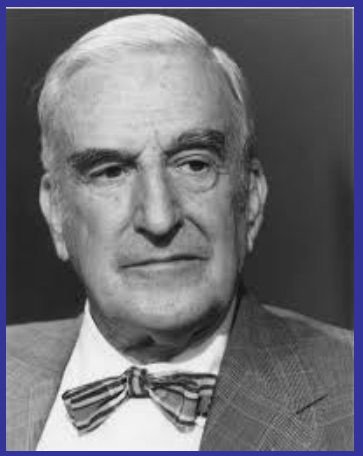
On the Shoulders of Giants:
Radiation Protection over 50 years

…….and some anecdotes, stories and secrets

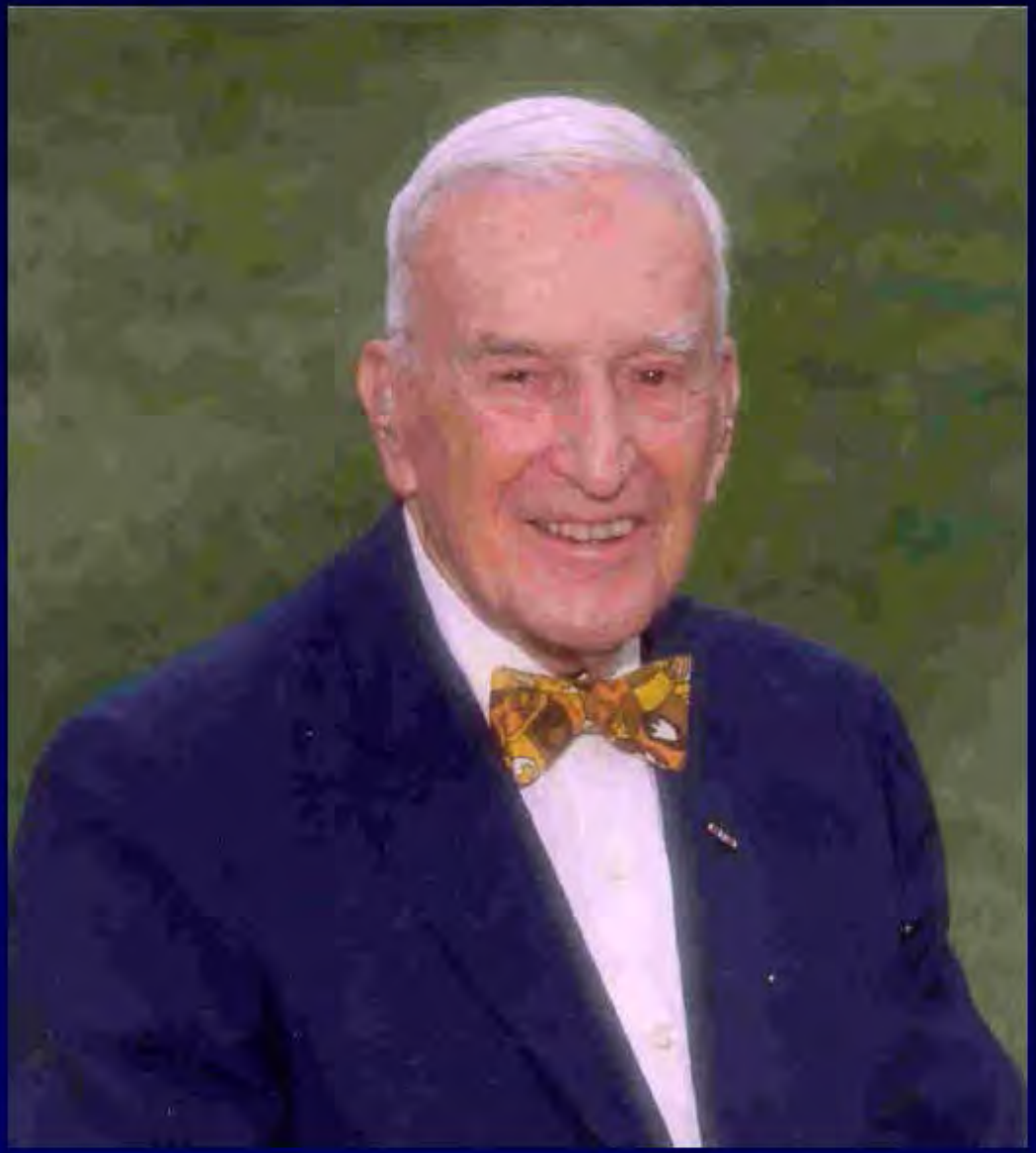
38th Lauriston S. Taylor Lecture

NCRP 50th Anniversary



Fred A. Mettler Jr, MD., MPH

Lauriston Sale Taylor 1902 – 2004



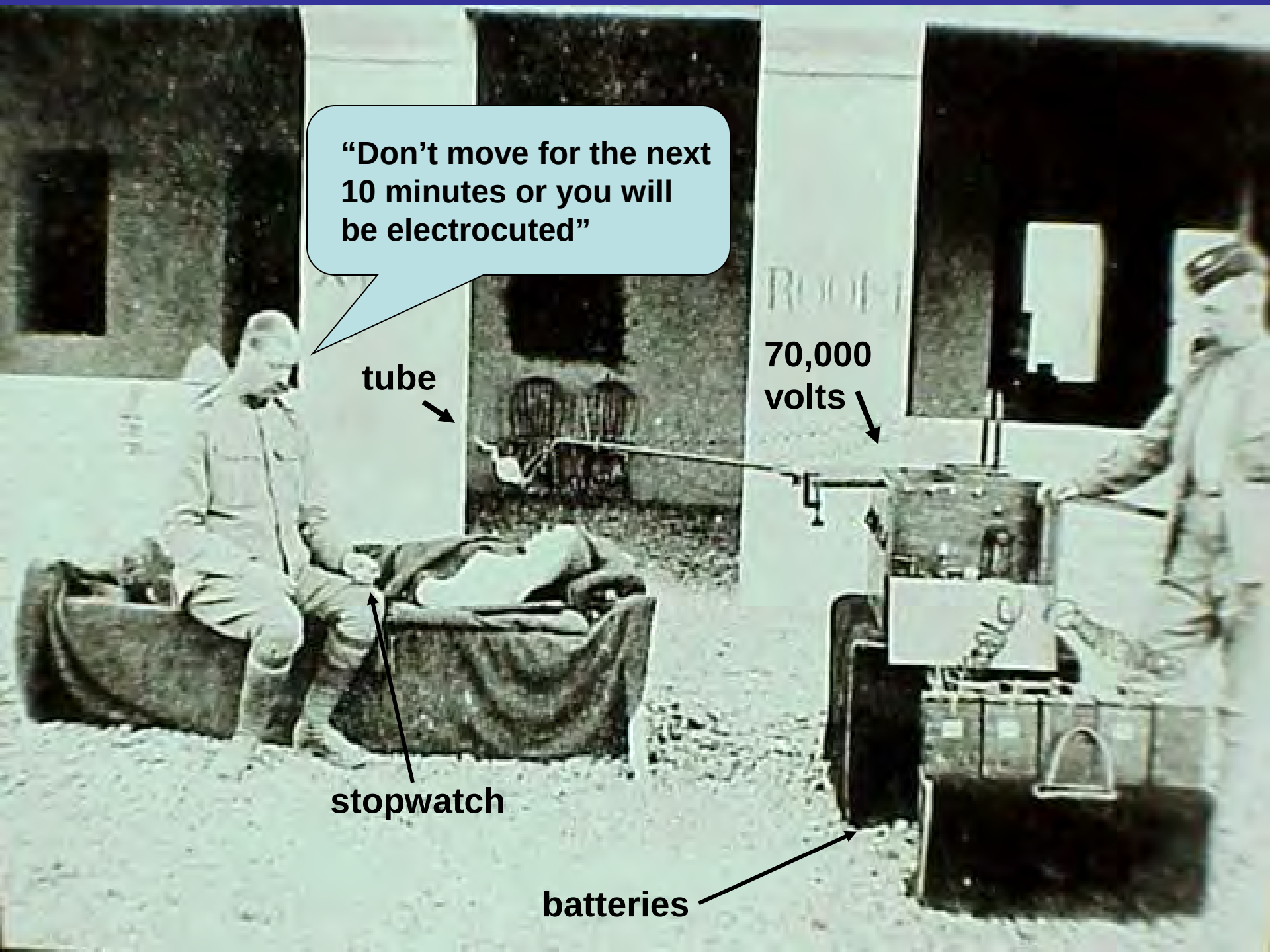
ROG

50+ year career

- 1925 Worked at Western Electric (Bell labs)
- 1925 Formation of ICRU (age 23)
- 1927 Began at Natl. Bureau of Standards
- 1928 Formation of ICRP (age 26)
- 1965 retires from NBS after 37 years
- 1965 National Academy of Sciences
- 1972 retires to work for NCRP
- 1977 Retires from NCRP
- Honorary President of NCRP until age 102

Early Radiation Safety NCRP Report #1

Laurie doing early “CPR”


“Don’t move for the next 10 minutes or you will be electrocuted”
tube
70,000 volts
stopwatch
batteries

Taylor Presiding at the First Meeting of the New National Council on Radiation Protection and Measurements, August 3, 1964

ROG

“If I have seen farther than others, it is because I was standing on the shoulders of giants”

Isaac Newton 1642-1727

…..really Bernard of Chartres 1159

The alternative……

"If I have not seen as far as others, it is because giants were standing on my shoulders"

Harold Abelson

Acknowledgement

I have stood on the shoulders of many Giants and when I asked for their help, advice and wise counsel they always gave it to me.

Thanks to the many of you who provided advice and ideas to me for the content of this lecture

As a child….. unknowingly being influenced by radiation Giants

Harald Rossi [8]

Edith Quimby

1958 Nobel Prize winners
Introduction to mutation by radiation

George W Beadle

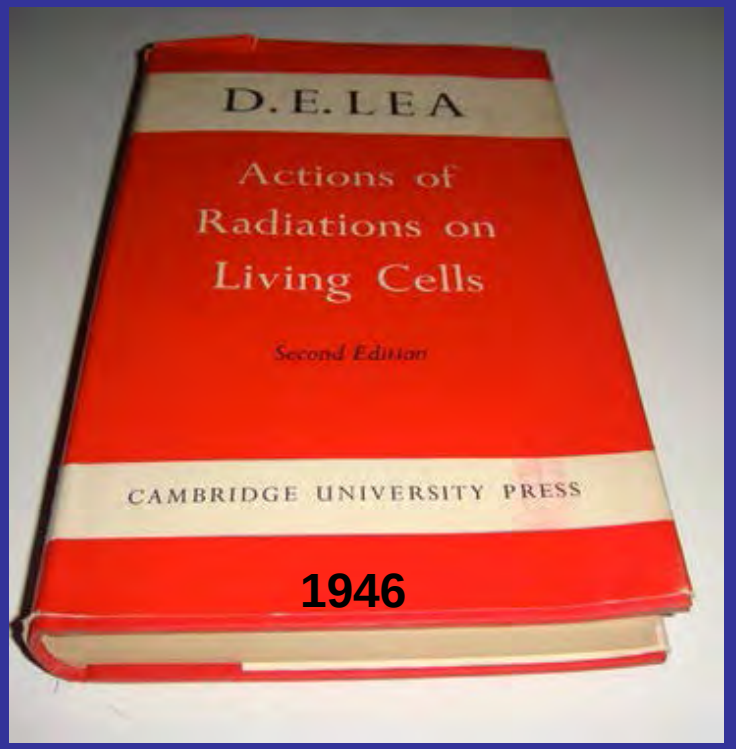
Edward L. Tatum

X-ray mutation of mold linked one gene to one enzyme

Director of Max Planck Institute for Biophysik

Radiation effects on cellular membranes

Boris Rajewsky



…and suggests I work with Alex Hollaender and gives me a reference

Oak Ridge National Labs – separate mouse macroglobulin

ALEXANDER HOLLAENDER: A RADIANT BIOLOGIST

Alexander Hollaender was director of ORNL's Biology Division from 1946 through 1966. Under his leadership, it became the Laboratory's largest division and gained international recognition for its contributions to radiation genetics, biochemistry, radiation carcinogenesis, and molecular biology.

