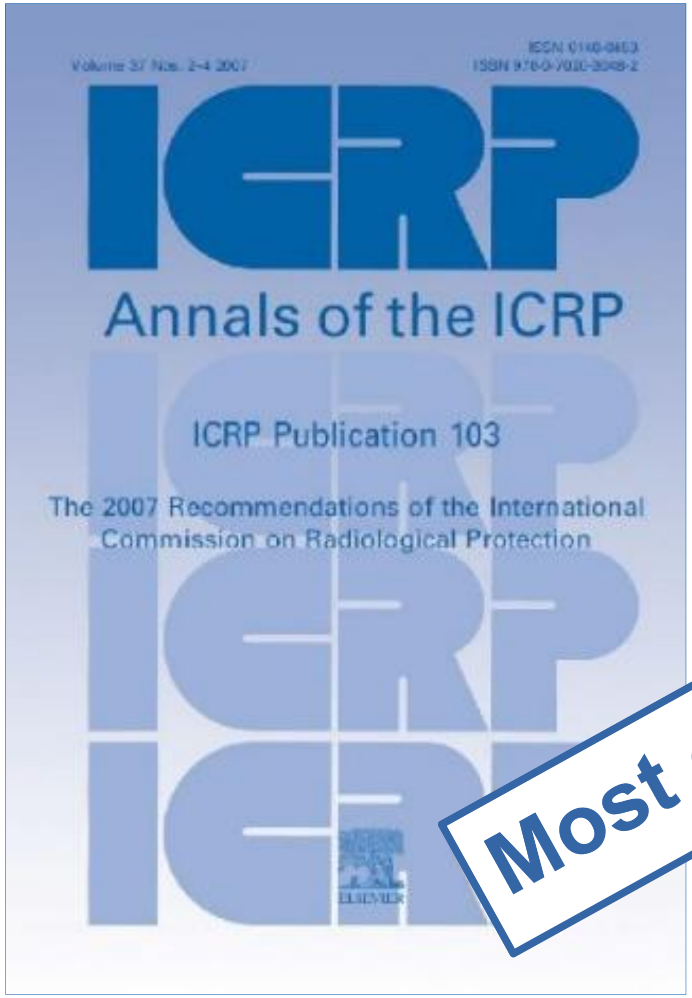
Chair: Kimberly Applegate, USA

Committee 4 Application

provides advice on the application of the Commission's recommendations for the protection of people and the environment in an integrated manner for all exposure situations

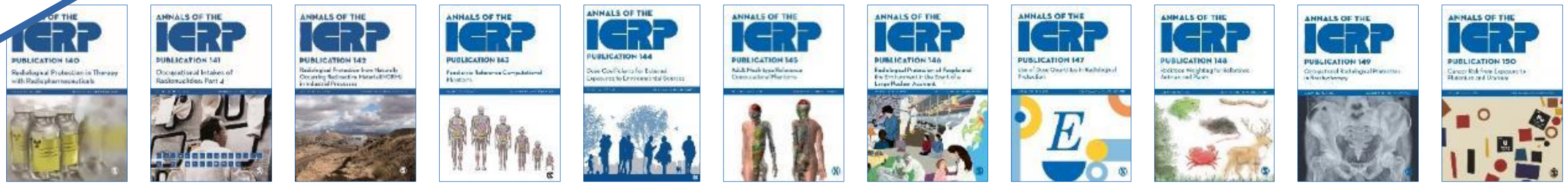
Chair: Thierry Schneider, France

ICRP Publications



- **General Recommendations** (most recent 2007)
- **Publications on specific as… adiological protection**, e.g., deep g… isposal
- **Publications … ools needed to implement radiologi… ion**, e.g., dose coefficients
- **… s that assess impacts of new scientific … gs**, e.g., cancer risks from uranium

Most of them are available at no cost!



31 Active ICRP Task Groups

TG36 Radiopharmaceutical Doses
TG91 Low-dose and Low-dose Rate Exposure
TG95 Internal Dose Coefficients
TG96 Computational Phantoms and R
TG97 Surface and Near Surface
TG98 Contaminated Sites
TG99 Reference Animals and Plants M
TG103 Mesh-type Computational Phantoms
TG105 The Environment in the System of RP
TG106 Mobile High Activity Sources
TG108 Optimisation in Medical Imagin
TG109 Ethics in RP in Medicine
TG111 Individual Response to Radiati
TG112 Emergency Dosimetry
TG113 Dose Coefficients for X-ray Imaging

TG114 Reasonableness and Tolerability
TG115 Risk and Dose for Astronauts
Imaging for Radiotherapy
PET/CT
w_R
the Circulatory System
on Emergencies and Malicious Events
Offspring and Next Generations
TG122 Detriment Calculation for Cancer
Classification Radiation-induced Effects
iple of Justification
Services
omedical Research
Exposure Situations and Categories
TG128 Individualisation & Stratification
TG129 Ethics in the practice of Radiological Protection

New Task Groups announced on the ICRP website

Membership identified through Open Calls

ICRP Mentorship Programme

- **Engagement of university students, early-career professionals, scientists in ICRP Task Groups**
- Mentees may come from educational, governmental, private, other organisations
- Assignment of specific roles or tasks
- Mentor is responsible for providing guidance and support to the mentee

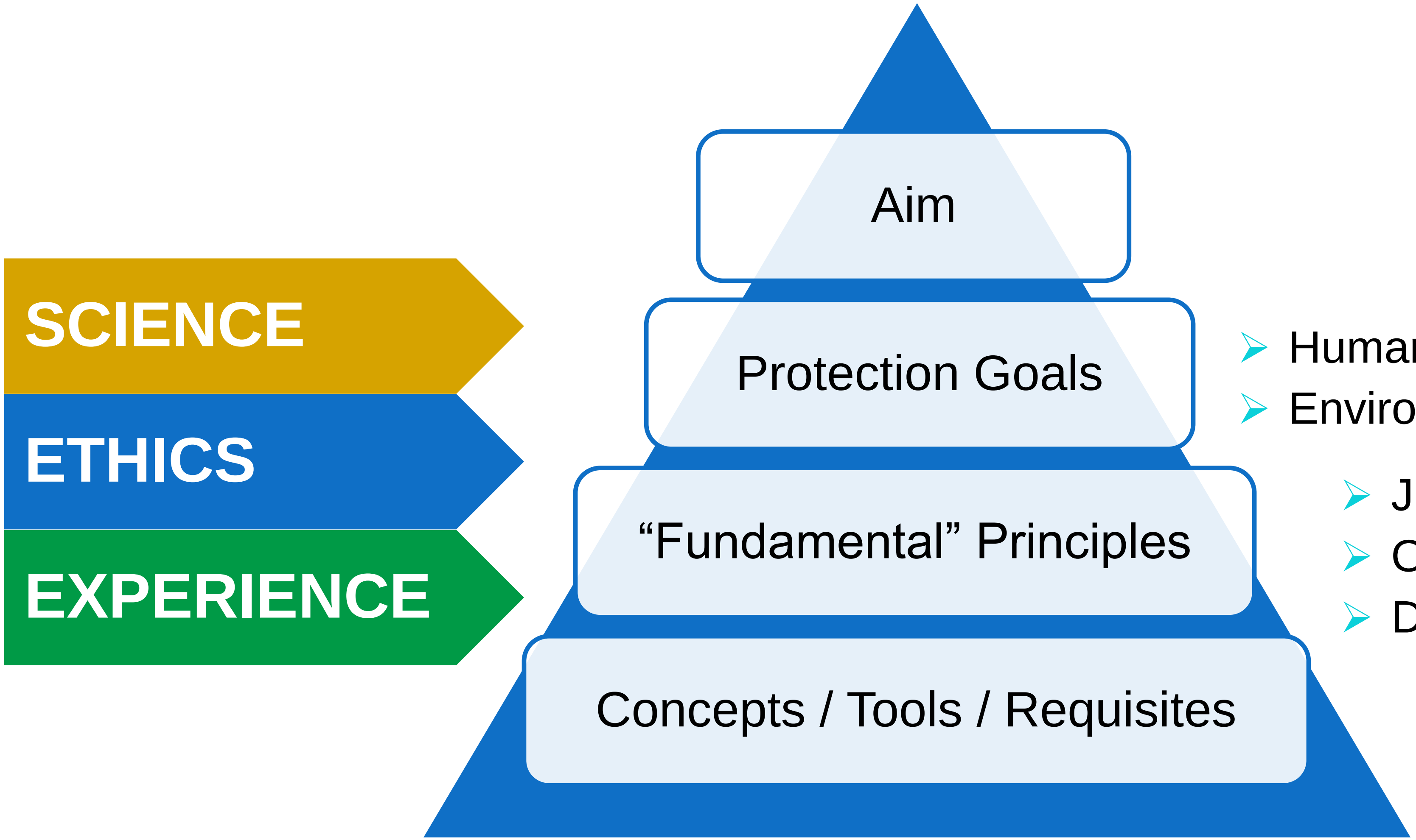
Task Group	Mentor	Task(s), Role	Application Deadline
Task Group 126 Radiological Protection in Human Biomedical Research	TBD	Task Group 126 is seeking mentees **from** [illegible] the organization of an international survey on national/regional practices of Ra[illegible]search involving Humans. The survey will be devoted to investigate the principles [illegible]uman biomedical research involving ionising radiation considering the ethi[illegible]aspects together with design, assessment (justification), evaluation and oversig[illegible]research. [illegible]bute to update literature, develop questionnaires, establish contact with relevant [illegible]stribute questionnaires and analyze results of the survey to be used by the wider Radiation [illegible]tion Community	27 October 2023

Currently 61 ICRP mentees!

