Treating Cancer with Radiation

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Outline

Me

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

The Field

- Very Interdisciplinary
  - Physics
  - Medicine
  - Biology
  - Chemistry
- Constantly Changing

You

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

Outline

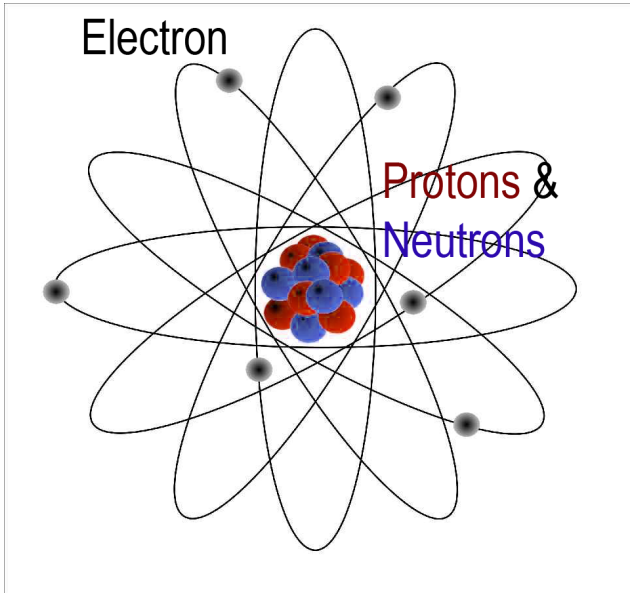
Plan for today

- Start with Science Basics
  - Radiation
  - Cells
- Cancer
- Specific Radiotherapy Treatments
- Videos of treatment strategies

