Illinois Institute of Technology

RADIATION BIOPHYSICS:
Course Introduction

ANDREW HOWARD

Radiation Biophysics: Introduction

- What we're trying to do: *provide you with an understanding of what happens when ionizing radiation interacts with biological tissue.*
- Your jobs generally involve knowing about ionizing radiation
  - how it is produced
  - what it is used for
  - how to deliver it
  - how to quantify it
  - how to minimize exposure of people and things to it.

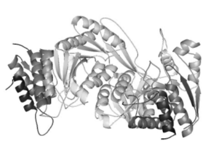
Introduction (continued)

- You have also learned about the biological effects of radiation in other settings.
- In this course the emphasis is on the *biological* effects, both harmful and beneficial, of radiation.
- But to put those biological issues in context:
  - We'll discuss radiation physics and radiation chemistry.
  - We won't spend a lot of time on those subjects: you've dealt with those subjects elsewhere.

Who is your instructor?

- I am primarily in the biology faculty within the Biological, Chemical, and Physical Sciences Department at IIT.
- But my graduate degree is in physics, so I'm reasonably familiar with physics and chemistry as well as biology.

Am I qualified to teach this?



- I'm a crystallographer:
  - I use X-ray diffraction to study the 3-D structures of large biomolecules
  - I am not a health physicist by specialization
  - My research is often affected by concerns for the radiation safety of my experiments.
  - I'm a *consumer* of rad. biophysics knowledge.
- I postdoc'd in toxicology in a DOE lab: mechanistic studies stuck with me

How will this course work?

- Two lecture sessions per day Monday-Wednesday; plus one more session Thursday morning
- Primarily lectures, but with discussion
- We'll have other activities (discussions and a computer game) late mornings & late afternoons
- Please communicate with me live and by email during and after the course:
- howard@iit.edu
- 773-368-5067 (cell), 312-567-5881 (office)

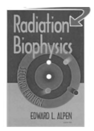
Evaluation

- Examination will be constructed over the weekend
- You will need to retain this material!

Course Plans (continued)

- the detailed schedule is on the Course Blackboard site
- http://blackboard.iit.edu/
- You should by now have received instructions on getting to that material

Course Sources



- Edward L. Alpen, *Radiation Biophysics*
  - 2nd Ed.: San Diego: Academic Press, 1998. 520 pp..., cloth. ISBN 0-12-053085-6. $69.95.
  - We'll work closely from textbook except in our discussion of radiation chemistry (chapter 6) and a lecture (I hope) at the end of the course on organismal biology and biochemistry
- Supplemental readings (HTML, books, journal articles)

Using Blackboard

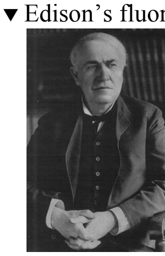
- Portal to online lectures
- Posting site for HTML and PowerPoint lecture materials
- Posting site for peer-reviewed literature
- Discussion board: Use it!
  - Your opportunity to mull over the material
  - Chance to get to know your classmates better
  - Participation may get evaluated

History of radiation biophysics I

- Early characterizers of the properties of X-rays and radioactivity:
  - Wilhelm Röntgen: X-rays, 1895
  - Becquerel: radioactivity
  - Rutherford: radioactive chain decay
  - The Curies: radium, polonium

History II

- Edison's fluoroscope: 1896



Radiation and Medicine: 1895

First medically observable deleterious effect from X-rays was recorded less than six months after Roentgen's discovery of X-rays. So the history of radiation biophysics goes back almost as far as the history of X-rays

Quantities, Units, and Definitions

The world of radiation research has gone through a major change in the units that it uses to express quantities. As recently as the 1970's when I was learning radiation quantitation, the traditional units for activity, dose, energy imparted, and equivalent dose were still in common use. In this course we will use the more modern units except in dealing with older research papers.