International Relationship: 35 Organisations in Formal Relations with ICRP (SLOs)

- Conference of Radiation Control Program Directors (CRCPD)
- European ALARA Network (EAN)
- European Alliance for Medical RP Research (EURAMED)
- European Association of National Metrology Institutes (EURAMET)
- European Association of Nuclear Medicine (EANM)
- **European Commission (EC)**
- European Federation of Organisations for Medical Physics (EFOMP)
- European Nuclear Installations Safety Standards Initiative (ENISS)
- Europ. Platform on Preparedness for Nucl. & Radiol. Emergency Response & Recovery (NERIS)
- European Radiation Dosimetry Group (EURADOS)
- European Radioecology Alliance (ALLIANCE)
- European Society of Radiology (ESR)
- European Training and Education in RP Foundation (EUTERP)
- Heads of the European RP Competent Authorities (HERCA)
- Ibero American Forum of Radiological and Nuclear Regulatory Organisations (FORO)
- IEC Electrical Equipment in Medical Practice (IEC/TC62)
- IEC Nuclear Instrumentation (IEC/TC45)
- Industrial Global Union‘s International Network (INWUN)
- Information System on Occupational Exposure (ISOE)
- International Agency for Research on Cancer (IARC)
- **International Atomic Energy Agency (IAEA)**
- **International Commission on Non-Ionizing Radiation Protection (ICNIRP)**
- **International Commission on Radiation Units and Measurements (ICRU)**
- **International Labour Organisation (ILO)**
- International Organization for Medical Physics (IOMP)
- **International Radiation Protection Association (IRPA)**
- International Society of Radiographers and Radiological Technologists (ISRRT)
- International Society of Radiology (ISR)
- Multidisciplinary European Low Dose Initiative (MELODI)
- **National Council on Radiation Protection and Measurements (NCRP)**
- **OECD Nuclear Energy Agency (NEA)**
- Social Sciences and Humanities in Ionising Radiation Research (SHARE)
- **United Nations Scientific Committee on the Effects of Atomic Rad iation (UNSCEAR)**
- **World Health Organisation (WHO)**
- World Nuclear Association (WNA)

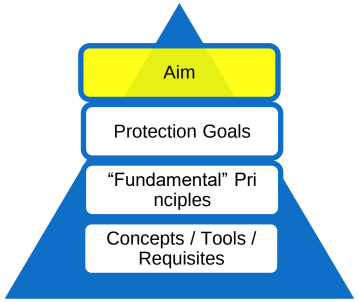
The System of Radiological Protection



- Human Health
- Environment

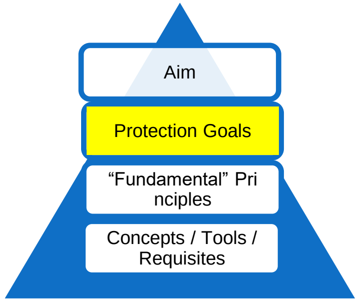
- Justification
- Optimisation
- Dose Limitation

Primary Aim



Contribute to 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

Protection Goals



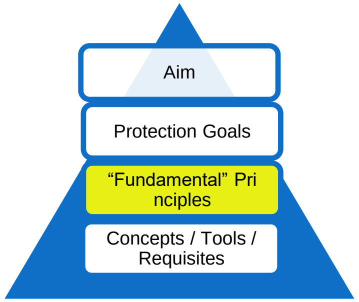
Human Health - Manage and control exposures so that:

- Harmful **tissue reactions** (deterministic effects) are prevented
- The risks of **stochastic effects** (cancer, heritable effects) are **reduced to the extent reasonably achievable**

Environment - Prevent or reduce the frequency of deleterious radiation effects to have a negligible impact on:

- the maintenance of **biological diversity**
- the **conservation of species**
- the health and status of natural **habitats, communities and ecosystems**

Fundamental Principles



Justification

Do more good than harm

Beneficence / Non-maleficence

Optimisation of Protection

Keep likelihood of exposures, number of people exposed, and magnitude of individual doses As Low As Reasonably Achievable (ALARA), taking into account economic and societal factors

Prudence

Individual Dose Limitation

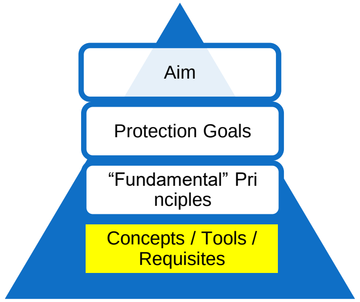
Doses to individuals should not exceed limits

(for regulated sources in planned exposure situations)

Justice

RP and ethics:
ICRP Publication 138

Concepts, Tools, and Requisites



Exposure situations

Existing
Planned
Emergency

Categories of exposure

Medical
Occupational
Public

Dose criteria

Reference levels
Dose Constraints
Limits
etc.

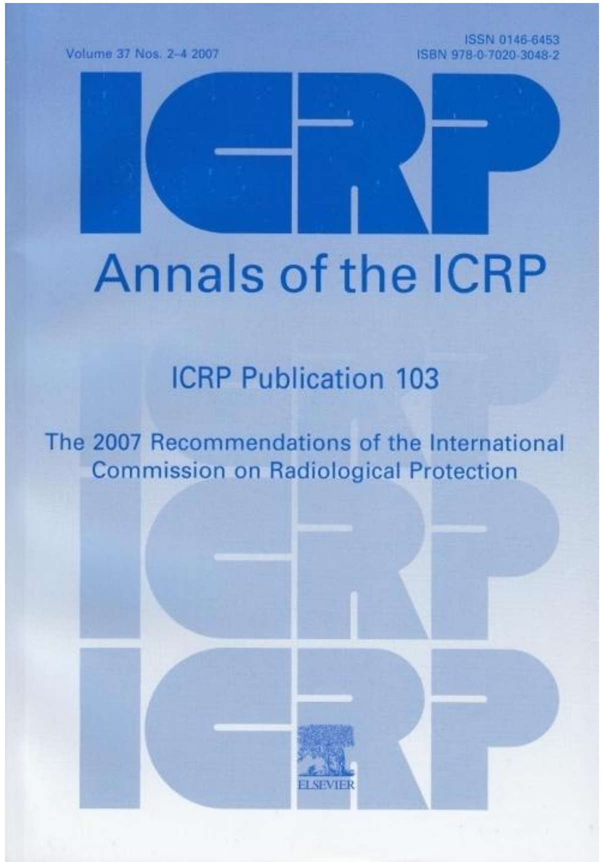
Key concepts

Dose (D, H_T, E)
Types of Effects
Representative person
RAPs
etc.

Requisites

Information
Training
Monitoring
etc.

System Review: Time for Action!



- ICRP Publication 103 forms the basis of radiological protection all over the world
- It is time now to review Publication 103 given **scientific and societal progress** made since 2007
- Identify **basic open questions** (“building blocks”): essential work required for the next general recommendation
- **International collaboration** is key!

>50 Publications since P103 (selected)

Fundamental Concepts
P104 Scope of Control
P147 Dose Quantities
P152 Detriment Calculation

Risk
P115 Lung Cancer Risk from Rn
P118 Tissue Reactions
P150 Plutonium and Uranium

Dose
P136 Dose Coeffs for Biota
P143/145/156 Mesh Phantoms
ICRU 95 Operational Quantities
P130/134/137/141/151/158

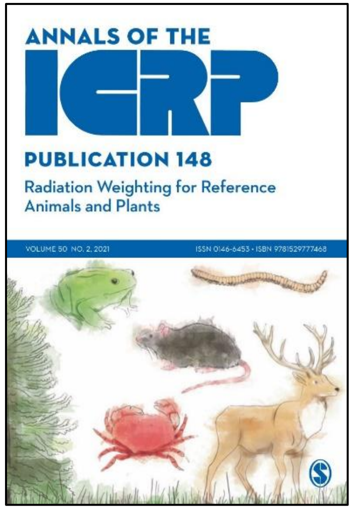
Ethics
P138 Ethical Foundations of RP
P157 Ethics for RP in Medicine

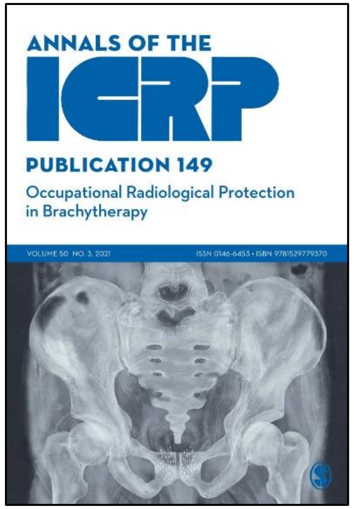
Environment
P108 RAPs
P114 Transfer Parameters
P124 Protection of Environment
P148 Radiation Weighting for RAPs

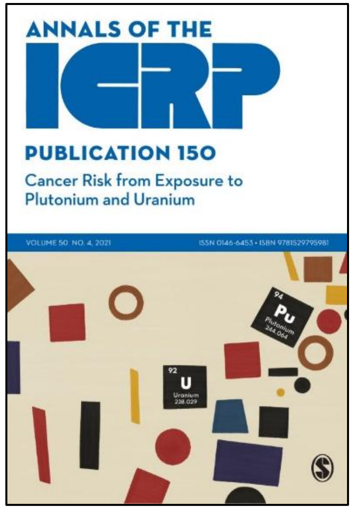
Exposure Situations
P122 Geological Disposal
P126 Radon
P132 Cosmic Radiation in Aviation
P142 NORM

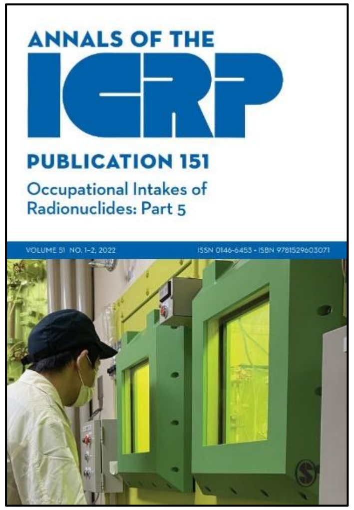
New Domains
P123 Astronauts
P153 Veterinary Practice

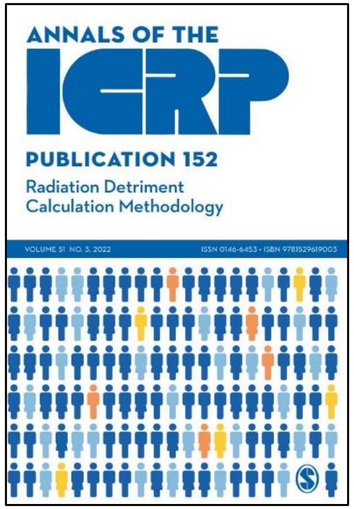
Many on RP in medicine for diagnosis and treatment (>10)

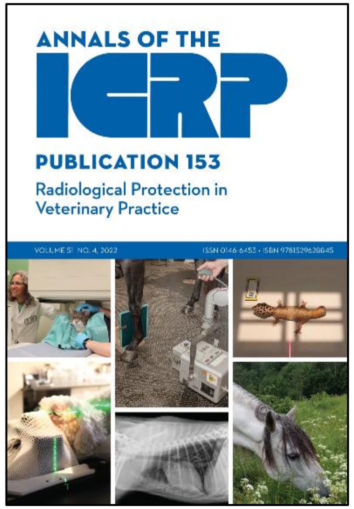












Initial Key Milestones (open access papers)

1. Keeping the ICRP recommendations fit for purpose
Clement et al 2021 JRP, www.doi.org/10.1088/1361-6498/ac1611

2. Areas of research to support the system of radiological protection
Laurier et al 2021 REB, www.doi.org/10.1007/s00411-021-00947-1

Thoughts from ICRP & invitation to contribute

3. Summary of the 2021 ICRP workshop on the future of radiological protection
Rühm et al 2022 JRP, www.doi.org/10.1088/1361-6498/ac670e

4. … A focus on research priorities - feedback from the international community
Rühm et al 2023 JRP, www.doi.org/10.1088/1361-6498/acf6ca

Summarises feedback from the community

Overarching Considerations

The review & revision process must be inclusive, accessible & transparent

The System must be based on solid science & ethical values

The System must be easier to communicate & easier to use

Updates must contribute to improved protection

The underlying basis must be robust to handle complex problems and complex scientific, ethical, and practical issues