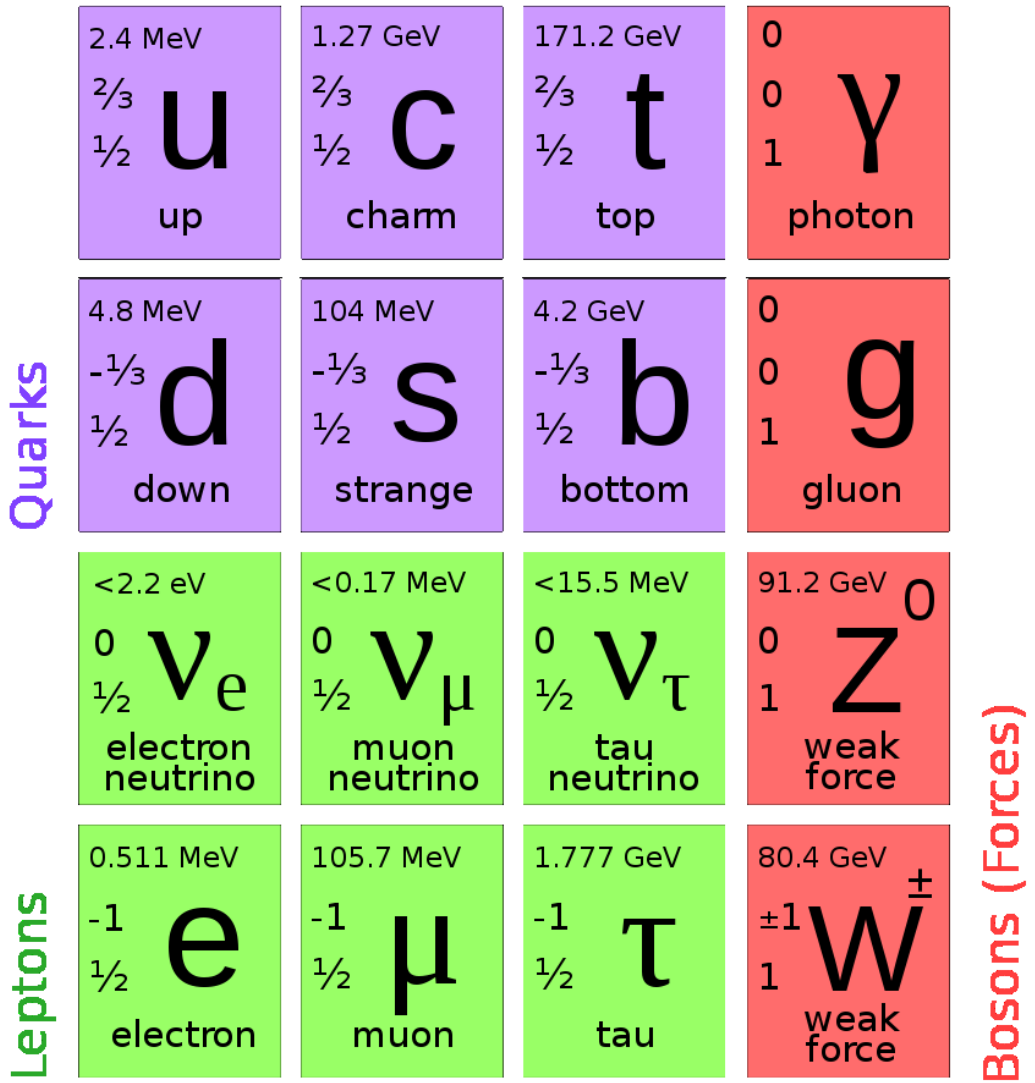
Outline

What is a particle?

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



Particle Zoo



The Most Important Particles

- 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

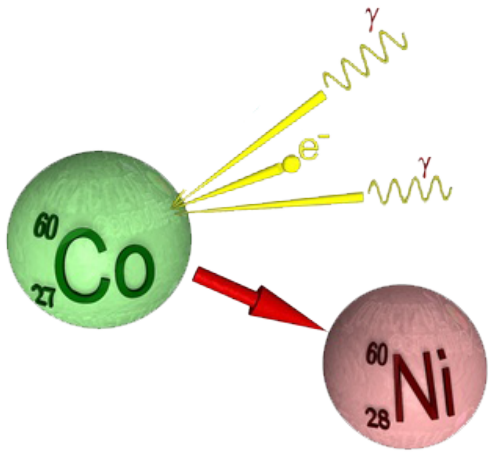
- Ionizing
  - Knocks electrons out of atoms
  - High energy
  - What we are talking about today
- Heat
  - Low energy
  - Only increases temperature

Ionizing Radiation

- Gamma: (γ) a high energy photon
- X-ray: photon with less energy than γ
- Beta: (β) an electron
- Alpha: (α) 2 protons + 2 neutrons

