Treat	ing	Cancer
with	Ra	diation

Nicole Ackerman

Prelude

Basics

Cancer

Radiotherapy

Wrapping Up

Treating Cancer with Radiation

Nicole Ackerman

2010-11-14

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Outline

Treating Cancer with Radiation

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Prelude

Caveats Plan for today

Basics

Cancer

Radiotherapy

Wrapping Up

Prelude Caveats

• Plan for today

2 Basics

3 Cancer

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5 Wrapping Up

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Me

Treating Cancer with Radiation

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- Caveats Plan for today
- Basics
- Cancer
- Radiotherapy
- Wrapping Up

Trained as a Physicist

- Currently learning biomedicine
- Familiar with college-level material
- Borrowed images for "Essential Cell Biology"

The Field

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Wrapping Up

• Very Interdisciplinary

- Physics
- Medicine
- Biology
- Chemistry
- Constantly Changing

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You

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Cancer

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Wrapping Up

- Different backgrounds
- Different Interests
- Will hopefully learn something
- Can't learn everything
- Won't be treating cancer (later today)

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Plan for today

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- Wrapping Up

- Start with Science Basics
 - Radiation
 - Cells
- Cancer
- Specific Radiotherapy Treatments

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• Videos of treatment strategies

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• Particles and Radiation

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- Cell Biology
- DNA

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What is a particle?

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Wrapping Up

- Building blocks of matter
 - atom = electrons, protons, neutrons
 - Studied at accelerators labs like SLAC, CERN
- Governed by quantum mechanics
 - Ignore that!



Particle Zoo

Treating Cancer with Radiation

Particles and Radiation



Bosons (Forces)

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The Most Important Particles

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Wrapping Up

Electron

- Carrier of Electric Charge (negative charge)
- In atoms
- Proton
 - Positively charged
 - In nucleus of atoms
 - Defines one element from another
 - Not actually fundamental
 - Ignore that!
- Photon
 - Particle that carries light
 - Visible (red->blue) light only one small energy range

Types of Radiation

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Wrapping Up

Ionizing

- Knocks electrons out of atoms
- High energy
- What we are talking about today
- Heat
 - Low energy
 - Only increases temperature



lonizing Radiation

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Wrapping Up

- Gamma: (γ) a high energy photon
- X-ray: photon with less energy than γ

- Beta: (β) an electron
- Alpha: (α) 2 protons + 2 neutrons

Radioactive Decay

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Wrapping Up

- One element becomes another
- Depends on number of neutrons and protons (isotope)
- Different types of decay α, β, γ
- Energy of emitted particles depends on isotope



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Accelerators

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Wrapping Up

• Particles gain energy through acceleration

- Rolling down a hill: gravity increases speed, energy
- Charged particles: electric field increases speed, energy
- Linear Accelerators (linacs)
 - Complicated structure
 - Can accelerate protons, electrons, ions
 - $\bullet\,$ Produce γ by electrons hitting plate





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Wrapping Up

- Electric fields give charged particles energy
- X-ray tubes
 - Electrons move across voltage
 - Hit plate where they cause X-rays



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Cells, Tissues, Organs

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Figure 1-9 Essential Cell Biology 3/e (© Garland Science 2010)

Cell Structure



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DNA Basics

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Wrapping Up

• Double Helix = 2 strands

- Redundancy is important for genetics
- We will ignore this (mostly)
- Four bases: A, T, G, C
 - A ONLY pairs with T
 - G ONLY pairs with C



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Figure 5-2b Essential Cell Biology 3/e (I) Garland Science 2016)

Full Structure

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Basics Particle

Cell Biology

Cancer

Radiotherapy

Wrapping Up





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Activity: DNA Modeling

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Radiotherapy

Wrapping Up

• Break into groups and use the magnetic modeling kit to make a model of DNA.

- Instead of A/T and G/C, just think of N/S
- (ignore different colors)
- WARNING: Keep away from credit cards, etc
- Please hold on to your model at the end

Genes

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Wrapping Up

• Groups of bases form genes

- Genes form the "laws" of the cell
- Genes determine physical characterization
 - Eyes: blue vs brown
 - Peas: yellow vs green



Mutations

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Wrapping Up

• All cells begin from the same DNA

- Mutations CHANGE the DNA over time
- One (or more) base changes
 - One single base changes
 - One part of DNA switches with another



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Mutations: Example

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Wrapping Up

Normal Gene GTGCACCTGACTCCTG<mark>A</mark>GGAG ---↓ GTGCACCTGACTCCTG<mark>T</mark>GGAG ---

Mutated Gene

single nucleotide changed (mutation)



5 µm





Causes of Mutations

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Wrapping Up

- Physics: Radiation
 - Breaks bonds in DNA
- Chemistry: Reactions
 - Certain chemicals can break bonds

- Introduce new molecules to DNA
- Biology: Viruses
 - Viruses change DNA

Mutations - Reactions



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Wrapping Up



Figure 6-24 Essential Cell Biology 3/e (© Garland Science 2010)

Mutations - Crossover

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DNA

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Wrapping Up

two homologous DNA double helices



 Moved genes can't be found

• Affects multiple genes at once

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• Can destroy entire chromosomes

Figure 6-30 Essential Cell Biology 3/e (© Garland Science 2010)

Chromosome Crossover (Normal)

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Figure 5-10 Essential Cell Biology 3/e (© Garland Science 2010)

Chromosome Crossover (Mutation)

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Figure 20-45 Essential Cell Biology 3/e (© Garland Science 2010)

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What is cancer? Cancer and Mutations

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- What is cancer?
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Tumors



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Cancer Cells

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What is cancer?