ICRP2025

8TH INTERNATIONAL SYMPOSIUM ON THE SYSTEM OF RADIOLOGICAL PROTECTION

7-9 OCTOBER 2025 • ABU DHABI, UAE

7-9 October 2025 at the Ritz-Carlton Abu Dhabi, Grand Canal

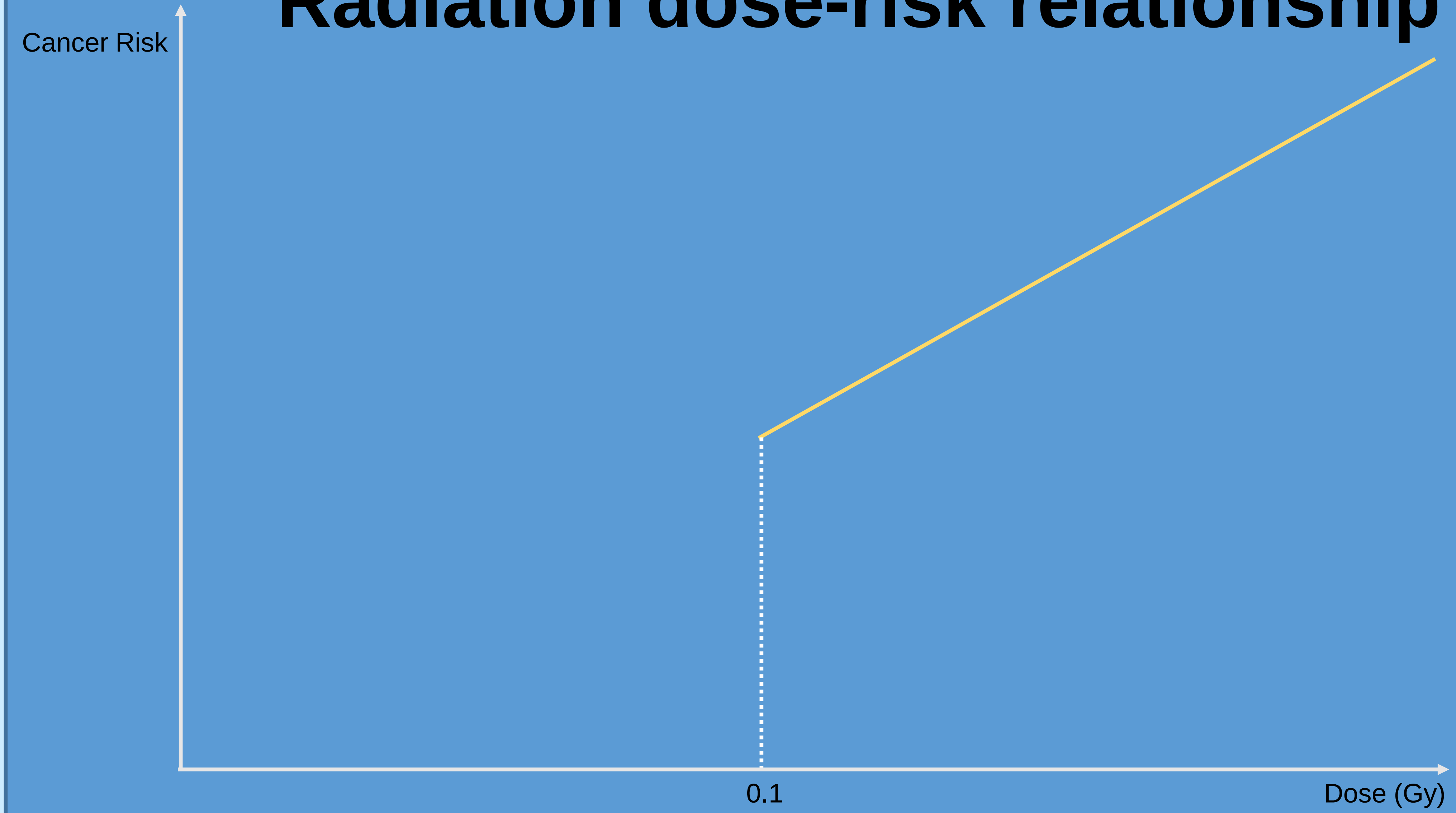
Registration and abstract submissions now open

Interested in exhibition space or sponsorship? Contact Kelsey Cloutier, ICRP Head of Stakeholder Engagement and Communications (kelsey.cloutier@icrp.org)