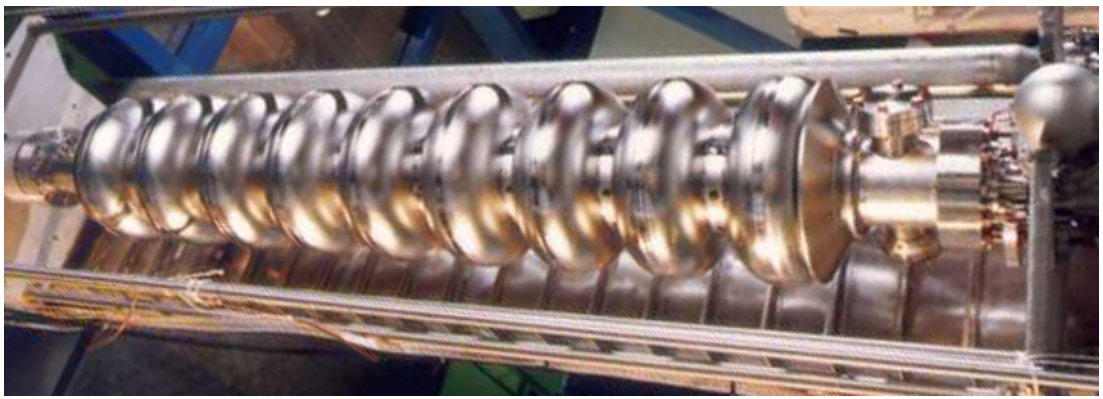
Radioactive Decay

- 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



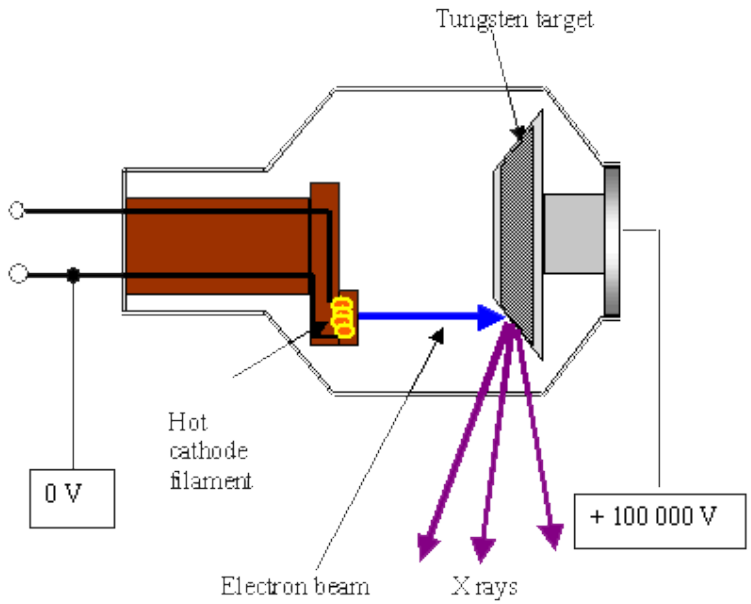
Accelerators

- 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
  - Produce γ by electrons hitting plate