Suggests I work with Louis Hempelmann and gives me a reference

U.S. Atomic Energy Commission
Fallout measurement

Harold Beck

John Harley [9] on roof of HASL with gummed film for fallout dosimetry

Louis H. Hempelmann MD
Epidemiology

Elinor Pulitzer

Oppenheimer & Hempelmann

Head of Radiological Safety (age 28 4 years out of medical school)

Jefferson Medical School

Robert Brent [30]

Robert Gorson

Residency and MGH and Boston
Medical physics

Edward Webster [16]

…suggests that I go to Public Health School and gives me a reference

Harvard PHS
Environmental Health

Dade Moeller [32]

….suggests that I should go take nuclear engineering at MIT and gives me a reference

Univ of Chicago and New Mexico

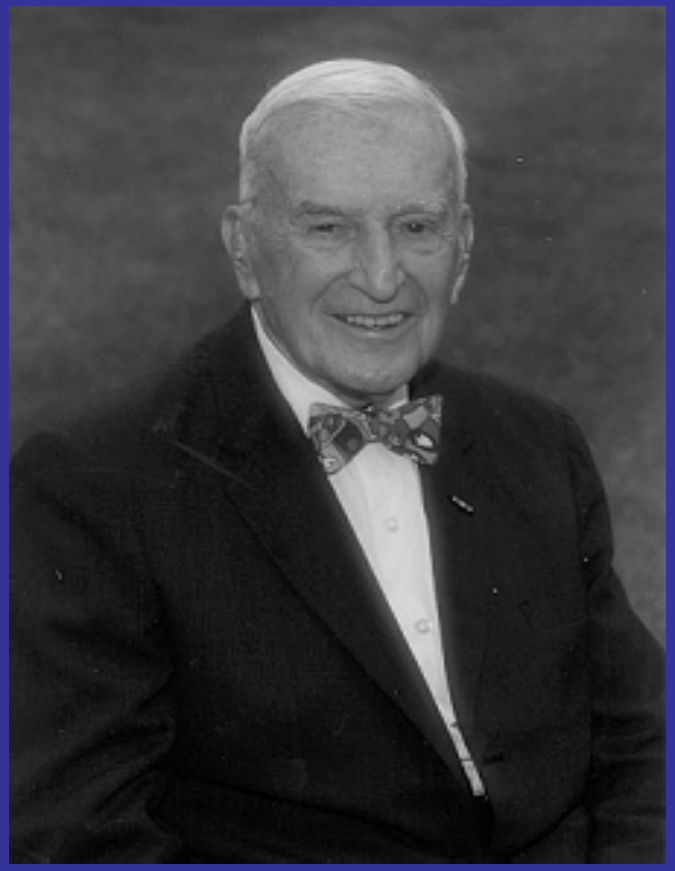
Introduction to radiation protection

Robert D. Moseley Jr. MD

Worst paying job offer but Introduces me to NCRP and UNSCEAR

My first NCRP meeting

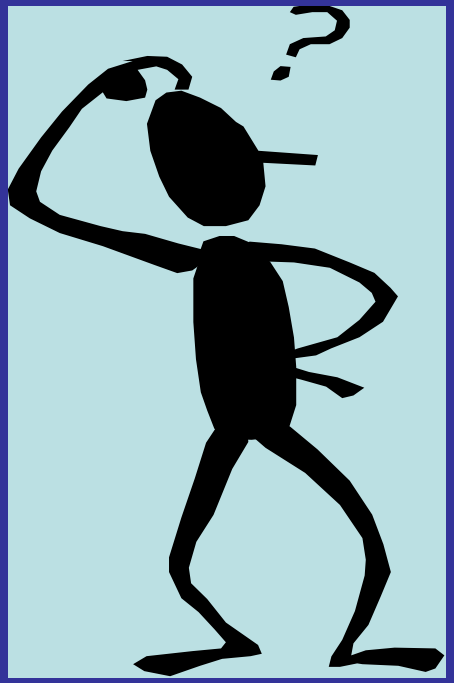
A nice guy shares a room and a secret…….
for cold war fallout shelter dosimetry and survival



The Lauriston Taylor secret cold war ultimate dosimeter and radioprotectant

….appropriate proportions if the quinine actually scintillates

Reflections over 50+ years



What were the most importance advances

and who was responsible for them ?

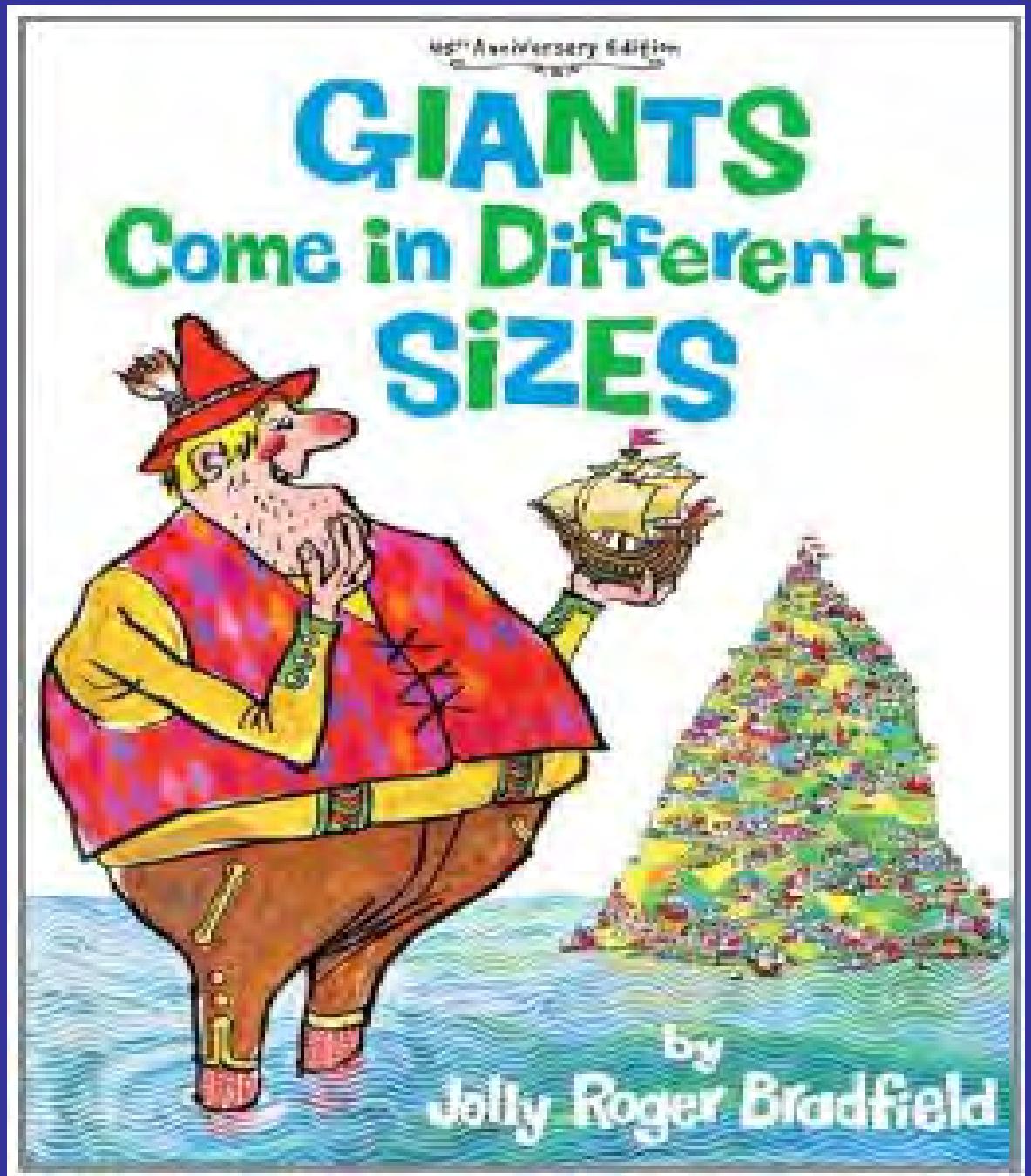
…and few predictions based on history

Computer and technological advances have been the main driver of change in our field

Conversion of everything to digital

and …….

…..and we must not forget the inventor of the internet



Some former and current Giants

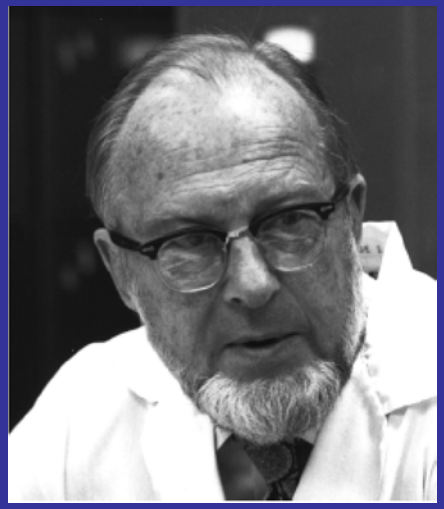
Genetics and radiation

Hermann J. Mueller

1927 X-rays used as the first intentional mutagen in fruit flies

1939 Cautioned about possible hazard from diagnostic radiology doses

Human population genetics



James V. Neel

“The Amazon tribes”

James Crow [5]

DNA in Forensics

Seymour Abrahamson

F1 Study RERF

Effects of in-utero exposure and future hereditary effects

- Teratology

Robert Brent [30]

W. Jack Schull

- Atomic Bomb (CNS)

- Childhood cancer survivor study

John Boice [33] **& Marilyn Stovall**

Radiation Biology -major advances

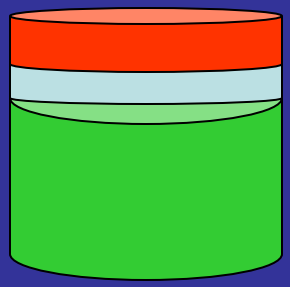
Radiation track structure and linear/quadratic (Douglas Lea)

Mammalian cell survival curves (Marcus, Puck and….. Leo Szilard feeder cells 1954)

Re-discovery that hypoxia is a problem in tumors (Thomlinson and Gray 1955)

Philip Marcus

Leo Szilard



The “new” biologists

DNA sequencing and genomics, gene expression and epigenetics are likely the future

Ann Kennedy

Sally Amundson

Edward Azzam

Joel Bedford

Kathryn Held

Amy Kronenberg

David Brenner

Radiation Units, Doses and Limits

By 1953 rad and rem in use

Genetically significant dose gone

No progress on Sv vs Sv

20 mSv vs 1 mSv limits are a problem

SI Units (NCRP Report 1985)

Harold Wyckoff [4]

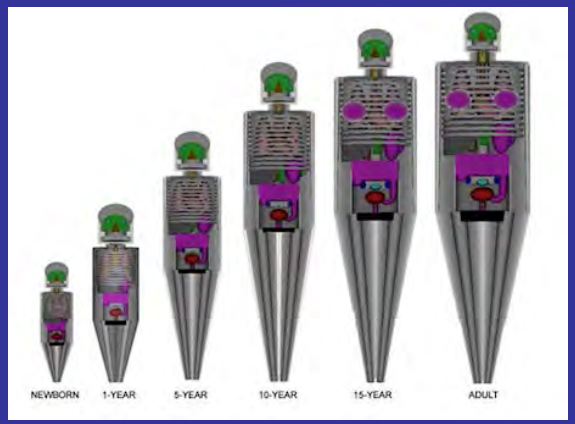
Randy Caswell

“You are young enough to learn..”