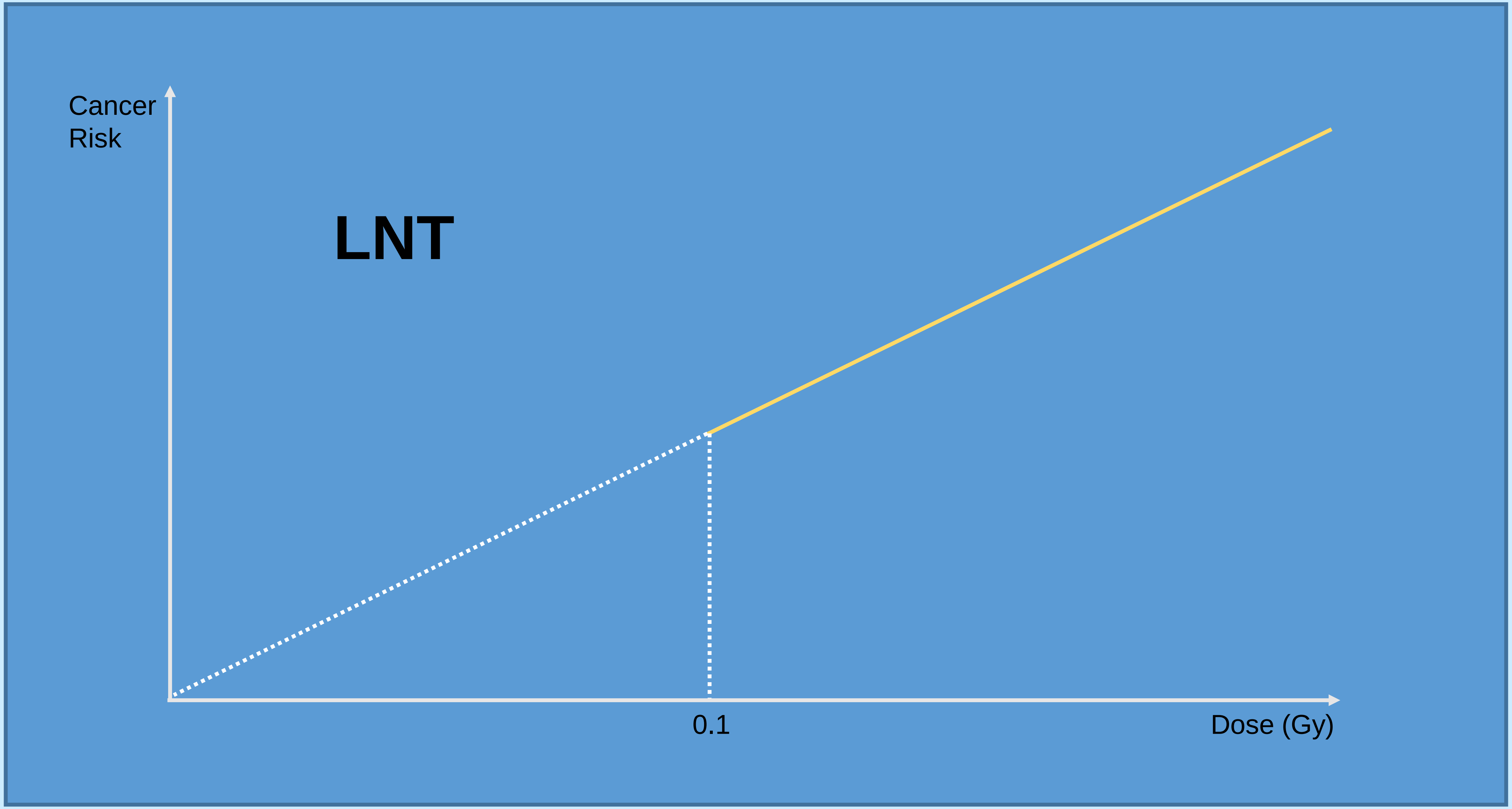
LNT

Linear Non-threshold
문턱없는 선형 모델

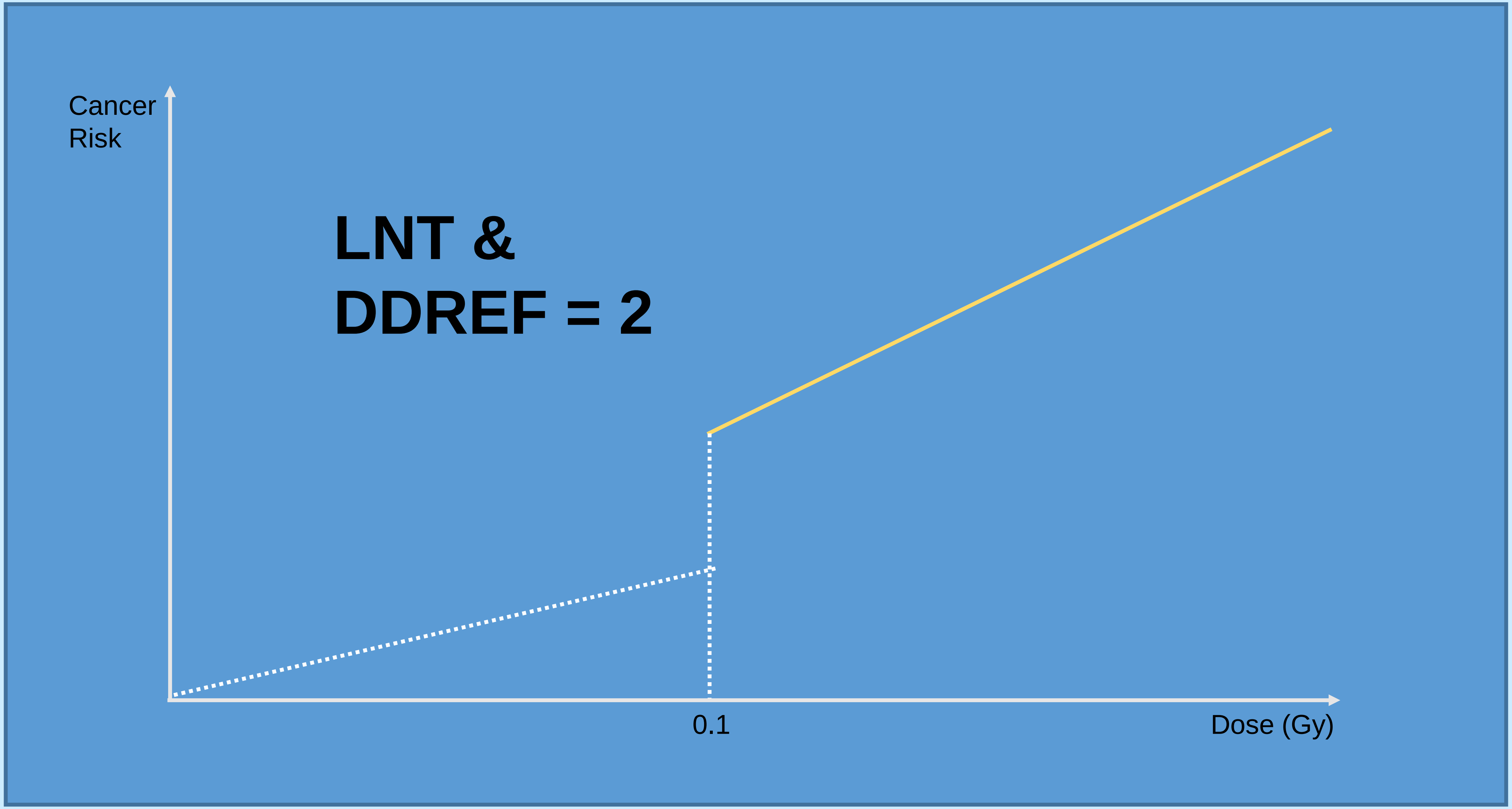
Radiation dose-risk relationship



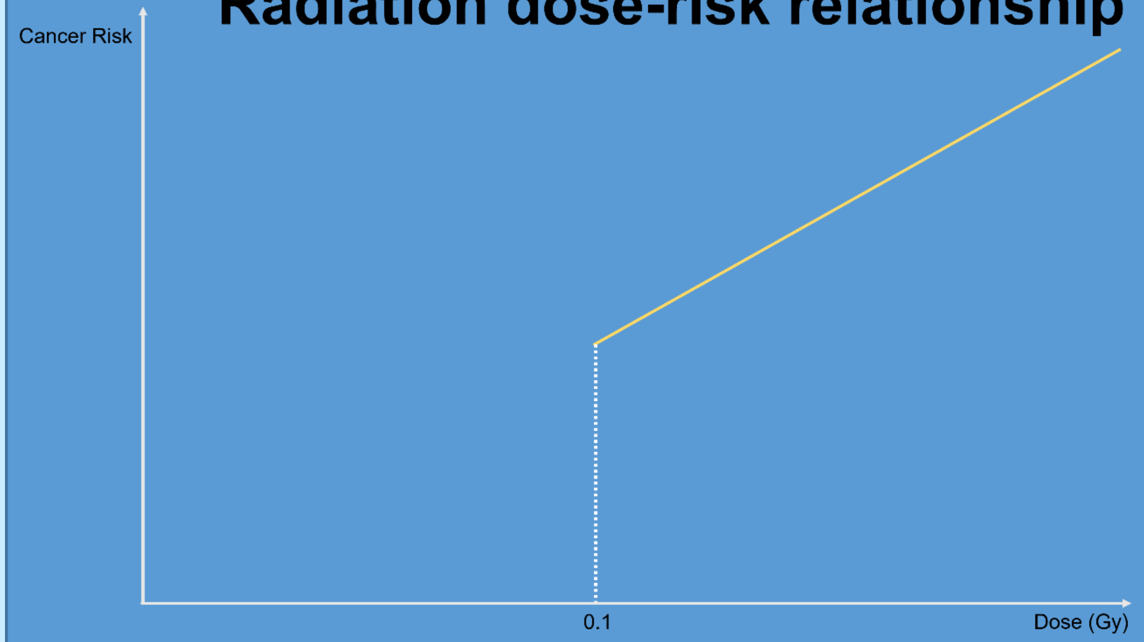
Radiation dose-risk relationship

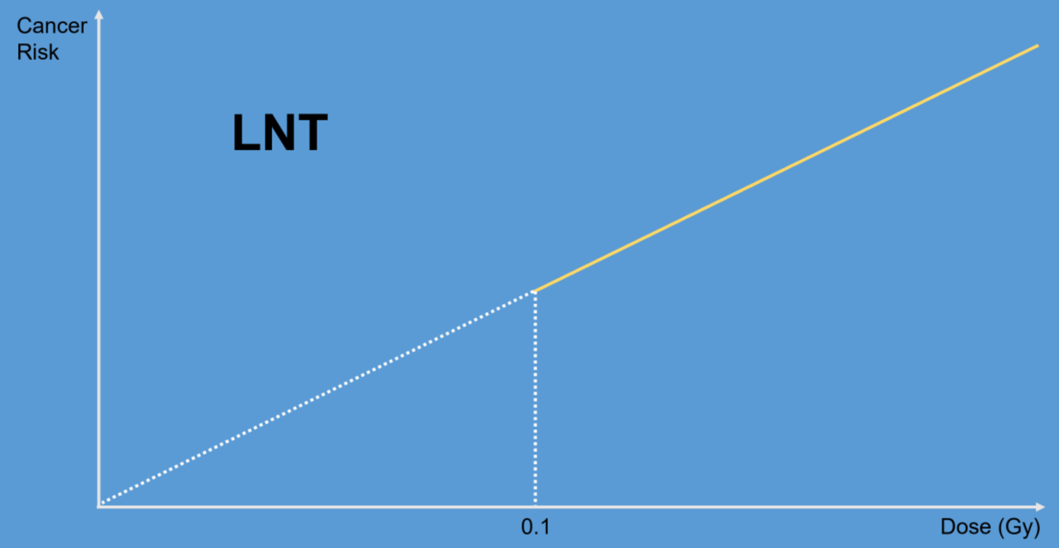


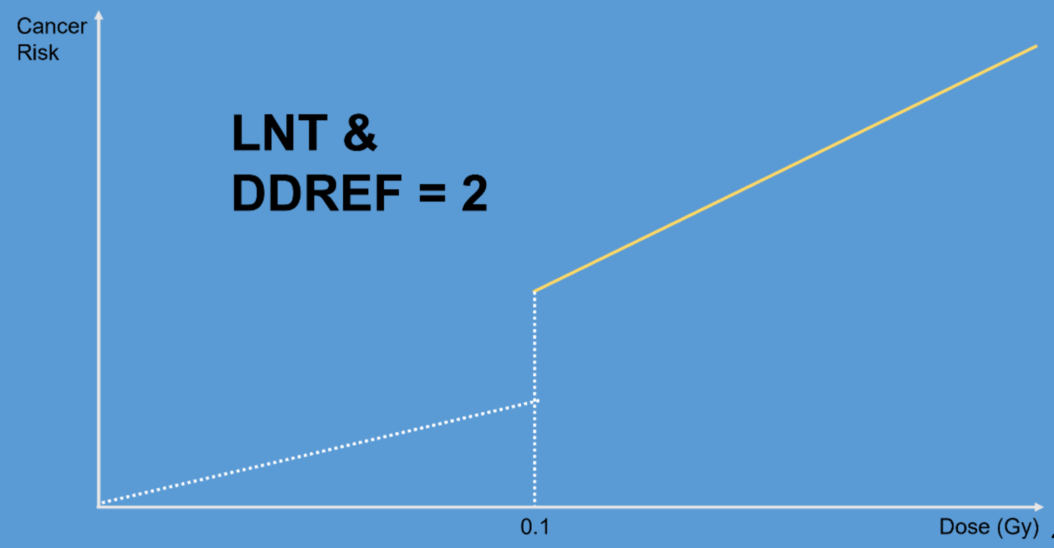
Radiation dose-risk relationship



Radiation dose-risk relationship





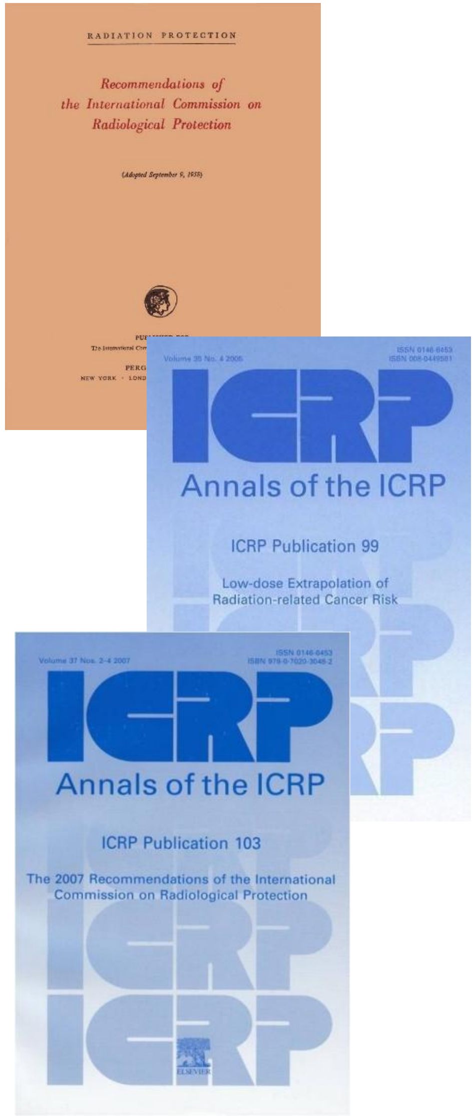


History of the Linear No-Threshold (LNT) model in ICRP

- **Pub 1, 1959**: « On the **assumption that the genetic effects are linearly related to the gonad dose** and **provided that no threshold dose exists**, it is possible to define a population dose average that is relevant to the assessment of genetic injury to the whole population. In the case of **somatic effects** no such dose can easily be defined although the annual per capita dose to certain tissues or to the whole body **may be relevant on the assumption of a non-threshold, linear dose-effect relation »**