X-ray tubes

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



Outline

Cells, Tissues, Organs

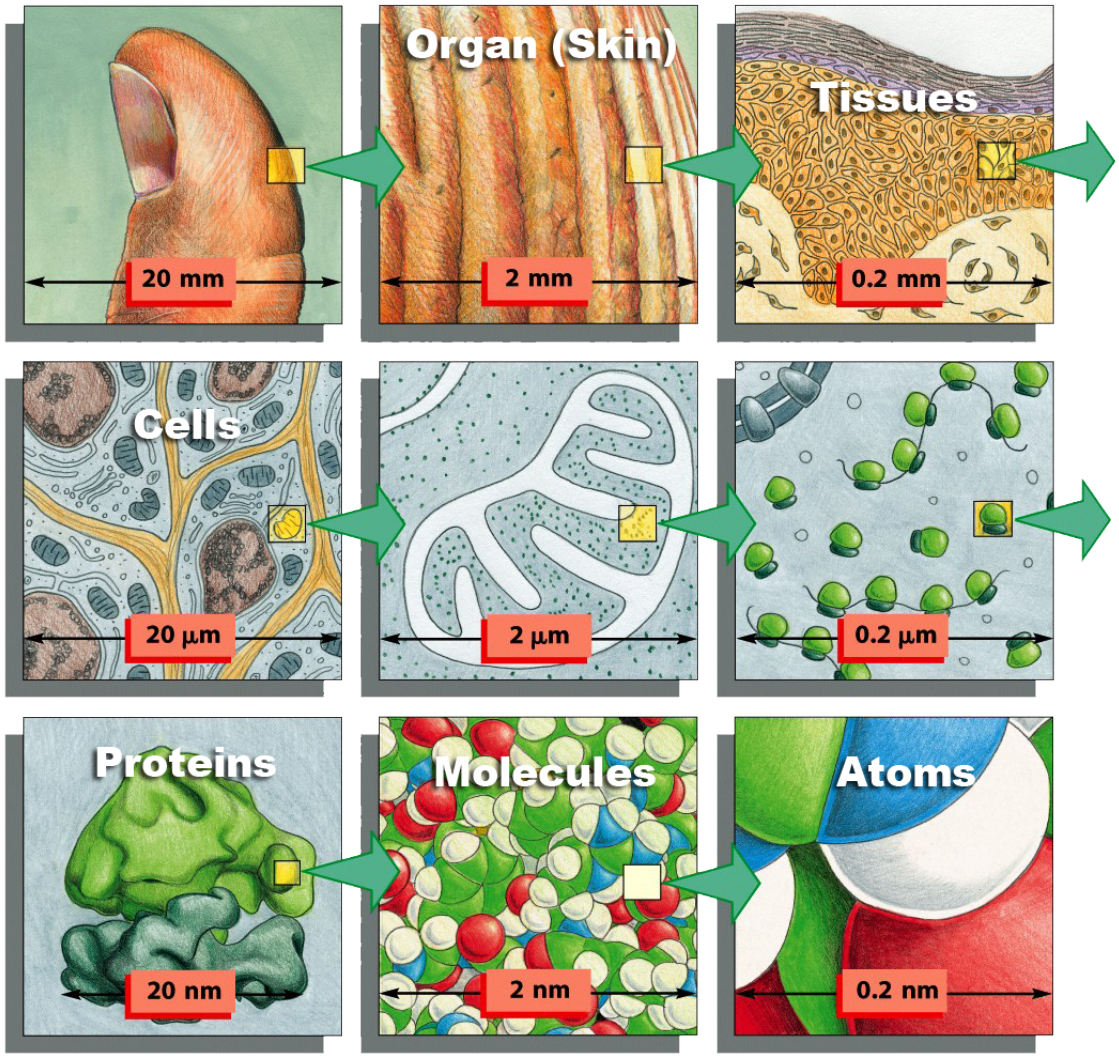
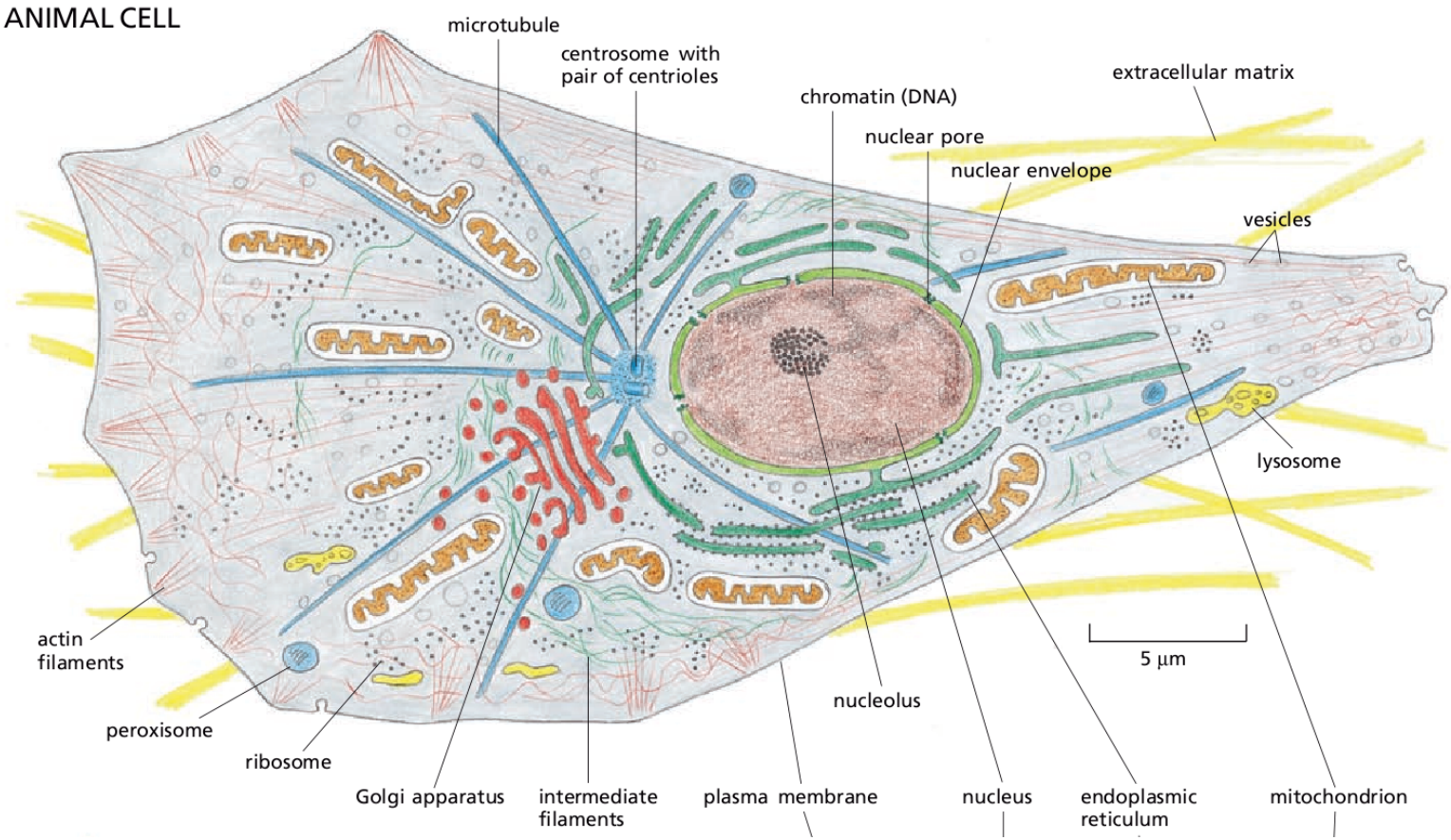