Dosimetry advances

- Models- Lung, GI tract
- Monte Carlo simulations
- Voxel CT scan based phantoms
- Computer power essential

Rich Leggett



Voxel phantoms

Keith Eckerman

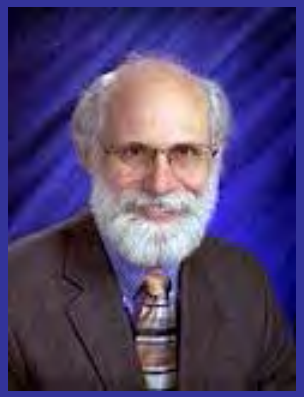
Wesley Bolch

John Auxier

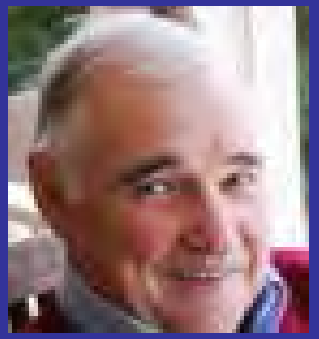
Dose reconstruction advances

- **Hiroshima/Nagasaki**
- **Veterans and workers**
- **Releases (Nevada testing, Hanford etc)**
- **US facilities (Apollo, Rocketdyne, Rocky Flats**
- **Techa River, Chernobyl, Fukushima**

Dan Strom

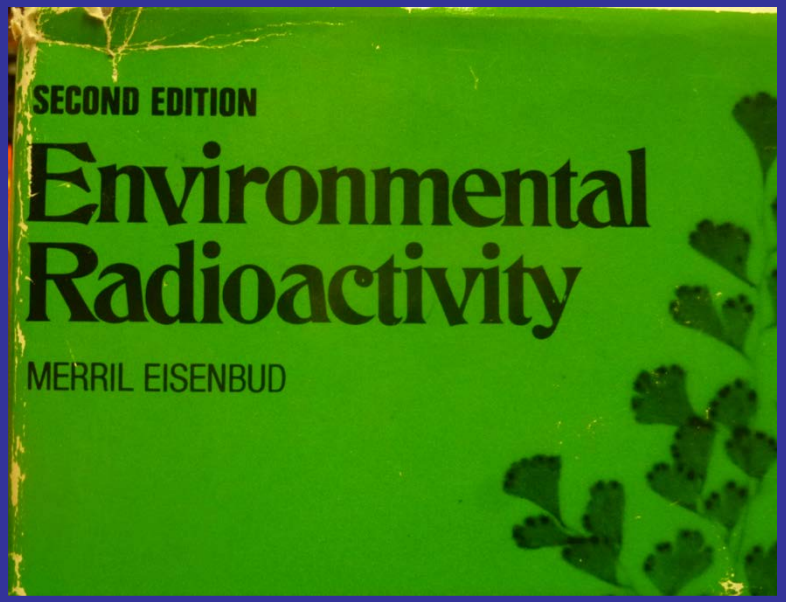


Bruce Napier



Rear Admiral John Till (ret)

Environment and radiation



Merril Eisenbud [7]

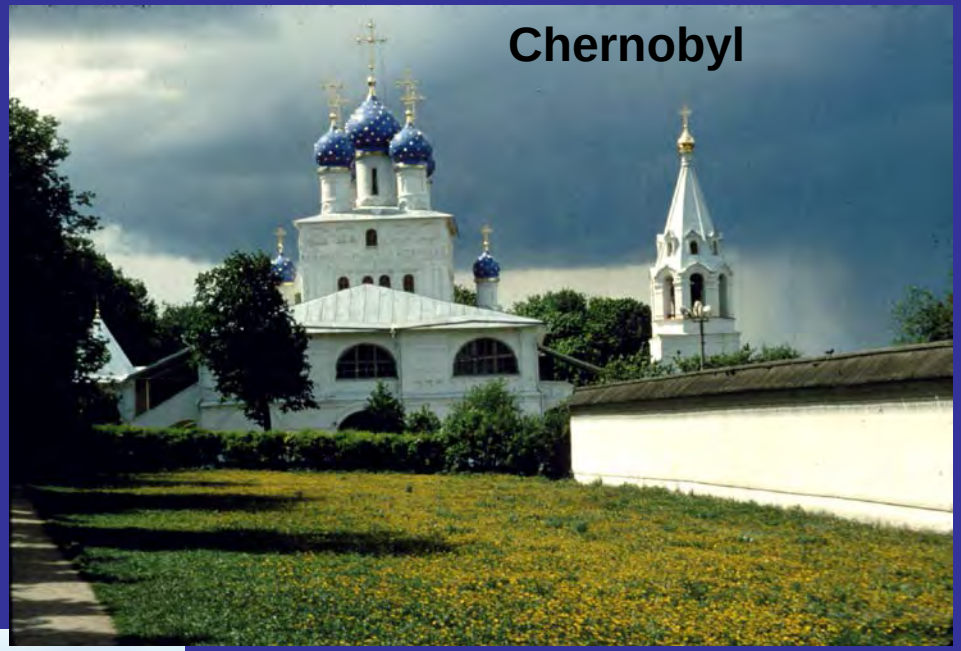
Their own families often don't know they are Giants

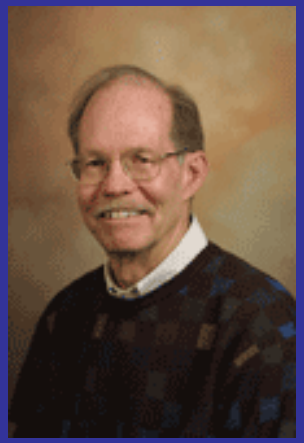
Environmental effects become a public concern

- **Chernobyl**
- **Efforts to protect plants/animals (ICRP)**

Red Forest

Most ecology ***populations*** appear unaffected if ***individual*** humans are protected



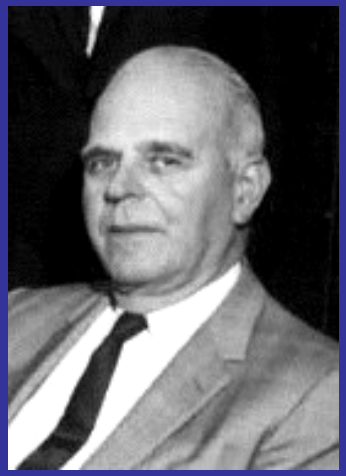


Ward Whicker

Chris Whipple

Health Physics coming into its own

- **HPS founded in 1956**
- **ABHP in 1960**
- **“Ask the Experts”**



Herbert Parker

Taylor lecturer #1

Elda Anderson

J. Newell Stannard

John Cameron

TLD QA and DEXA

John Frazier

Ken Mossman

Radon major advances

- Miner data
- Smoking and radon
- Residential radon

Jay Lubin et.al.

Naomi Harley

Simplicity in Statistics

Table 4-8 • Sample Size Required for Statistical Precision in Obtaining Dose-Response Data on Carcinogenesis

Dose Level	Sample Size
1 Gy	1,000
0.1 Gy	100,000
0.01 Gy	10,000,000

Charlie Land [34]

Epidemiology

- Site specific cancer estimates
- Meta analyses (good or bad ?)

  e.g Nuclear worker studies
- Practical lower limit ?

The Pope visits Brazil

1 million people

Risk assessment

Probabilistic risk assessment
WASH-1400

Risk-informed decision making

Risk-managed decision making

“Adoption of LNT was a turning point in risk management”

Norman Rasmussen (Red Sox)

Chris Whipple

David Hoel

The linear non-threshold (LNT) hypothesis

- May be true or not. “No conclusive evidence to reject the assumption” NCRP 136

Arthur Upton [13]

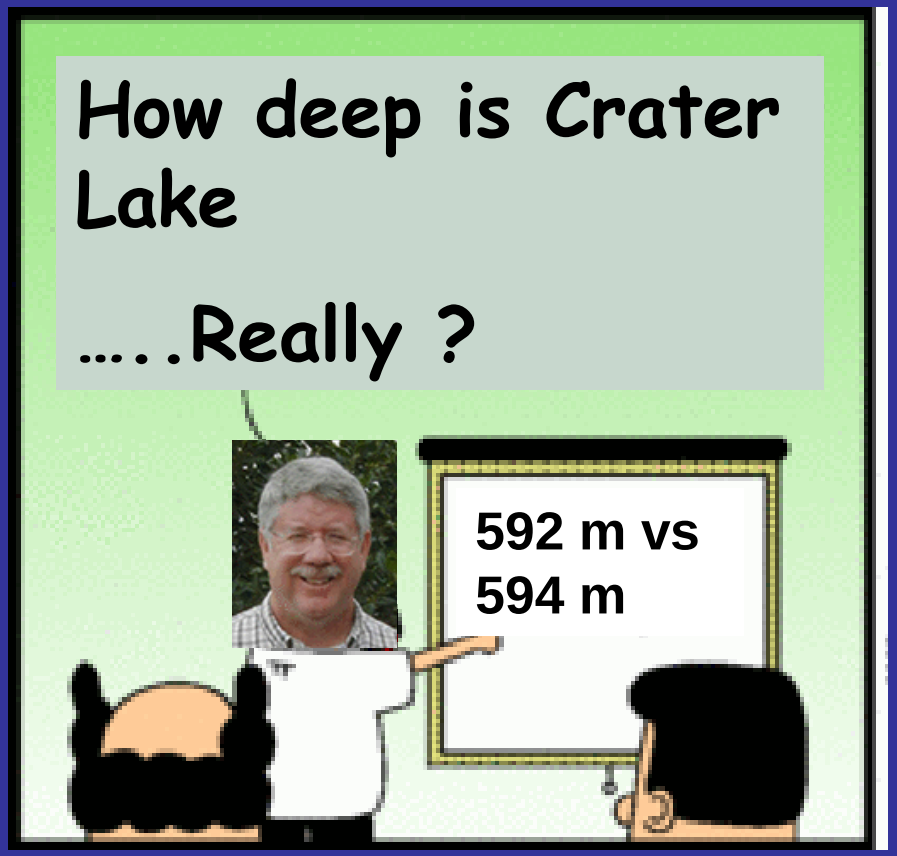
- Not a comforting concept to the public.