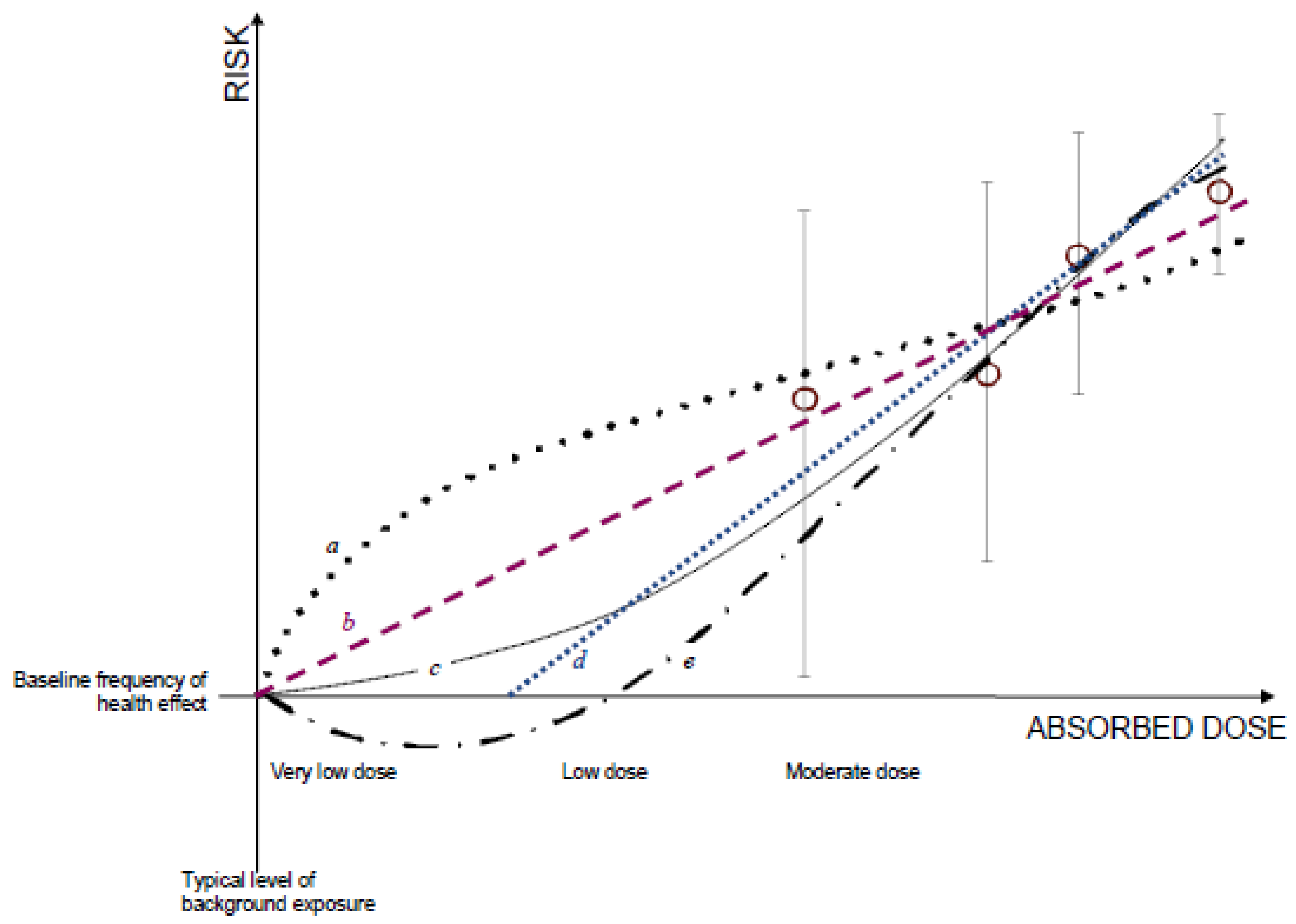
- **Pub 99, 2005: «** while existence of a low-dose threshold does not seem to be unlikely for radiation-related cancers of certain tissues, the **evidence does not favour the existence of a universal threshold**. The **LNT hypothesis, combined with an uncertain DDREF** for extrapolation from high doses, remains a prudent basis for radiation protection at low doses and low dose rates"

- **Pub 103, 2007**: "…the practical system of radiological protection recommended by the Commission will continue to be based upon the assumption that at doses below about 100 mSv **a given increment in dose will produce a directly proportionate increment in the probability of incurring cancer** or heritable effects attributable to radiation. This dose-response model is generally known as 'linear-non-threshold' or **LNT**. …the Commission considers that the adoption of the LNT model combined with a judged value of a dose and dose rate effectiveness factor (**DDREF**) provides a **prudent basis for the practical purposes of radiological protection**, i.e., the management of risks from low-dose radiation exposure »



Plausible dose-response relationships for the risk of cancer in the ranges of very low, low and moderate doses

[UNSCEAR report 2012 Annex A (fig 1), 2015]



Doses are in addition to the total background exposure to natural sources of radiation.

The data points and confidence intervals represent observations of increased frequency of occurrence of a specific cancer type in populations exposed to **moderate doses**.

The various lines represent the following plausible dose-response relationships for inferred risks of cancer for exposures in the range of **low and very low doses**:

(a) supralinear;

(b) linear non-threshold (LNT);

(c) linear-quadratic;

(d) threshold and (e) hormetic.

Criticisms of the LNT model

- Biological: inconsistencies with experimental data
- Epidemiological: uncertainties of data at low doses
- Historical: scientific errors, or even deliberate distortion of results
- Practical: limits the benefits of using ionizing radiation

Radiology

Maurice Tubiana, MD
Ludwig E. Feinendegen, MD
Chichuan Yang, MD
Joseph M. Kaminski, MD

Radiology 2009; 251:13–22

The Linear No-Threshold Relationship Is Inconsistent with Radiation Biologic and Experimental Data[1]

THE RADIATION SAFETY JOURNAL
HEALTH PHYSICS

Health Phys. 97(5):493–504; 2009

DOES SCIENTIFIC EVIDENCE SUPPORT A CHANGE FROM THE LNT MODEL FOR LOW-DOSE RADIATION RISK EXTRAPOLATION?
Averbeck, Dietrich*

Commentary

Toxicology Research and Application

Toxicology Research and Application
1–3
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DOI: 10.1177/2397847317694998
journals.sagepub.com/home/tor
SAGE

LNTgate: The ideological history of cancer risk assessment

Edward J Calabrese

What Would Become of Nuclear Risk if Governments Changed Their Regulations to Recognize the Evidence of Radiation's Beneficial Health Effects for Exposures That Are Below the Thresholds for Detrimental Effects?

Jerry M. Cuttler[1] and Edward J. Calabrese[2]

Dose-Response:
An International Journal
October-December 2021:1–6
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DOI: 10.1177/15593258211059317
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SAGE

DOSE–RESPONSE

Implications of recent epidemiologic studies for the linear-nonthreshold model and radiation protection

NCRP Commentary n°27, 2018

Critical review of recent studies (10y)

- 29 studies (occupational, medical, environmental)

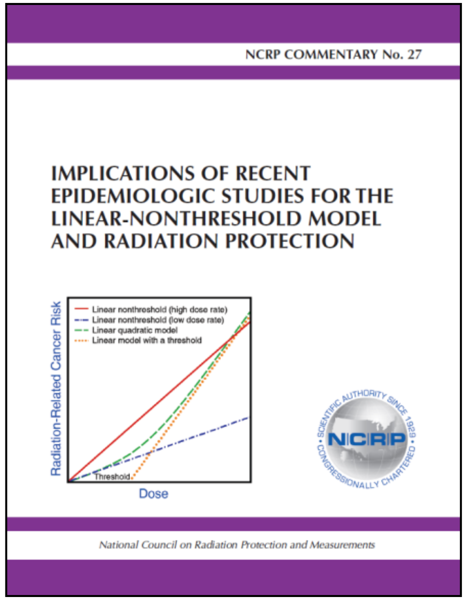
Systematic application of quality criteria

- Epidemiology - Dosimetry – Modelling
- Composite score of specific strengths and weaknesses

Overall evaluation of the support to LNT

- Most of the quantitative low dose-rate epidemiological data **broadly support a LNT model** for total solid cancer and leukemia.

➡ **The LNT model, perhaps with a DREF >1, is prudent and practical for radiation protection purposes**

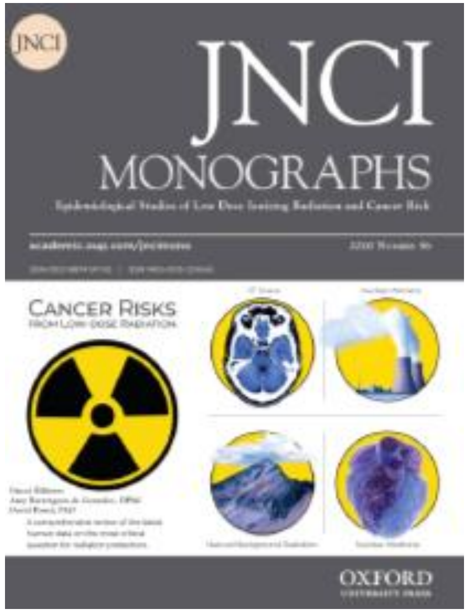


[NCRP 2018; Shore et al J Radiol Prot. 2018]

Low dose epidemiology: Meta-analyses, pooled analyses and syntheses

ICRP

[Shore et al IJRB 2017]



[Berrington de Gonzalez et al; Hauptmann et al. JNCI Monographs, 2020]

Mutation Research/Genetic Toxicology and Environmental Mutagenesis
Volume 873, January 2022, 503436

Cancer risk following low doses of ionising radiation – Current epidemiological evidence and implications for radiological protection

W. Rühm [a], D. Laurier [b], R. Wakeford [c]

Brain cancer after radiation exposure from CT examinations of children and young adults: results from the EPI-CT cohort study

Michael Hauptmann, Graham Byrnes, Elisabeth Cardis, Marie-Odile Bernier, Maria Blettner, Jérémie Dabin, Hilde Engels, Tore S Istad, Christoffer Johansen, Magnus Kaijser, Kristina Kjaerheim, Neige Journy, Johanna M Meulepas, Monika Moissonnier, Cecile Ronckers, Isabelle Thierry-Chef, Lucian Le Cornet, Andreas Jahnen, Roman Pokora, Magda Bosch de Basea, Jordi Figuerola, Carlo Maccia, Arvid Nordenskjold, Richard W Harbron, Choonsik Lee, Steven L Simon, Amy Berrington de Gonzalez, Joachim Schüz, Ausrele Kesminiene

[Hauptmann et al. 2022 Lancet Oncol]

RESEARCH

OPEN ACCESS

Check for updates

Cancer mortality after low dose exposure to ionising radiation in workers in France, the United Kingdom, and the United States (INWORKS): cohort study

David B Richardson,[1] Klervi Leuraud,[2] Dominique Laurier,[2] Michael Gillies,[3] Richard Haylock,[3] Kaitlin Kelly-Reif,[4] Stephen Bertke,[4] Robert D Daniels,[4] Isabelle Thierry-Chef,[5] Monika Moissonnier,[6] Ausrele Kesminiene,[6] Mary K Schubauer-Berigan[6]

[Richardson et al. BMJ 2023]

Low dose epidemiology: obtained results on cancer risks

Solid cancers – INWORKS [Richardson et al. BMJ 2015]

Pooled analysis - 3 cohorts of workers - n = 308 297

-> **Significant association when excluding cumulated doses above 100 mGy**

Solid cancers – ICRP TG91 [Shore et al IJRB 2017]

Meta-analysis – 22 LDR studies – n > 900 000

-> **Significant association when excluding studies with mean doses above 100 mGy**

Thyroid cancer – PIRATES [Lubin et al. JCEM 2017]

Pooled analysis - 9 cohorts of children - n = 107 594 - low-dose (< 200 mGy)

-> Significant association when excluding doses above 100 mGy

Leukemia (excluding CLL) – [Little et al. Lancet Haematol 2018]

Pooled analysis - 9 cohorts of children - n = 262 573 - low-dose (< 100 mSv)

-> Significant association when excluding doses above 100 mSv

Solid cancers – NCI [Hauptmann et al. JNCI Monographs, 2020]

Meta-analysis – 22 studies – Mean dose < 100 mSv

-> Significant association when excluding studies with doses above 100 mGy

Brain tumors – Epi-CT [Hauptmann et al. Lancet Oncol 2023]