Cancer and Mutations Treating Cancer

Radiotherapy

Wrapping Up

• Are "normal" cells that:

- Reproduce too quickly
- Don't listen to other cells
- Don't die when they are supposed to

- Initially only have 2-3 differences
- Can mutate at a faster pace

Outline

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Cancer What is cancer Cancer and Mutations

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Oncogenes

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Cancer and Mutations Treating Cancer

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Wrapping Up

• "onco" means cancer

- When certain genes mutate, they lead to cancer
 - Turn OFF important checks
 - Turn ON bad behaviours



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Figure 20-49 Essential Cell Biology 3/e (© Garland Science 2010)

Specificity

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Cancer What is cancer? Cancer and Mutations

De die the second

Wrapping Up

Why certain people?

Why certain organs?

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Activity: Mutations

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Cancer What is cance

Cancer and Mutations Treating Cancer

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Wrapping Up

- We are going to be cells
- We'll see how cancer can form
- Our model is very simple for a cell
 - Only 4 genes
 - Only 4 cell actions
 - Lemons are "nutrients", but too much is bad

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• Rate of mutation is high

Activity Rules:

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Cancer What is cancer

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Wrapping Up

- Each cell gets a turn
- Then all cells roll the mutation dice
- On a turn you do one of the following:
 - Fix DNA (costs 1 nutrient) (if mutated)
 - Divide (costs 1 nutrient) (must be free space adjacent)

- Take 1 Nutrient
- Oie, if you have 4 nutrients

GENES

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Wrapping Up

If it mutates you don't follow one of the rules:

- Broke (can't fix DNA)
- Move (don't need to be on substrate)
- Food (always take nutrient at beginning of turn)

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• Immortal (never dies)

Outline

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Wrapping Up

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Methodology

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Basics

- Cancer What is cancer Cancer and Mutations
- Treating Cancer

Radiotherapy

Wrapping Up

• Chemotherapy

• Uses chemicals

- Radiotherapy
 - Uses Radiation
- Surgery
- Normally a combination of many treatments

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Choosing Treatment

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Cancer What is cancer? Cancer and Mutations Treating Cancer

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Wrapping Up

• Cancer type/behaviour

- Individual health considerations
- Some can be tested ahead of time on biopsies

- Facilities available, doctor speciality
- Health Insurance

General Considerations

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Wrapping Up

- Sparing healthy tissue
- Risks
- Complete Eradication
- Killing cells
 - Chemically tell them to die

- Block essential proteins
- Damage DNA

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Cancer

Radiotherapy Principles Types Challenges



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Radiotherapy Principles

Types

Challenges

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DNA Damage

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ACTIVITY

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Challenges

Wrapping Up

- Use previous DNA model
- What determines damage?
- What makes damage easy or hard to fix?

Targeting Tumor

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Wrapping Up

Geometrical localization

- Biological traits
 - Rapid Division
 - Growing new blood vessels

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• Certain cell markers

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- Principles
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X-Ray/Gamma Therapy

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- Radiotherapy Principles **Types** Challenges

Wrapping Up

• Can be from

- X-ray tube
- Radioactive source
- External to the body.
- Radiation strongest at skin, weaker as you move in

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• First done months after discovery of x-rays

Brachytherapy

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Cancer

Radiotherapy Principles Types Challenges

Wrapping Up

- Inserts "seeds" into body
- Each seed contains radioactive material
- Damages cells right around seed
- Some are left inside, others are removed

Brachytherapy

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Wrapping Up



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Accelerator Therapy

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Wrapping Up

• Different Particle Types

• Higher energy photons

- Protons
- Ions
- Different Beam Patterns

Trilogy

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Cyberknife

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Proton Facility

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Ion Facility

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Shaping

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Wrapping Up

Breathing (etc)

- Increases risk to neighboring organs
- Constant monitoring vs. increased restraint

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Pediatric

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Wrapping Up

• Children have higher risks for certain cancers

- Lower tolerance for long-term risk
 - Secondary cancers
 - Fertility risk
- Cell division high throughout body

Conclusions

Treating Cancer with Radiation

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- Prelude
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- Cancer
- Radiotherapy
- Wrapping Up

- Mutations cause cancer
- Radiation can damage DNA, killing cells
- Many radiotherapy techniques exist
- There are challenges and risks, like any cancer therapy