- Has caused lots of angst and ? Expense
- Laurie Taylor was not a fan of LNT

Probability of causation (POC) has come with good and bad

- Radioepidemiological tables
- Suggested use of POC by WHO, IAEA, ILO, NAS, NCRP
- IREP & RADRAT were logical steps forward
- Political issues have distorted science
- Compensation programs confusion continues

Tackling uncertainty about risks ……..and other things



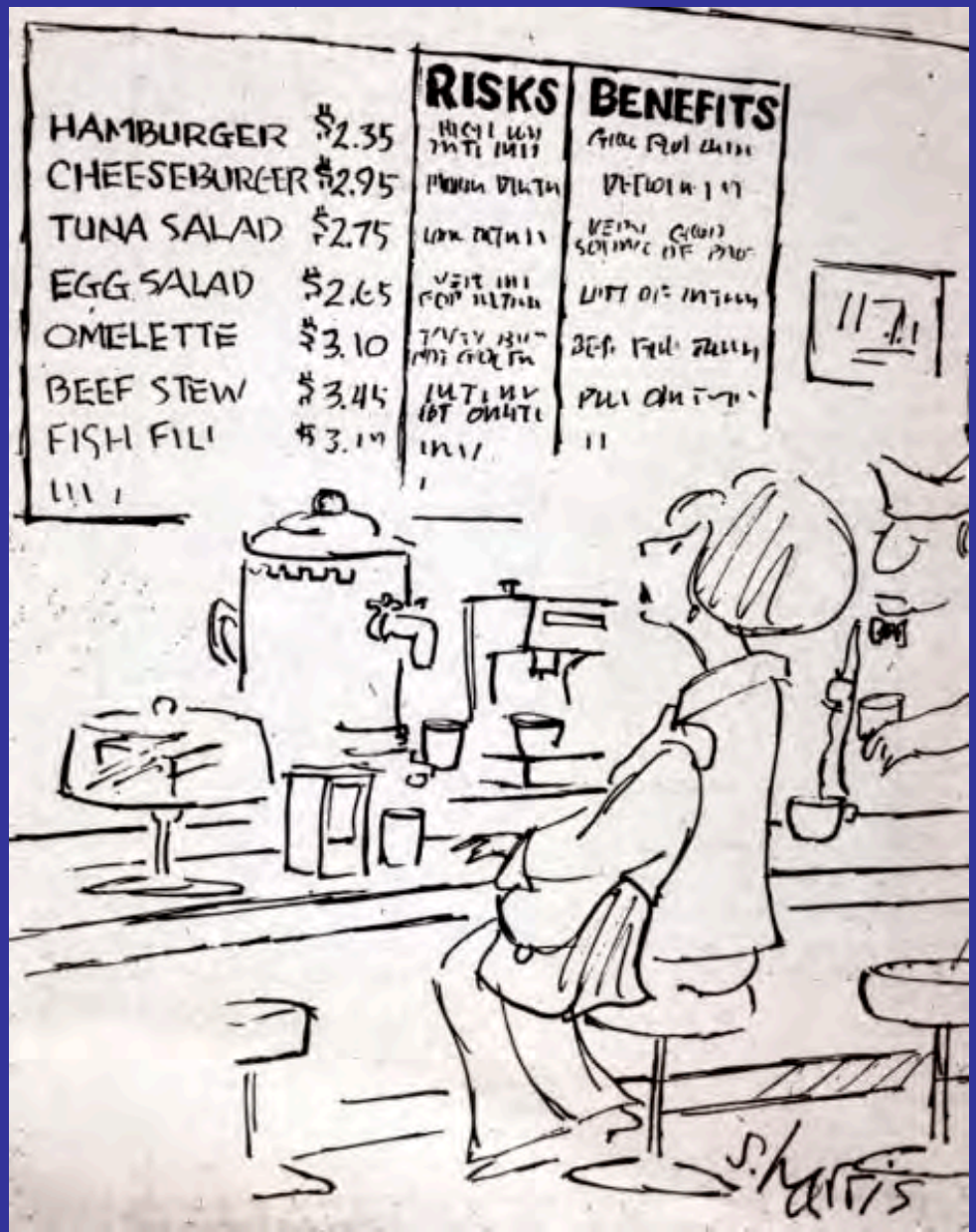
P.S. Owen Hoffman is not really Dilbert

Owen Hoffman was a National Park Ranger

"All risk estimates are probably within a factor of 3 of the truth"

W. Sinclair

Risk communication and psychological issues



One of the most important issues with least public progress

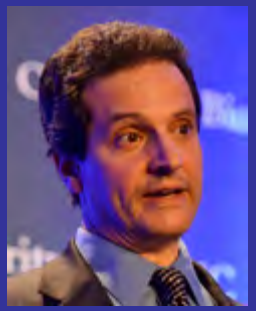
- Risk Perception, Acceptability, Amplification
- TMI > Chernobyl > Fukushima

Paul Slovic

Evelyn Bromet

Susan Wiltshire

Paul Locke

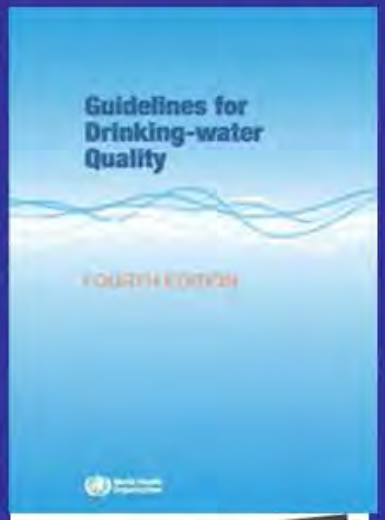


Steve Becker

Example leading to public confusion

Incoherence among drinking liquids

+



Water limit

= 10 Bq/l for ^{137}Cs

+

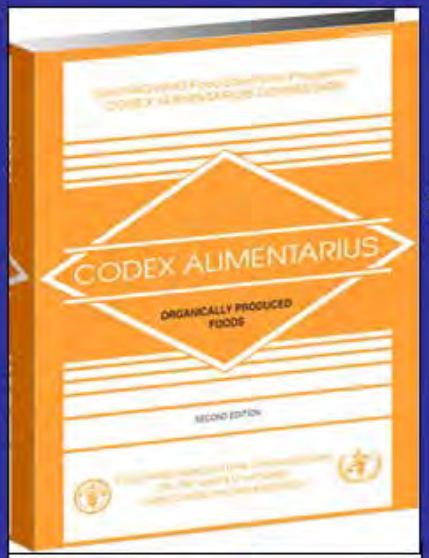
Limits 100 x higher for juice

= 1000 Bq/l for ^{137}Cs

A.Gonzalez

Incoherence with non-edible vs. edible items

+



Edible rice limit

= 1000 Bq/kg for ^{137}Cs

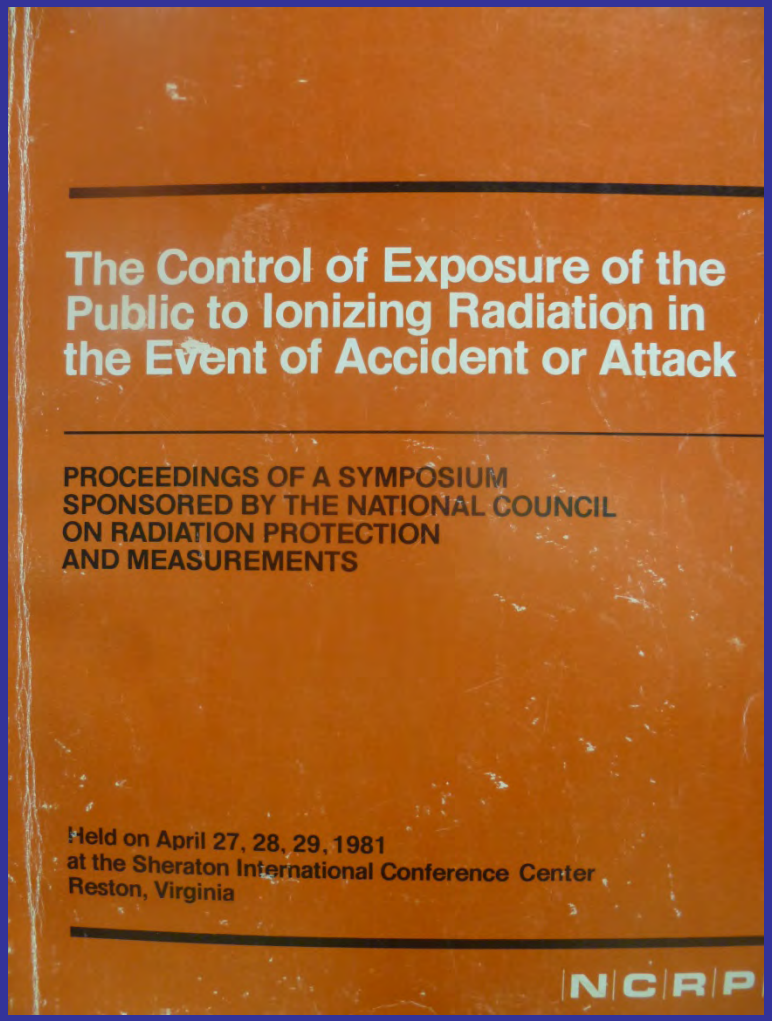
+

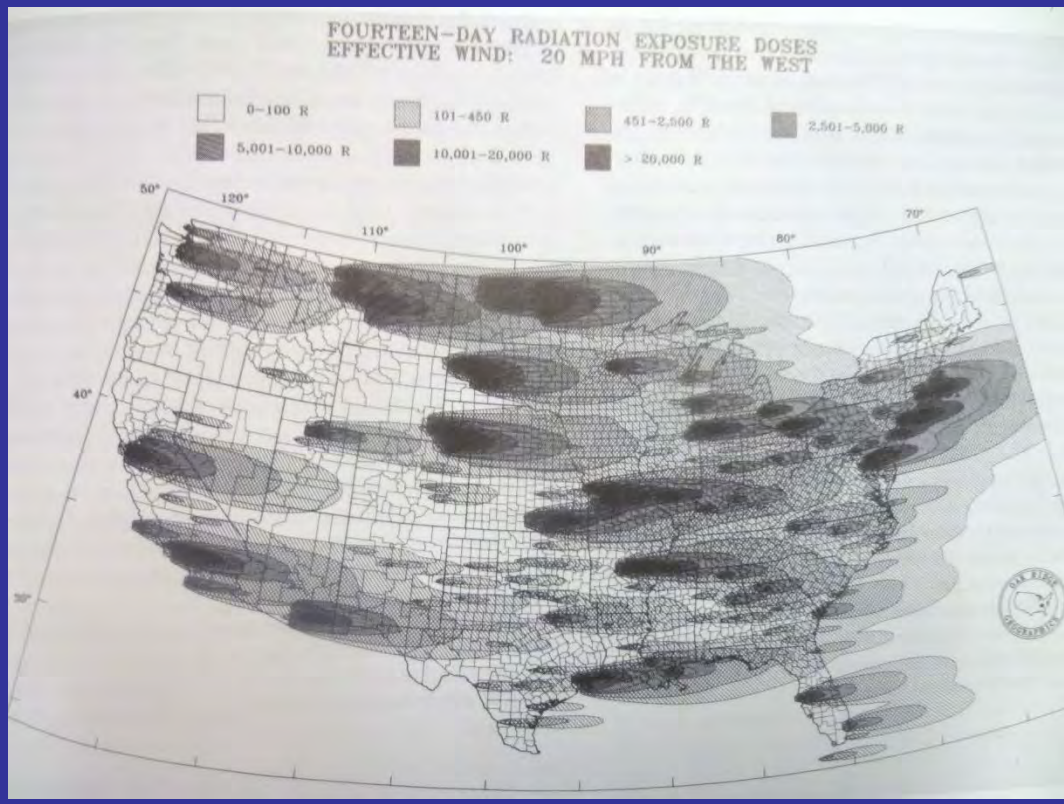
10 x higher than for rice wrapping paper