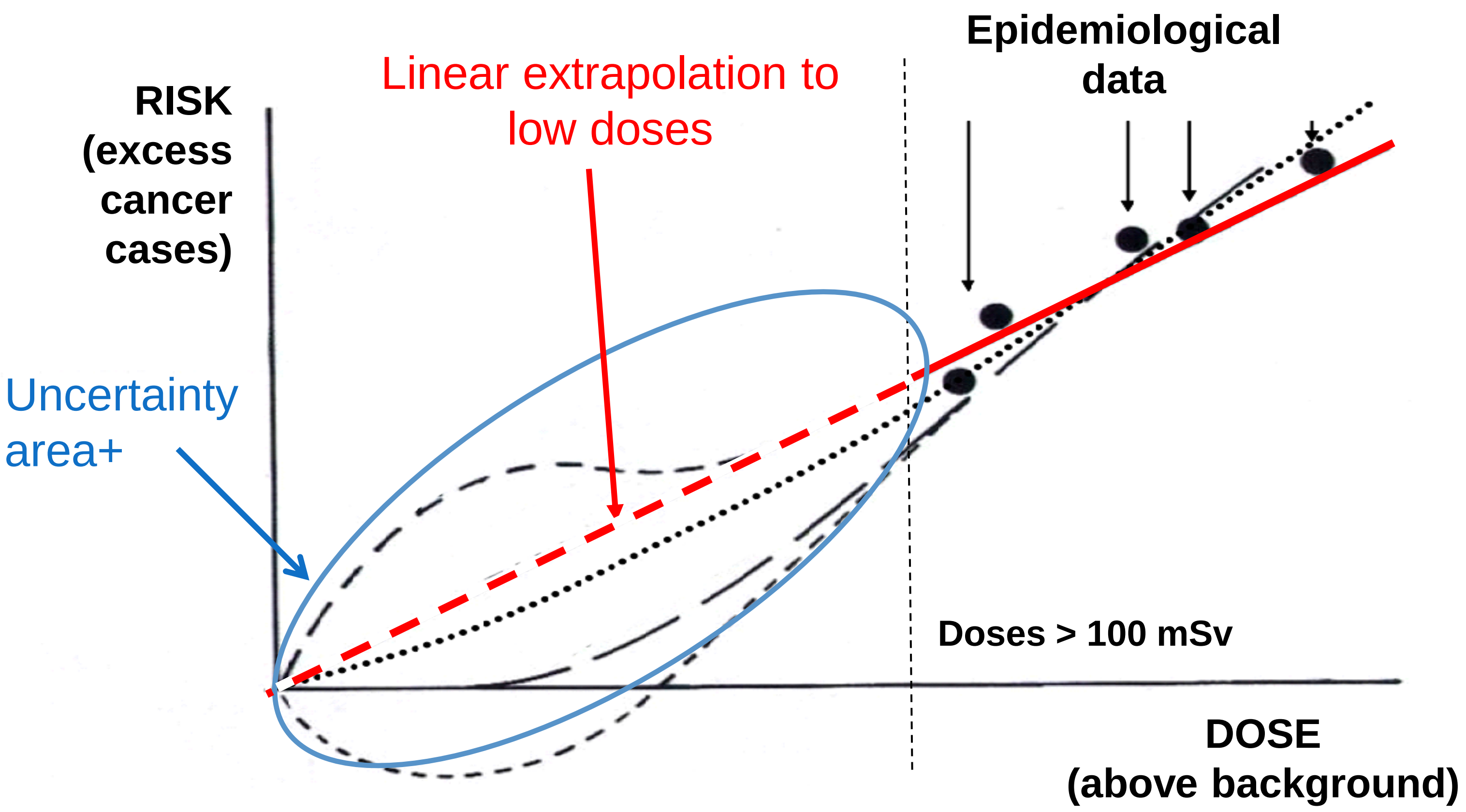
Pooled analysis - 9 cohorts of children - n = 658 752 – CT scans

-> Significant association when excluding cumulated doses above 100 mGy

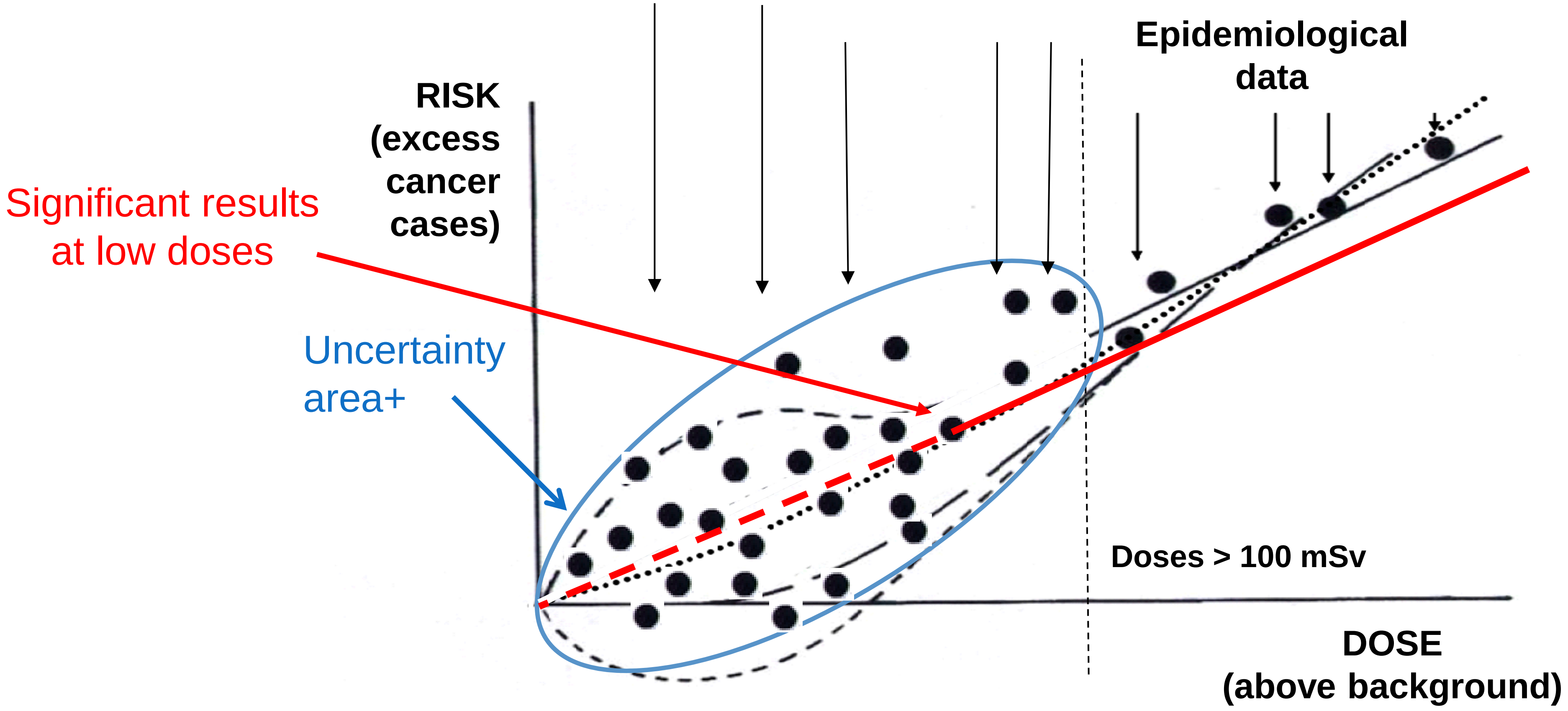
Low dose epidemiology: obtained results on cancer risks

- Clear **improvement in knowledge in the last 2 decades** about cancer risks associated with low doses
- There is **some evidence of some excess risk of some cancers** following low-level exposure to radiation
- There is some evidence of an **increased risk of cancer with repeated or protracted dose**
- The epidemiological evidence for an overall material deviation from a **linear no-threshold dose-response at low doses or low dose-rates** is not persuasive

Dose response relationship: extrapolation of epidemiological observations toward low doses