Quantities, Units, Definitions

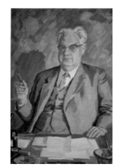
Quantity	Exposure (em only)	Dose	Energy Imparted
Definition	$\Delta Q/\Delta m$	$\Delta E_d/\Delta m$	E_d
SI Unit	C kg^{-1}	Gray	Joule
Unit definition		J kg^{-1}	kg m^{2}s^{-2}
Old Unit	Röntgen	Rad	Erg
Definition	1 esu cm^{-3}	100 erg g^{-1}	g cm^{2}s^{-2}
Conversion	1 R = 2.58 * 10^{-4} C kg^{-1}	1 Gy = 100 Rad	1 J = 10^7 erg

Honorees

- Louis Gray (1905-65)

Louis Gray (1905-65)

- Rolf M. Sievert



Additional Quantities: Equivalent Dose

- Effects of a dose depend on how much energy is deposited per unit mass and on how influential that energy is in the medium:
- $H_{T,R} = D_R W_{T,R}$ (D_R=dose, $W_{T,R}$= weight factor)
  for tissue T, radiation type R.
- If R is ^{60}Co photons, W_R=1 (reference type)
- Unit: Sievert (1 J/kg)

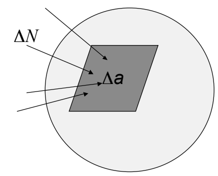
RBE and Kerma

- RBE (relative biological effectiveness):
  - describes weight factors for specific biological endpoints (e.g. carcinogenesis) as well as specific radiation types.
  - Often used in context of radiation-induced tumors and other long-term problems.
- Kerma: *K*inetic *E*nergy *R*eleased to the *M*edium
  - Let ΔE_K =initial kinetic energy of all charged particles liberated. Then Kerma $K = \Delta E_K / \Delta m$
  - Dimensions of dose (book says energy—that's wrong)
  - Units: Gy or rad.

Fluences and Flux Densities

- Let ΔN = # particles entering a sphere with cross sectional area Δa (total area $a = 4\pi r^2$)
- Particles enter during time interval dt
  —Then—
- Particle fluence = $\Phi = \Delta N / \Delta a$
- Particle flux density = $\phi = \Delta\Phi / \Delta t$

Fluence and Flux Visuals

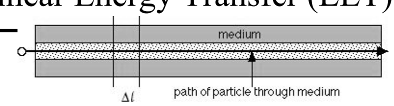


- Area through which particles enter = Δa
- Total Surface area $a = 4\pi r^2$
- ΔN particles enter in time Δt
- Particle fluence $\equiv \Phi = \Delta N/\Delta a$
- Flux Density = $\phi = \Delta\Phi/\Delta t$

Energy Fluence, Flux Density

- Let ΔE_f = sum of energy (exclusive of rest energy) of all particles entering sphere of cross-sectional area Δa
- Energy fluence: $\Psi = \Delta E_f/\Delta a$
- Energy flux density: $\psi = \Delta\Psi/\Delta t$

Linear Energy Transfer (LET)



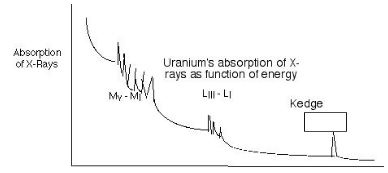
- LET defined as dE_L/dl, where dE_L is the energy locally imparted to the medium over the length interval *dl*.
- Dimensions: Energy / length; units: J/m
- *restricted range stopping power*: don't look for energy deposited far from path.

What does LET depend on?

- Nature of radiation
  - Alpha particles can be stopped by paper
  - Betas can be stopped by aluminum
  - Photons can get through almost anything
- Nature of medium (density, chemistry)
- Energy of radiation

LET's dependence on energy

- Dependence on energy manifests itself often in subtle ways:
  e.g. more absorption near absorption edges.



Charged Particle Equilibrium

CPE exists at a point *p* centered in a volume *V* if each charged particle carrying a certain energy out of *V* is replaced by another identical charged particle carrying the same energy into *V*. If CPE exists, then dose = kerma.

08/04/2008 RadBio Bootcamp, Lecture 1 p. 25 of 27

Radioactivity Measurements

- Let *dP* be the probability that a specific nucleus will undergo decay during time *dt*.
- Decay constant of a nuclide in a particular energy state is $\lambda = dP/dt$.
- Half-time or half-life: time required for half of starting particles to undergone transitions.
  $T_{1/2}=\ln 2 / \lambda$
  (not ln (2/ λ), as the book claims)

08/04/2008 RadBio Bootcamp, Lecture 1 p. 26 of 27

Activity

- Let *dN* = expectation value (most likely number) of nuclear transitions in time *dt*.
- Then activity $A = dN/dt = -\lambda N$
  (note that the minus sign is just keeping track of disappearance rather than appearance)
- Dimensions: time^{-1}
- Units: 1 becquerel = 1 disintegration /sec
- Old unit: Curie: $3.7 \cdot 10^{10}$ s^{-1}

08/04/2008 RadBio Bootcamp, Lecture 1 p. 27 of 27