= 100 Bq/kg for ^{137}Cs

A.Gonzalez

Nuclear weapon issues diminish and then come back again





1960-1985

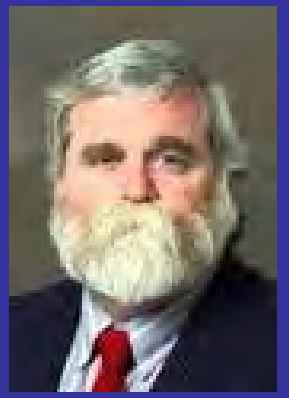
Terrorism

Bryce Breitenstein

Pat Durbin [31]

- Decorporation of wounds and internally deposited radionuclides
- Research on radioprotective methods

  Judith Bader, Norm Coleman
- Rapid personal dosimetry



William Blakely

Scenarios, planning and response

850,000 people within glass injury range
(workday population in Los Angeles)

Cham Dallas

Brooke Buddemeier

Charles Miller

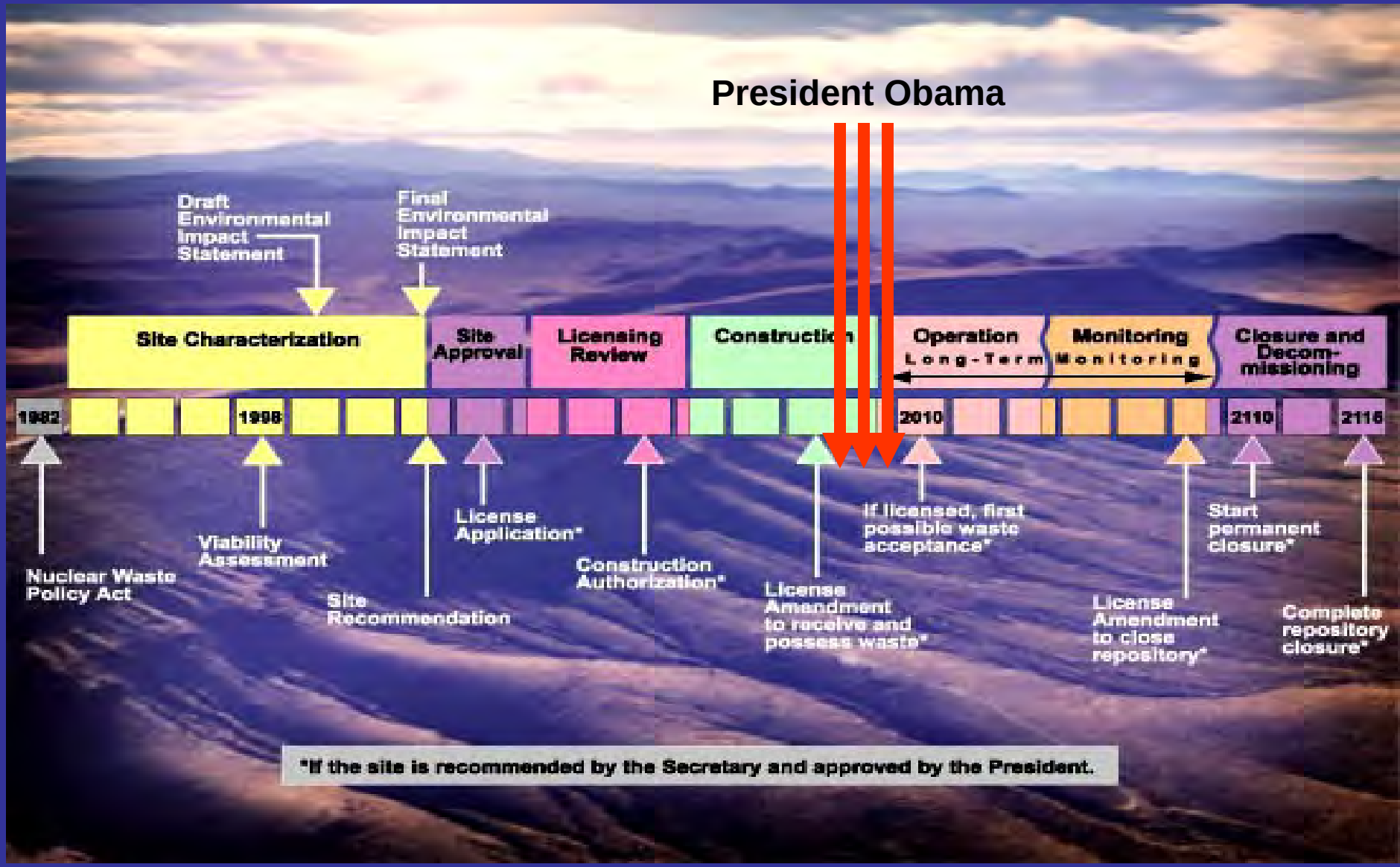
Robert Whitcomb

There has not been use of a nuclear weapon for > 65 years

My prediction: There will be use of a nuclear weapon in the next 50 years (…or sooner)

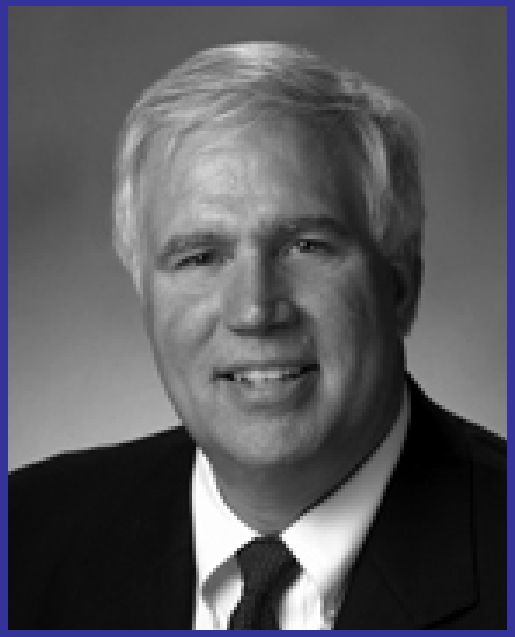
30 years ago a nuclear uptick was projected..

Radioactive waste and Yucca Mountain Issues



Reactor spent fuel continues to remain a problem

Dry cask storage is “interim” solution for spent fuel rods



Dick Meserve

Legacy waste

56 million gallons 177 tanks 60 leaking.

Began 20 yrs ago

? End by 2047 Total Cost ~ at least $300 billion.

Pipe scale (NORM) waste issues

aka……the plaintiff lawyers 401k plan

Radiation detected near New Mexico nuclear waste site

AP February 20, 2014

New radioactive leak reported at Japan's Fukushima plant

AP February 20, 2014

Waste will remain a serious issue for the next century

Understanding radium, plutonium and uranium metabolism and effects

Radium

(R. Evans, O. Raabe)

Plutonium

(Wright Langham, G. Voelz)

Uranium facility epidemiology

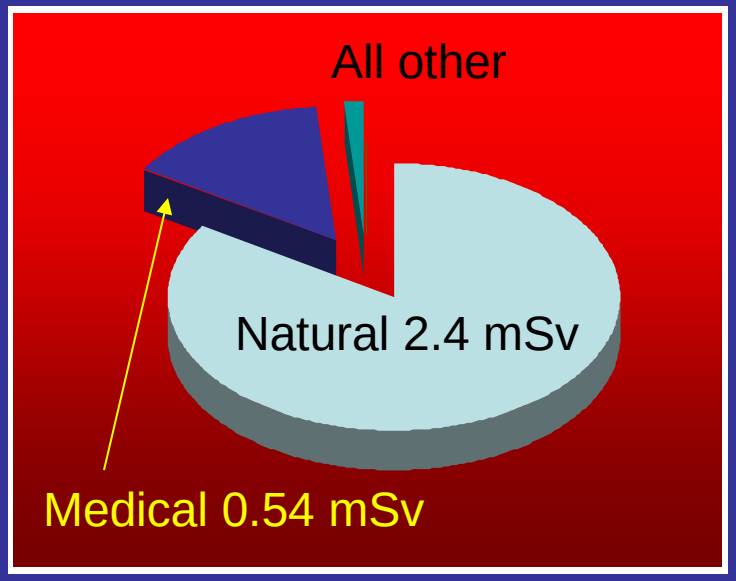
(J.Boice et.al.)

George Voelz

“I didn’t know how famous Dad was …..”

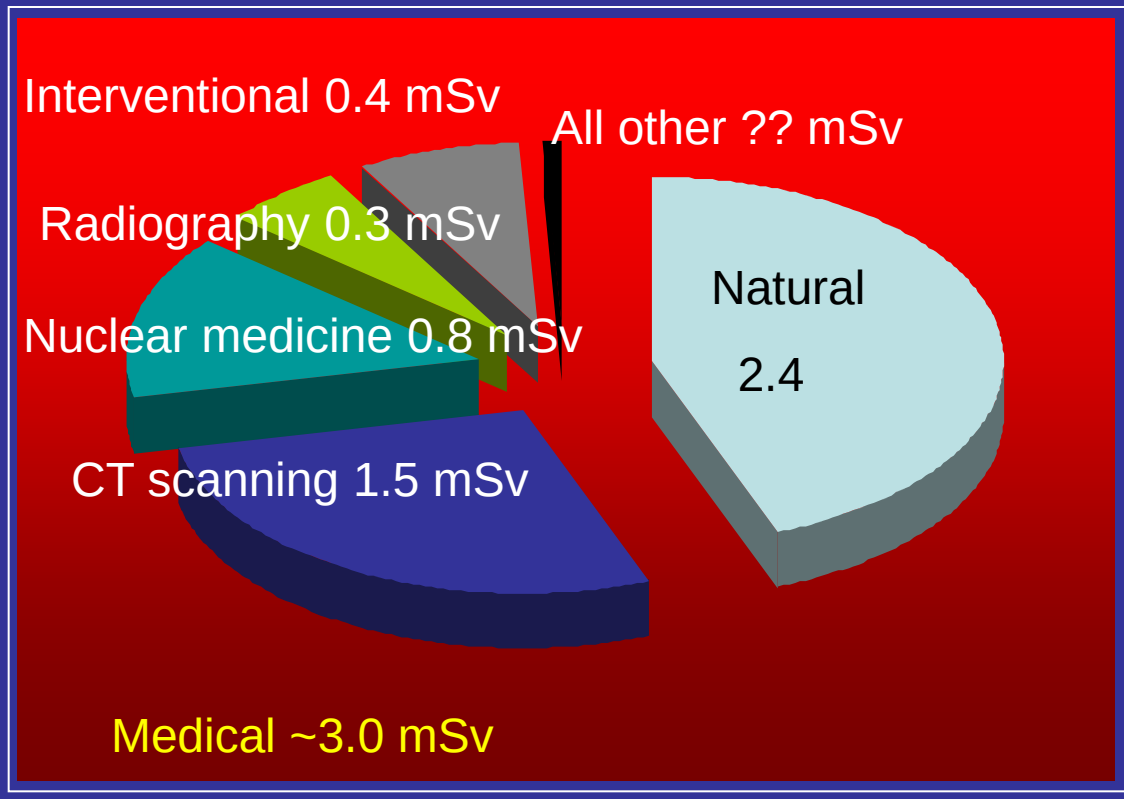
Changes in U. S. medical radiation exposure

U.S. 1980



Total 3.0 mSv per capita

U.S. 2006



Total ~ 5.4

Who are the these “Giants” who were indirectly responsible for a Nobel Prize and the CT scanner ?