Dose response relationship: epidemiological observations at low doses

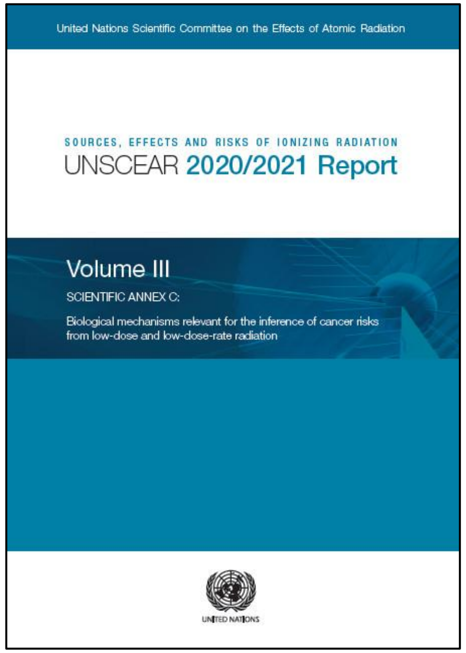


Low dose radiobiology: obtained results on cancer risks

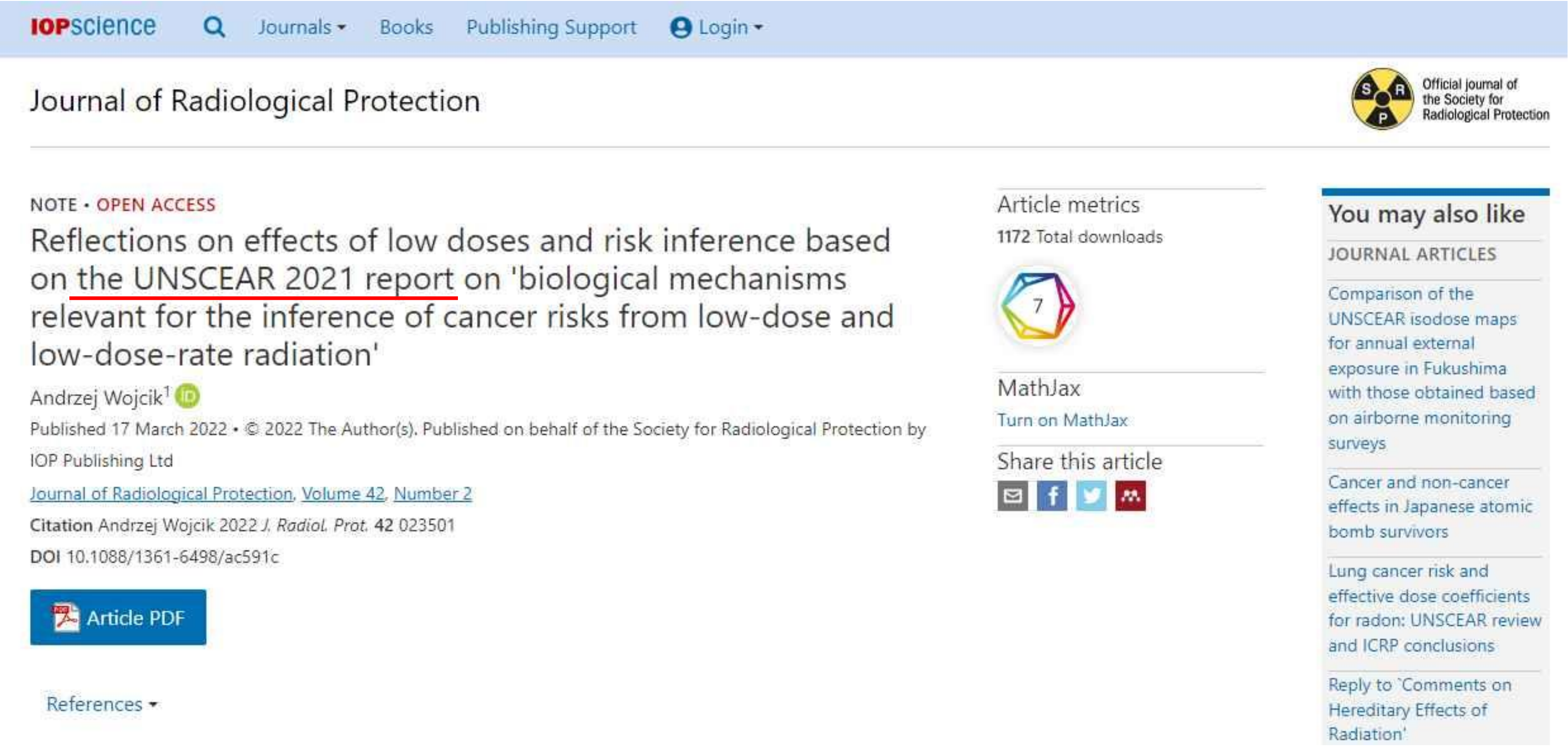
UNSCEAR 2021 report “Biological mechanisms relevant for the inference of cancer risks from low-dose and low-dose-rate radiation“

- Good experimental support for the linearity of dose-response relationships for the majority of mutagenic parameters
- Mutagenic effects (double-strand breaks) are observed at doses of the order of 10 mGy
- Existence of non-mutational mechanisms, but how ionising radiation affects these processes is still poorly understood

→ **Concludes in favour of the LNT model**



Low dose radiobiology: obtained results on cancer risks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NOTE • OPEN ACCESS

Reflections on effects of low doses and risk inference based on the UNSCEAR 2021 report on 'biological mechanisms relevant for the inference of cancer risks from low-dose and low-dose-rate radiation'

Andrzej Wojcik[1]

Published 17 March 2022 • © 2022 The Author(s). Published on behalf of the Society for Radiological Protection by IOP Publishing Ltd

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DOI 10.1088/1361-6498/ac591c

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Reply to 'Comments on Hereditary Effects of Radiation'

UNSCEAR 1994 Annex B. Adaptive responses to radiation in cells and organisms

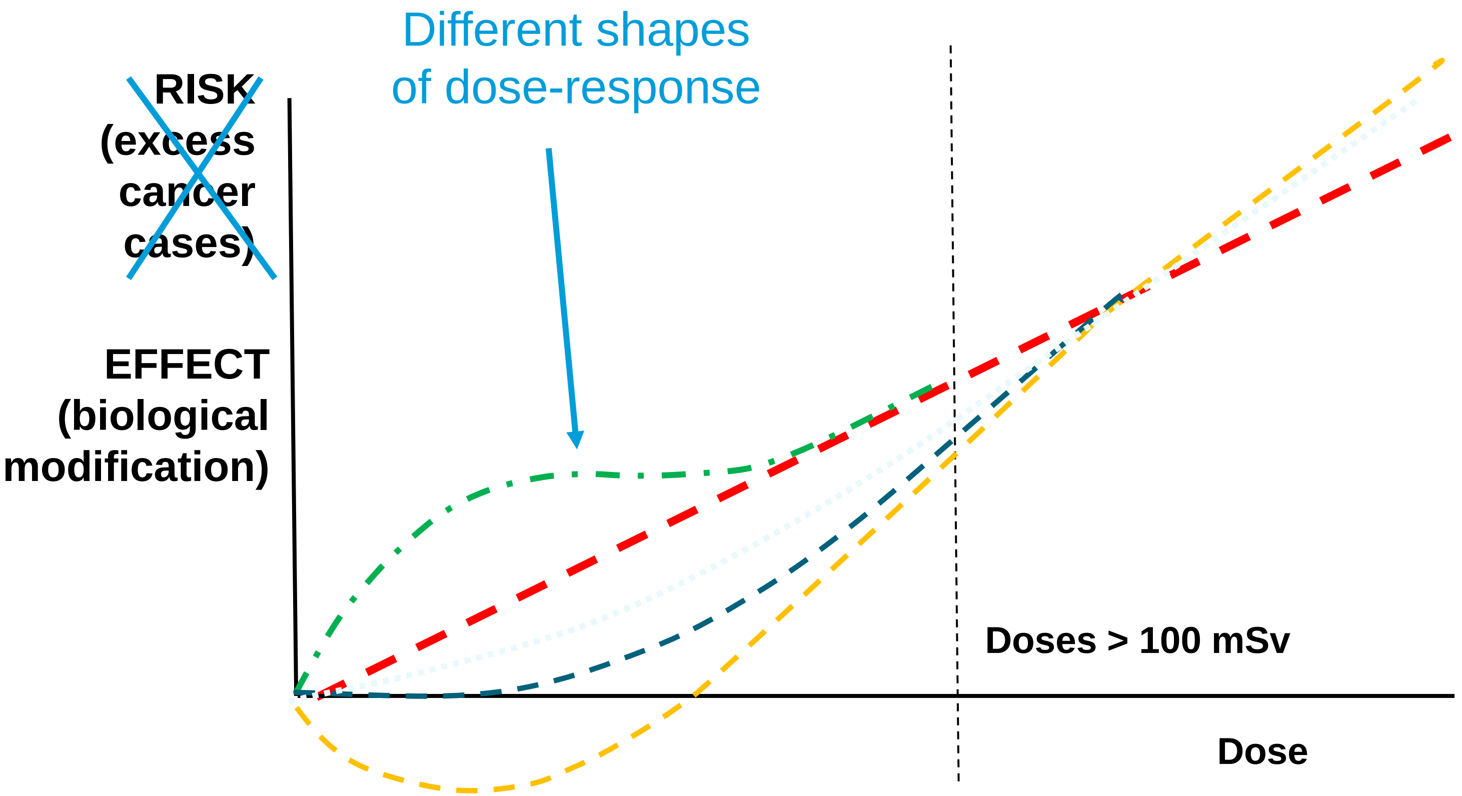
UNSCEAR 2000 Annex G. Biological effects at low radiation doses

UNSCEAR 2006 Annex C. Non-targeted and delayed effects of exposure to ionizing radiation

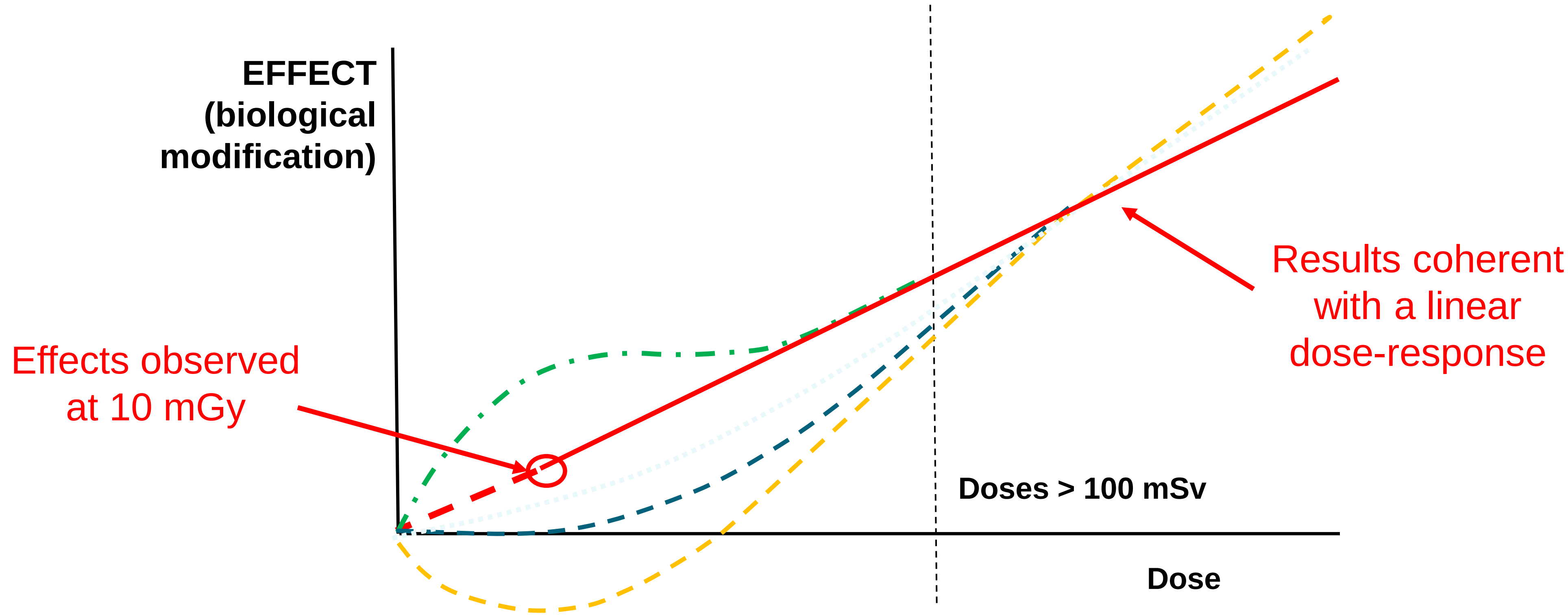
UNSCEAR 2012 Annex A. Attributing health effects to ionizing radiation exposure and inferring risks

… All UNSCEAR reports published since 1994 on effects and mechanisms of low doses very consistently state that, overall, **no data exist that question the validity of LNT.** …

