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

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

...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

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

Harold Beck
Louis H. Hempelmann MD
Epidemiology

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

Elinor Pulitzer
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

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
DNA in Forensics

Seymour Abrahamson
F1 Study RERF
Effects of in-utero exposure and future hereditary effects

- Teratology
- Atomic Bomb (CNS)
- Childhood cancer survivor study
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)
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)

“You are young enough to learn..”
Dosimetry advances

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

Voxel phantoms

Keith Eckerman

Wesley Bolch

John Auxier

Rich Leggett
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

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

wikipedia
Most ecology populations appear unaffected if individual humans are protected.
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
Radon major advances

- Miner data
- Smoking and radon
- Residential radon

Jay Lubin et.al.  
Naomi Harley
### Table 4-8: Sample Size Required for Statistical Precision in Obtaining Dose-Response Data on Carcinogenesis

<table>
<thead>
<tr>
<th>Dose Level</th>
<th>Sample Size</th>
</tr>
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<tbody>
<tr>
<td>1 Gy</td>
<td>1,000</td>
</tr>
<tr>
<td>0.1 Gy</td>
<td>100,000</td>
</tr>
<tr>
<td>0.01 Gy</td>
<td>10,000,000</td>
</tr>
</tbody>
</table>
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

- 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

How deep is Crater Lake

....Really?

592 m vs 594 m

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

Evelyn Bromet  Susan Wiltshire  Paul Locke  Steve Becker
Example leading to public confusion
Incoherence among drinking liquids

Water limit
= 10 Bq/l for $^{137}\text{Cs}$

Limits 100 x higher for juice

= 1000 Bq/l for $^{137}\text{Cs}$
Incoherence with non-edible vs. edible items

Edible rice limit = 1000 Bq/kg for $^{137}\text{Cs}$

10 x higher than for rice wrapping paper

= 100 Bq/kg for $^{137}\text{Cs}$
Nuclear weapon issues diminish and then come back again.
Terrorism

- Decoration of wounds and internally deposited radionuclides
- Research on radioprotective methods
- Rapid personal dosimetry

Judith Bader, Norm Coleman

Bryce Breitenstein, Pat Durbin

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

President Obama

*If the site is recommended by the Secretary and approved by the President.
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
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

Natural 2.4 mSv

Medical 0.54 mSv

Total 3.0 mSv per capita

U.S. 2006

Natural 2.4 mSv

Interventional 0.4 mSv

Radiography 0.3 mSv

Nuclear medicine 0.8 mSv

CT scanning 1.5 mSv

Medical ~3.0 mSv

Total ~ 5.4 mSv

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

?? Amish farmers
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
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)
- Use of technetium-99m in 1960’s
- PET scanner

Hal Anger
Gordon Brownell
James Adelstein
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

About 100% Lethality

- Bone
- Marrow
- GI etc
- Respiratory
- Other organ failure

Months

0-1 0.5-1.5 4-15

10 Gy

5 Gy
Chernobyl and Belarus accidents

Angelina Guskova MD

24 hours post exposure

8 Gy ~ 12-15 Gy

90 days-

pulmonary failure death
Tokaimura criticality accident

Worker A  ~17 Gy
survived 82 days

Worker B  ~10 Gy
survived 210 days

Kaz Maekawa MD

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
Non-ionizing radiation

- Ultrasound

- Radiofrequency

Wesley Nyborg

Marvin Ziskin

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?
Giants sometimes come in twos

Naomi\textsuperscript{23} and John Harley\textsuperscript{9}

Both Taylor Lecturers
Mega mouse genetic experiments

Liane Russell

William (Bill) Russell
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?
Some Giants impart knowledge through books

Eric Hall

Radiobiology for the Radiologist
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
- 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 Fry's
- Robert Ricks
- Ron Goans
- Al Wiley
- Dick Toohey
NCI Radiation Epidemiology

- Gil Beebe
- Bob Miller
- John Boice
- 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 Pochin² (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
<table>
<thead>
<tr>
<th>Name</th>
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<tr>
<td>W. Sinclair</td>
<td>9</td>
<td>(3)</td>
</tr>
<tr>
<td>L. Taylor</td>
<td>9</td>
<td>(2)</td>
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<tr>
<td>K. Miller</td>
<td>9</td>
<td>(2)</td>
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<tr>
<td>G. Failla</td>
<td>9</td>
<td>(1)</td>
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<tr>
<td>R. Shore</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>R. Newell</td>
<td>9</td>
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<tr>
<td>K. Kase</td>
<td>8</td>
<td>(3)</td>
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<tr>
<td>S. Feitelberg</td>
<td></td>
<td>8</td>
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<td>M. Fry</td>
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<tr>
<td>C. Braestrup</td>
<td></td>
<td>7</td>
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<tr>
<td>D. Moeller</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>J. Boice</td>
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<td>7</td>
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</table>
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
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’Brian
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
Thank you