?? Amish farmers

CNET › News › Digital Noise: Music and Tech › How the Beatles funded the CT scan

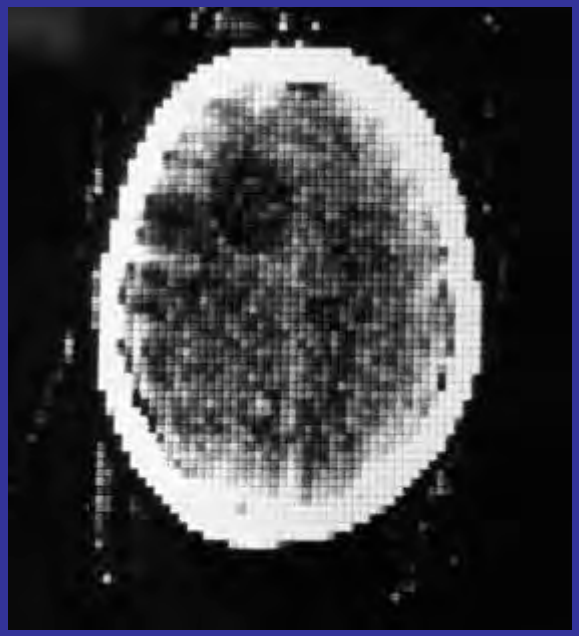
How the Beatles funded the CT scan

Money from the Beatles' success convinced EMI to let one of its engineers pursue independent research. He ended up winning the Nobel prize for medicine.

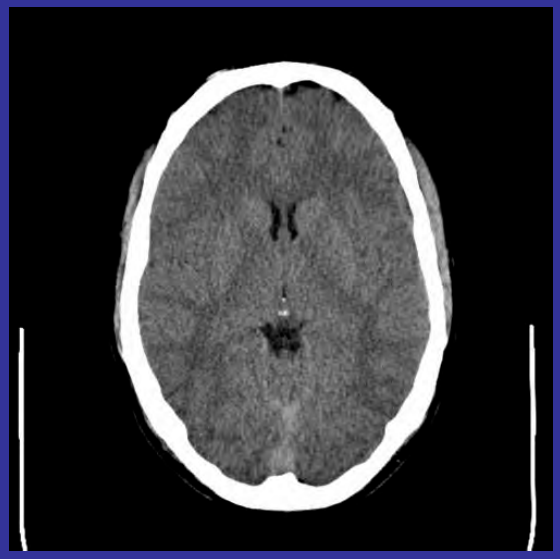
by Matt Rosoff | July 21, 2008 11:07 AM PDT

Sir Godfrey Houndsfield

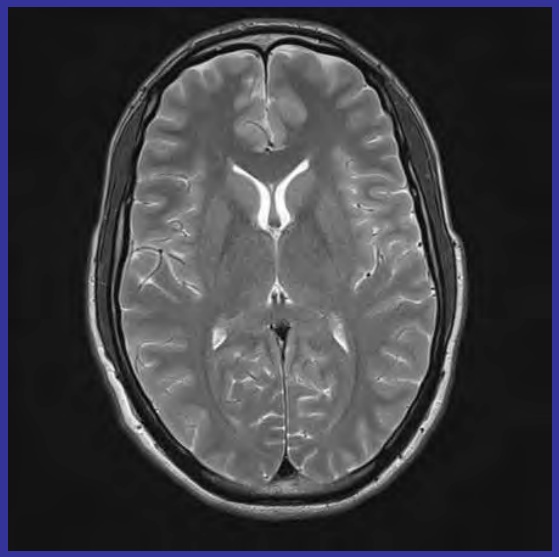
Nobel Prize in Medicine 1979



1971



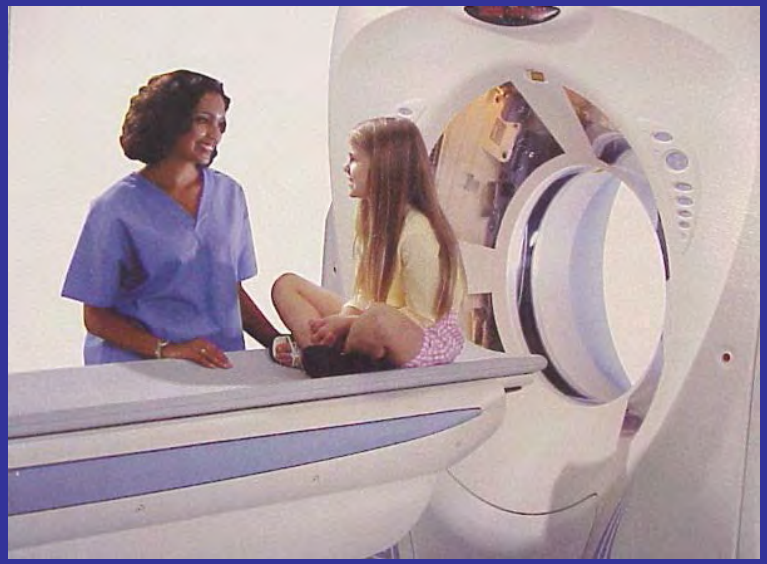
Now



CT

MRI

Diagnostic Radiology (CT)



Dave Brenner

Kimberly Applegate

Don Frush

Julie Timins

Some of the physics team…..

Cynthia McCollough

Walter Huda

Terry Yoshizumi

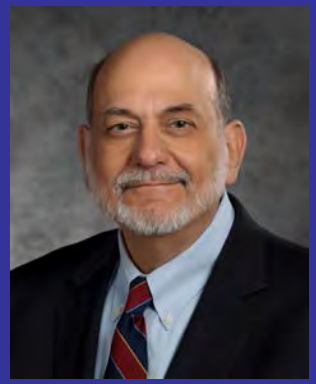
Mahesh Mahadevappa

Larry Dauer

Fluoroscopy injuries continue despite intensive efforts

Louis Wagner

Steve Balter



Don Miller

Mammography.. A success story

- Direct film > low dose > digital
- FDA and ACR accreditation including continuing education and experience

Edward Sickles

Lawrence Rothenberg

Stephen Feig

Nuclear Medicine

- Gamma Camera (1956)

Hal Anger

- Use of technetium-99m in 1960's
- PET scanner

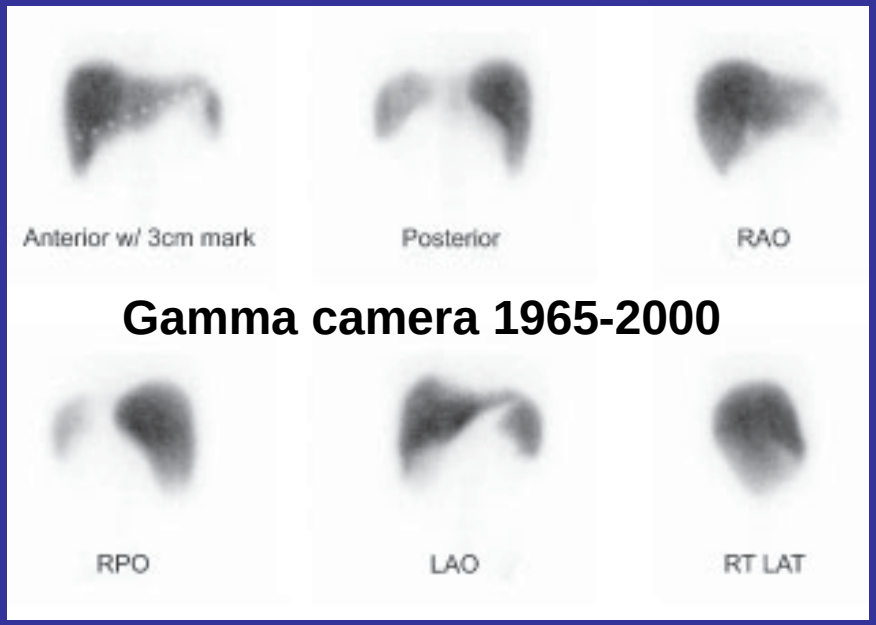
Gordon Brownell

James Adelstein [24]

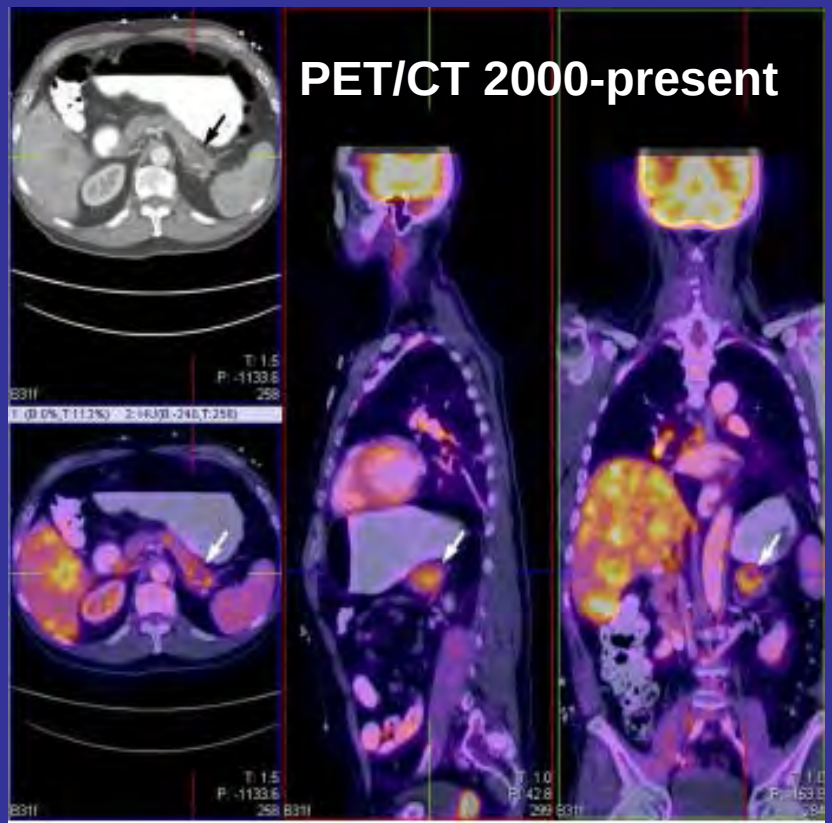
Mike Stabin

Incredible progress in NM imaging

Rectilinear 1950-1965



Gamma camera 1965-2000



PET/CT 2000-present

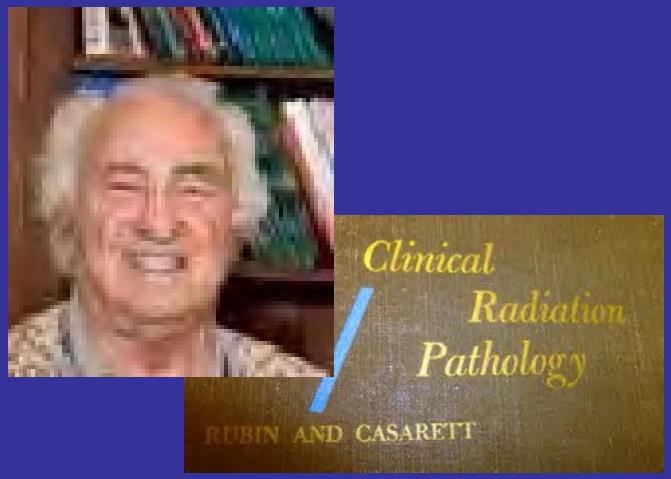
Radiation Oncology over 50 years

- Radium and Cobalt-60 gone

  Replaced by linear accelerators etc
- Computerized treatment planning
- Hybrid diagnostic and therapeutic equipment
- Patient and tumor specific biology

Effects of Radiotherapy

- **Understanding radiopathology**
- **Response to fractionation – differential response normal tissue vs tumor and early vs late changes**
- **Issues with children**



Phil Rubin

Can I have my book ?