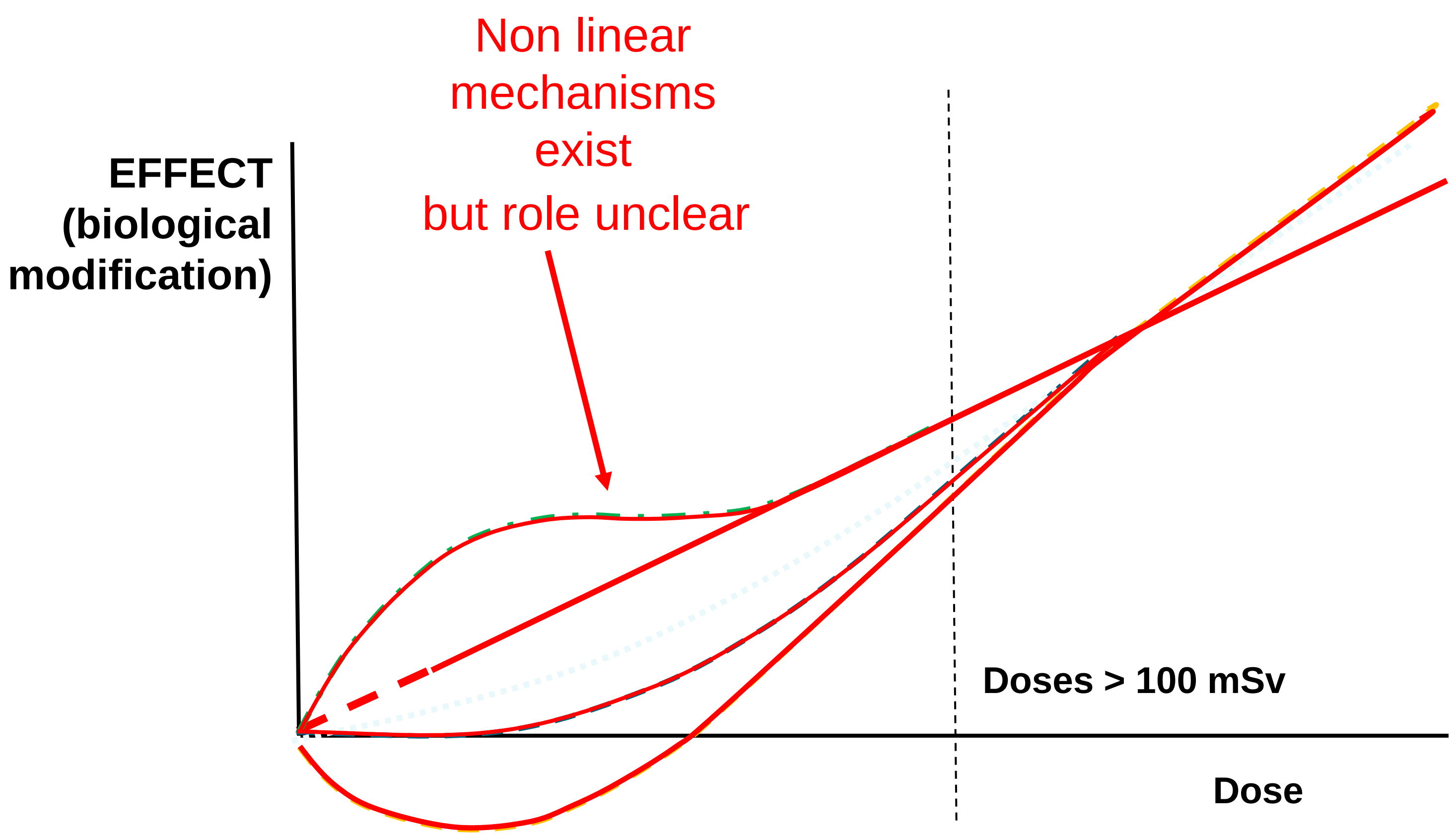
Dose response relationship: biological results at low doses



Dose response relationship: mutagenic mechanisms at low doses



Dose response relationship: non-mutagenic mechanisms at low doses



Assessment of radiation-related health risks by ICRP C1

TG 102 – Detriment Calculation

TG 91 – Dose and dose rate effects

TG 121 – Risks for next generations

TG 111 – Individual response

TG 122 – Update of cancer detriment

Radiation related risks

TG 115 – RP of astronauts

TG 123 – Effects classification

TG 119 – Circulatory diseases

TG 128 – Stratification of RP

TG 118 – RBE, Q, WR

TG91 Draft Report: Public Consultation until June 13, 2025

Webinar on 28 May 2025 12:00-14:00 UTC

MAIN POINTS

- This report evaluates the **current scientific evidence on low-dose and low-dose-rate biological effects of ionising radiation**, in terms of the low dose effectiveness factor (LDEF) and the dose rate effectiveness factor (DREF). The report reviews results on endpoints related to the risk of all solid cancer, at sub-cellular, cellular, tissue and organism, and population levels. In this report, low doses are those below 100 mGy, and low dose rates are those below 0.1 mGy min-1 when averaged over about an hour, for low linear energy transfer (LET) exposures.

…..

- While **considerable uncertainties remain**, the ranges of LDEF and DREF values obtained here are narrower than those obtained in previous evaluations. The overall conclusion of this report is that, based on current scientific evidence, **LDEF and DREF values much larger than 3 or less than 1 are unlikely**. These ranges appear largely consistent for the various sources of data reviewed in this report.

Impact of recent results from biology and epidemiology on the validity of the LNT

Journal of Radiological Protection

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OPINION ARTICLE • OPEN ACCESS

The scientific basis for the use of the linear no-threshold (LNT) model at low doses and dose rates in radiological protection

Dominique Laurier[2,1], Yann Billarand[1], Dmitry Klokov[1] and Klervi Leuraud[1]

Published 29 June 2023 •

Journal of Radiological Protection, Volume 43, Number 2

Citation Dominique Laurier *et al* 2023 *J. Radiol. Prot.* **43** 024003

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Article PDF

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EDITORIAL

The LNT risk model and radiological protection

Richard Wakeford[1,*], Mikhail Balonov[2], John D Boice Jr[3,4], John D Harrison[5,6], Ohtsura Niwa[7], R Julian Preston[8] and Roy E Shore[9]

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[J. Radiol. Prot. 43 (2023) 040201]

Two more recent papers on the LNT

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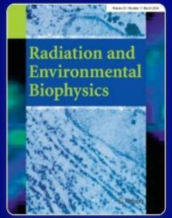
The scientific nature of the linear no-threshold (LNT) model used in the system of radiological protection

Debate | Open access | Published: 02 September 2024

Volume 63, pages 483–489, (2024) Cite this article



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Andrzej Wojcik & Friedo Zölzer

Abstract

During the first half of the 20th century, it was commonly assumed that radiation-induced health effects occur only when the dose exceeds a certain threshold. This idea was discarded for stochastic effects when more knowledge was gained about the mechanisms of radiation-induced cancer. Currently, a key tenet of the international system of

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Invited article / Review

역학연구에서의 비역치선형모델: 방사선 노출 사례

이원진*

고려대학교 의과대학 예방의학교실

The Linear No-Threshold Model in Epidemiological Studies: An Example of Radiation Exposure

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Department of Preventive Medicine, Korea University College of Medicine

Received August 3, 2024
Revised August 15, 2024
Accepted August 18, 2024

ABSTRACT

The linear no-threshold (LNT) model is an assumption that explains the dose-response relationship for health risks, allowing for linear extrapolation from high doses to low doses without a threshold. The selection of an appropriate model for low-dose risk evaluation is a critical component in the risk assessment process

ICRP

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Interpretation of the INWORK epidemiological study (Richardson et al. BMJ 2023)

Dear all

I would like to come back to our discussions about the **interpretation of the INWORK epidemiological study (Richardson et al. BMJ 2023).** This study has been evoked in my presentation on LNT during the MC meeting, during the ICRP symposium in session 17 “Effects & dose-response: cancer, circulatory disease, and beyond”, and in the Committee meetings, in C1 and in the C1-C2 join session.

The principal conclusion coming from INWORKS is that **the findings provide support to the Radiological Protection System**. Two main results of the INWORKS study are

- **There is an association between cancer risk and radiation exposure when exposure is protracted over a long period**
- **There is an association between cancer risk and radiation exposure even in the low dose range**

Currently, the radiation detriment calculation is based mainly on risk models derived from the Japanese atomic bomb survivor study (LSS). That study is surely a valuable source of information about the effects of ionising radiation, but that population was exposed acutely to radiation, and the survivors received low to high doses, at high dose rate.
INWORKS demonstrates a positive association between radiation dose and cancer risk in a population that was exposed protractedly to radiation, and workers received low to moderate doses, cumulated at low dose rates. This is indeed an important finding which provides a complement to our knowledge about the effects of radiation exposure derived from studies of populations exposed acutely. **These results are clearly in support of the current system of radiological protection.**

Interpretation of the INWORK epidemiological study (Richardson et al. BMJ 2023)

When we consider the findings on the full INWORKS cohort, the results are very coherent with the risk estimates derived from the A-bomb survivor study (see Leuraud et al. REB 2021) for a detailed comparison of the results of the LSS and those of INWORKS). These results are of major interest in the discussion about DREF.

Of course, as most of the research studies, when you try to answer a scientific issue, you often raise other issues. This is the case in the recent INWORKS article, **in which some of the results raise questions about the estimate of the dose-risk relationship when restricting to low doses or when excluding early workers from the analysis.** These results needs to be further investigated.

Finally, I would like to emphasize a point that seems fundamental to me, namely that **no epidemiological study should be considered in isolation.** Even if the LSS or INWORKS are clearly major studies in this field, **their results must be considered in the context of all the available data.** Thus, **suggesting that a single result could have a direct impact on regulatory aspects is a misinterpretation of the recently published INWORKS results.**

Best regards
Dominique

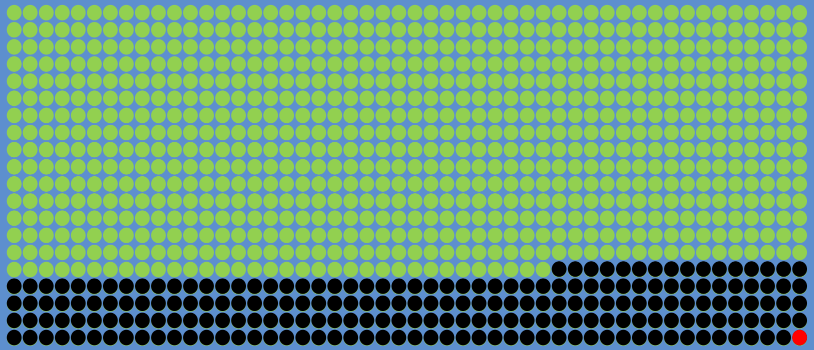
CANCER AMONG WORKERS: Conclusions

- **Miner studies have provided strong evidence of excess lung cancer. Dose response quite linear.**

- **Worker studies provide evidence of association with broader group of solid cancers. Dose-response is quite linear.**

- **Excess attributable cases in worker studies are quite small, given the typical low dose distributions in these cohorts.**

Large pooling studies provide statistical precision, and allow us to turn our focus towards questions of: confounding, selection, and measurement error.



Among 1000 workers*

216 deaths - 64 by cancer or leukaemia

of which 1 attributable to exposure to ionizing radiation

- **based on results form the INWORKS cohort : 308,297 workers, with mean dose 24 mSv and follow-up 27 years (i.e., age at end of follow-up 58 years).**

Berrington de Gonzalez et al; Hauptmann et al. JNCI Monographs, 2020

Courtesy of David Richardson, UC Irvine at ICRP 2023 Symposium

48