H Rodney Withers

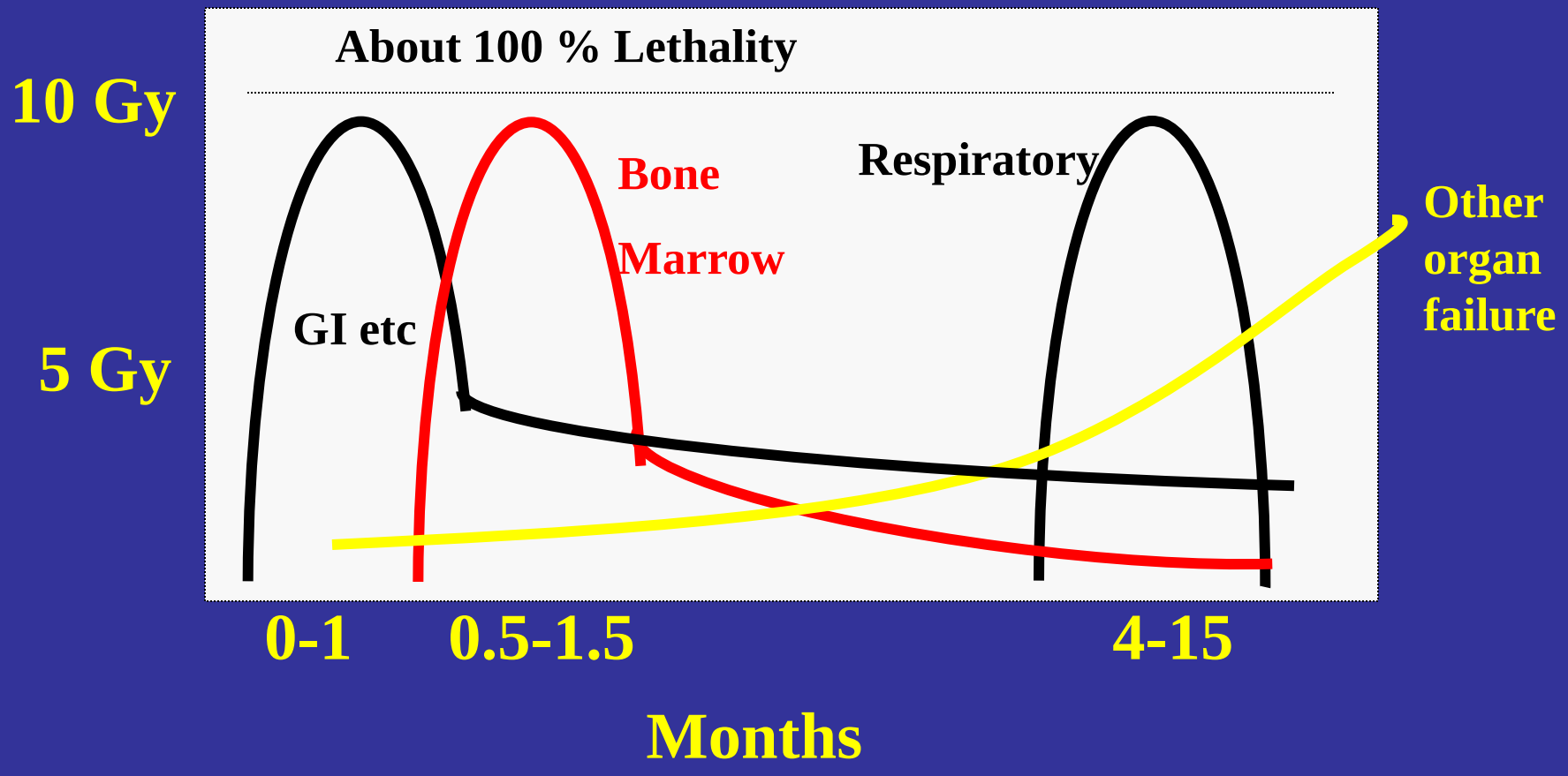
Sandy Constine

Rare,but major accidents in radiotherapy continue

- Spain 1990 human error
- Costa Rica 1996 human error
- Panama 2000 human error
- Poland 2001 machine failure
- France 2005 human error

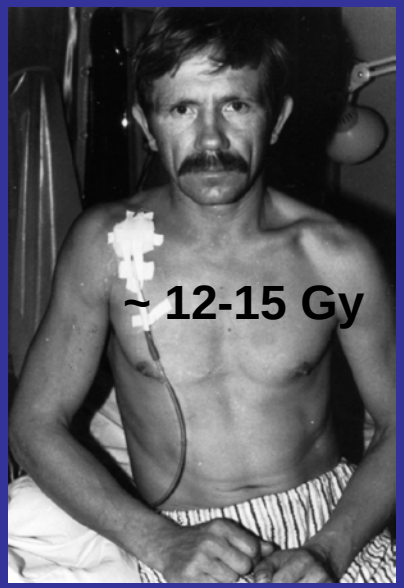
- **Accidents will continue as long as humans are around and machines get more complex**

Medical treatment of severe acute radiation syndrome—breakthroughs and lessons



Chernobyl and Belarus accidents

Angelina Guskova MD



24 hours post exposure

90 days-

pulmonary failure death

Tokaimura criticality accident

Kaz Maekawa MD

Worker A ~17 Gy

survived 82 days

Worker B ~10 Gy

survived 210 days

Long term survival will remain unlikely after > 12 Gy

Unless multi- system failure is solved

Lost and stolen radioactive sources continue to be a problem

SY Chen

Non-ionizing radiation

- Ultrasound

Wesley Nyborg [25]

Marvin Ziskin

- Radiofrequency

Gary Zeman

Space facts and the future

- 12 people have walked on the moon
- 535 astronauts have been in space (37 countries)

  including Malaysia, Syria, Mongolia, Cuba (> 119 PY)
- Virgin Galactic now selling trips to the public
- Mars trips

Francis Cuccinota

Which former or current NCRP director qualified for astronaut training ?


ZME Science

Giants sometimes come in twos

Naomi[23] and John Harley[9]

Both Taylor Lecturers

Mega mouse genetic experiments

Liane Russell

William (Bill) Russell

Radiation Biology and Medicine

Shirley and Michael Fry[18]

Health Physics

Genevieve and Charles Roessler

Giants sometimes leave us too early

Elaine Ron

Goeff Howe

Shaggy dog story

A young giant getting fatherly advice

But still….in our field even giants have to pump their own gas

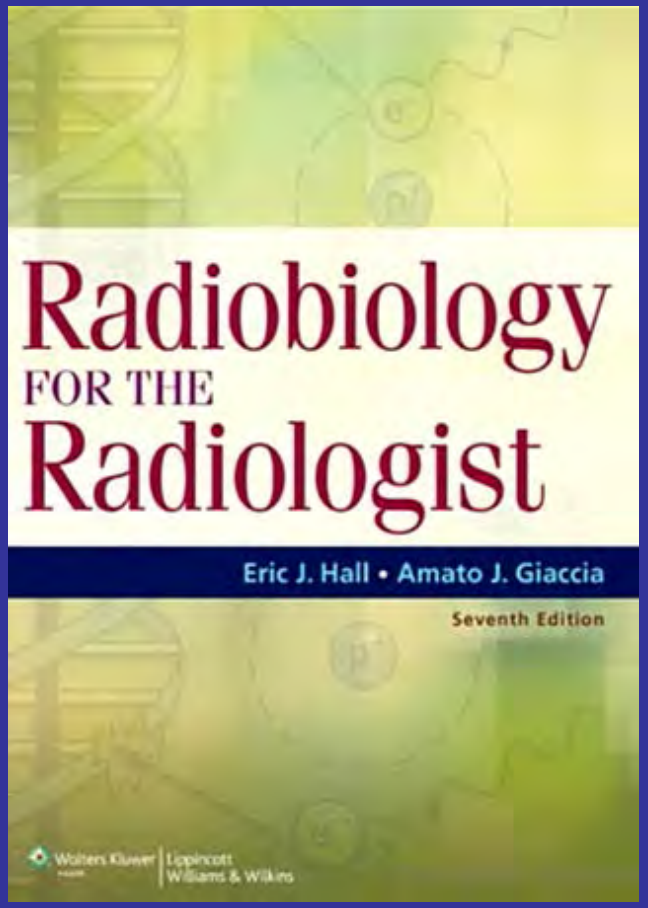
Who will turn out to be a Giant can be difficult to recognize……

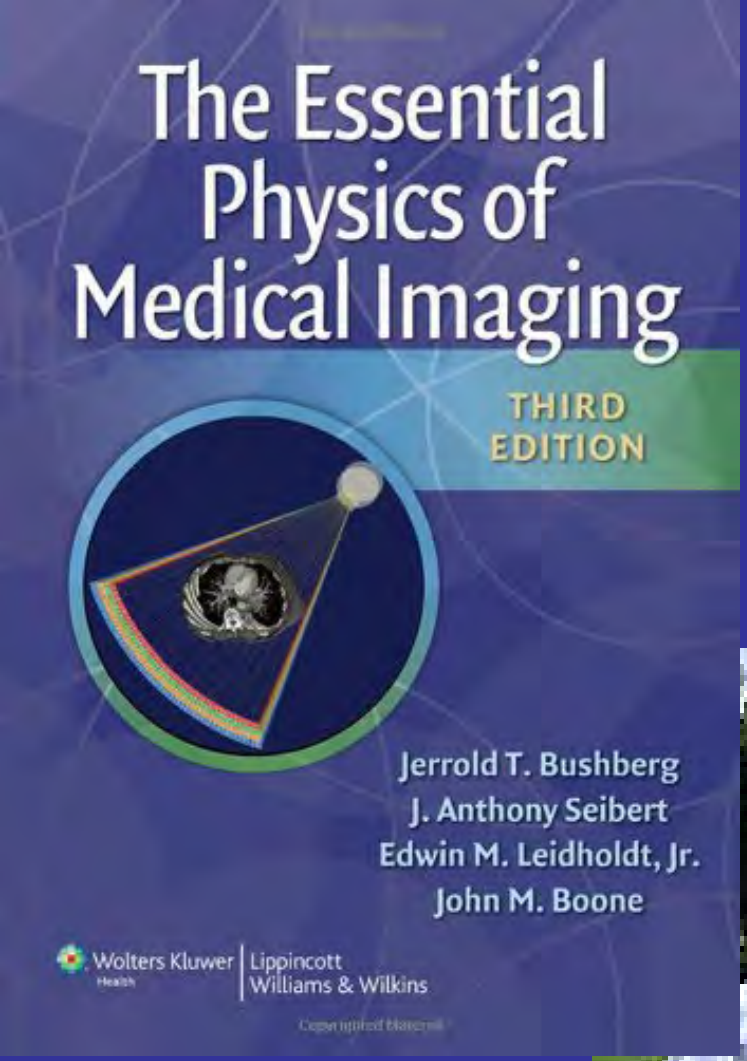
Would you give this kid a Q clearance and $25 million for radiation research ?

John Boice Jr [33]

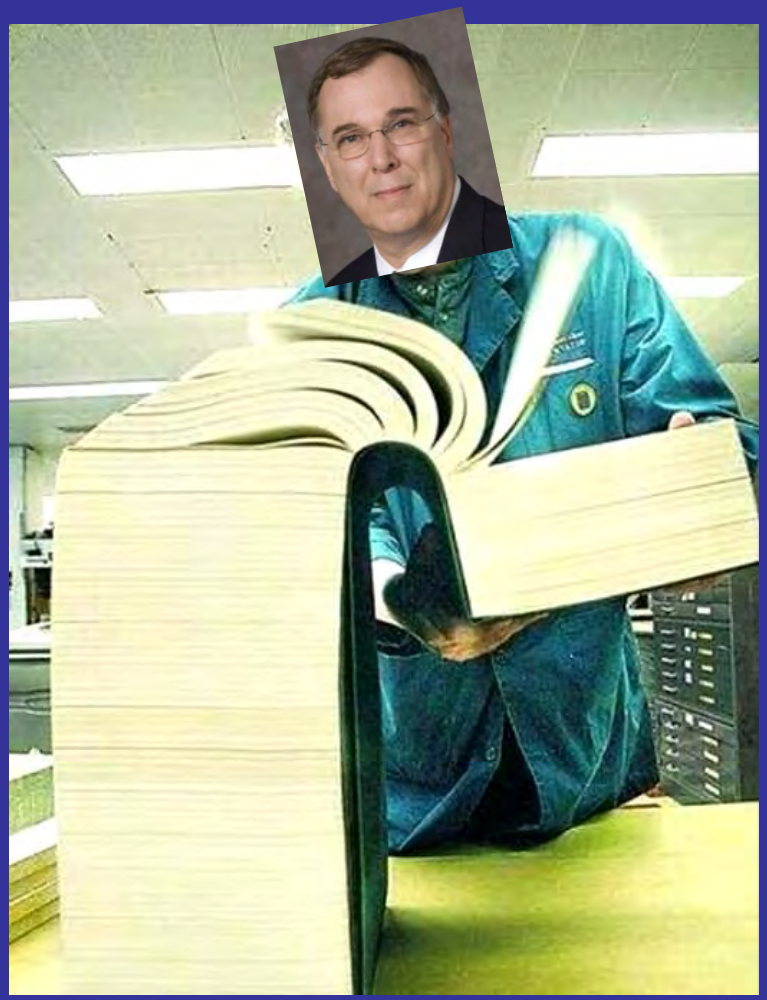
Some Giants impart knowledge through books

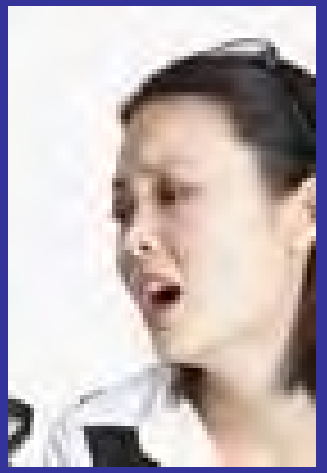
Eric Hall [22]




The Essential Physics of Medical Imaging
THIRD EDITION
Jerrold T. Bushberg
J. Anthony Seibert
Edwin M. Leidholdt, Jr.
John M. Boone
Wolters Kluwer Health
Lippincott Williams & Wilkins

The **“study guide”** of the ***Essential*** Physics of Medical Imaging is in progress





Editors are giants too..

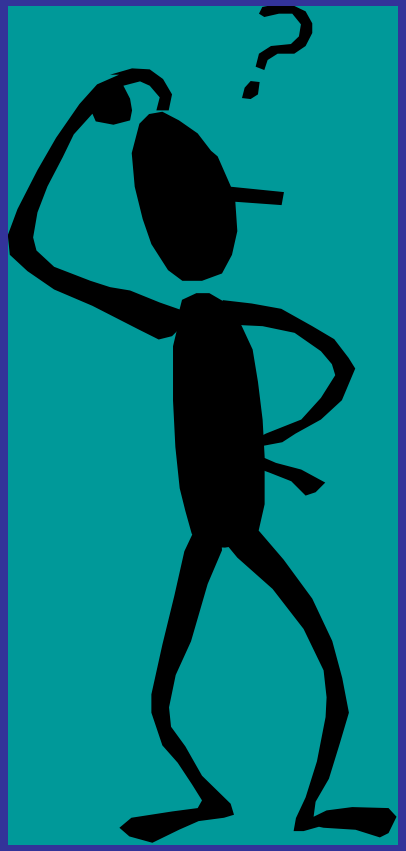
Gen Roessler

Richard Vetter

Mike Ryan

Michael Fry

Are there certain spots where Giants historically hang out ?



Particular Universities

- Columbia
- Wisconsin
- Univ of Rochester
- UC Berkeley
- Univ of Chicago

RERF

- S. Shigematsu
- D. Hoel
- J. Neel
- G. Beebe
- W. Schull
- S. Jablon
- D. Preston
- R. Shore
- Evan Douple
- R. Ullrich

Lovelace ITRI

- Bruce Boecker
- Fletcher Hahn
- Joe Mauderly
- Ray Guilmette
- Bruce Muggenberg
- Roger McClellan

Hanford - PNNL

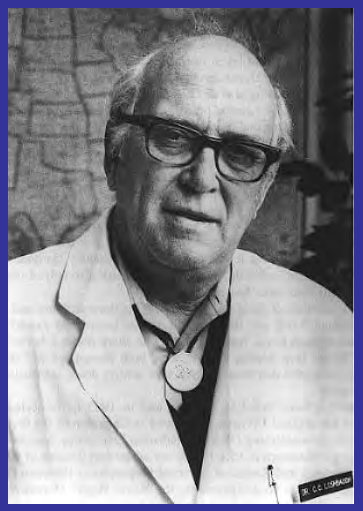
- **Bill Bair[21]**
- **Ron Kathren**
- **Dan Strom**
- **Bruce Napier**
- **Bill Morgan**
- **Tony Brooks**
- **Bill Morgan**
- **Les Braby**
- **Kathryn Pryor**

First PhD in Rad Biol.

Can't they get better office paneling ?

Oak Ridge

- Clarence Lushbaugh
- The Frys
- Robert Ricks
- Ron Goans
- Al Wiley
- Dick Toohey



NCI Radiation Epidemiology

- **Gil Beebe**
- **Bob Miller**
- **John Boice[33]**
- **Andre Bouville**
- **Elaine Ron**
- **Kiyohiko Mabuchi**
- **Jay Lubin**
- **Ruth Kleinerman**
- **Martha Linet**

U.S. Government

- **U.S. FDA (CDRH)**
  John Villforth
  Don Miller
  John McCrohan
  Orhan Suleiman

- **US NRC**
  Don Cool
  Vince Holahan

- **EPA**
  Julian Preston
  Mary Clark
  Michael Boyd

DOE
Stephen Musolino

- **State**
  Jill Lipoti
  James Yusko

ICRP Giants

- **Lauriston Taylor**
- **Rolf Sievert**
- **Dan Beninson**
- **Sir Edward Pochin**

Sir Edward Pochin [2] (ICRP Weighting factors) visits Albuquerque

or “a knight comes to dinner at the Mettler’s”

Fighting anti-nuclear dragons

My UNSCEAR Giants

Philanthropic Giant- Yohei Sasakawa

Has given tens of $ millions for radiation related disasters

How do you get cash after a tsunami ?

Then there are “NCRP” Giants

Who are they ?????

I reviewed all reports 1-174 1931-thru 2013

1354 persons: chairs and committee members

6 NCRP Committees

- C. Meinhold 6 (3)
- R. Roesch 6 (3)
- H. Rossi 6 (3)
- H. Parker 6 (2)
- R. Gorson 6 (1)
- W. Bair 6 (1)
- L. Marinelli 6
- P. Durbin 6
- H. Wyckoff 6

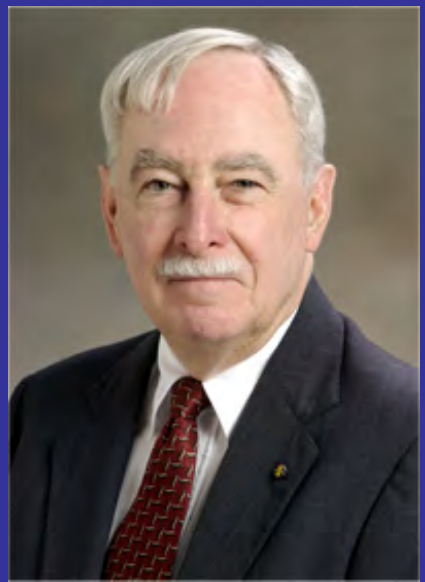
7-9 Committees

W. Sinclair	9 (3)	K. Kase	8 (3)
L. Taylor	9 (2)	S. Feitelberg	8
K. Miller	9 (2)	M. Fry	7 (3)
G. Failla	9 (1)	C. Braestrup	7 (3)
R. Shore	9	D. Moeller	7 (2)
R. Newell	9	J. Boice	7

The NCRP Super Giants of all time

- Edith Quimby 12 (4)

- John Poston 12 (2)



To do more work and get on the next NCRP Giant list…..

- **More committees are becoming available but space is limited……**
- **Limited bookings for 2015 and 2016**
- **Make your reservation now**
- **Call John Boice at any time day or night**

NCRP Past Presidents

Lauriston S. Taylor
1929–1977

Warren K. Sinclair
1977–1991

Charles B. Meinhold
1991–2002

Thomas S. Tenforde
2002-2012

The Giants who really keep the other Giants from making silly mistakes

- W. Roger Ney
- W. Beckner
- D. Schauer
- E. I. White

T. Fearon
J. Spahn
M. Rosenstein
C. Maletskos
Otha Linton

Laura Atwell

Cindy O’Brien

My personal Giants

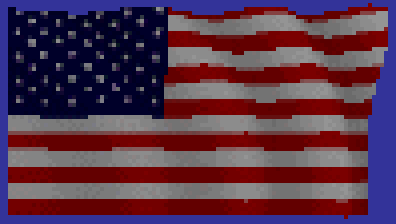
Radiation protection is a time-limited career.

…….. Family is forever

So many Giants……
……so little time

A gathering of Giants this morning


RHJ



Thank you