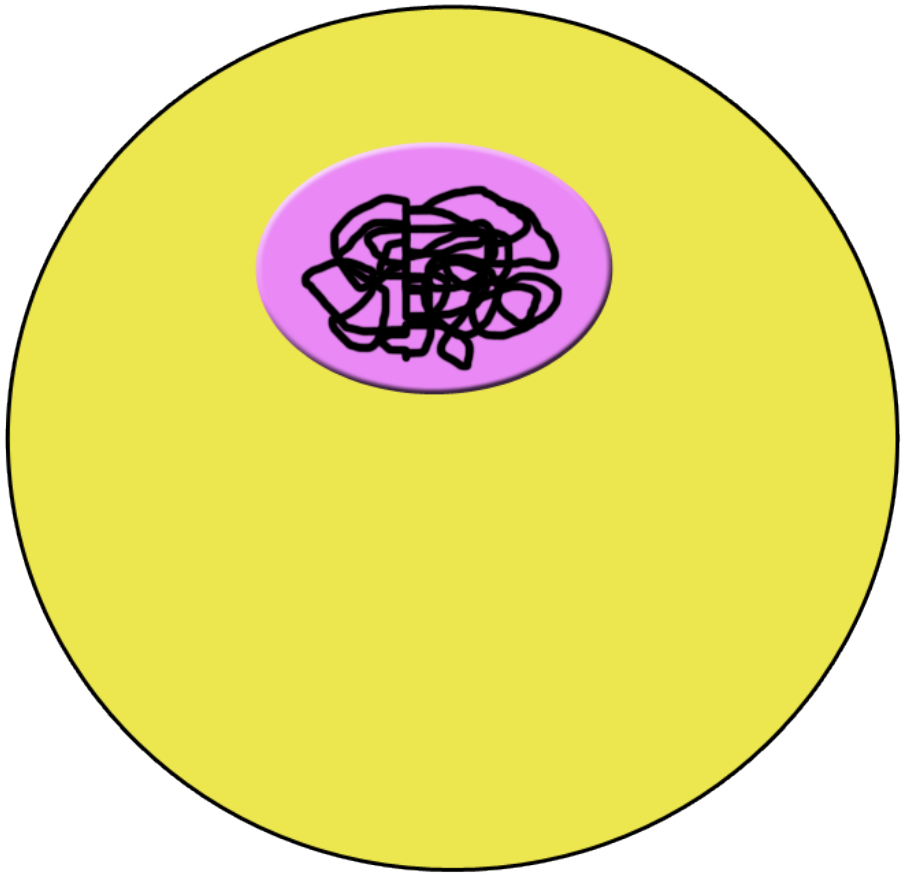


Figure 1-9 Essential Cell Biology 3/e (© Garland Science 2010)

Cell Structure



Simple Cell



Outline

DNA Basics

- 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

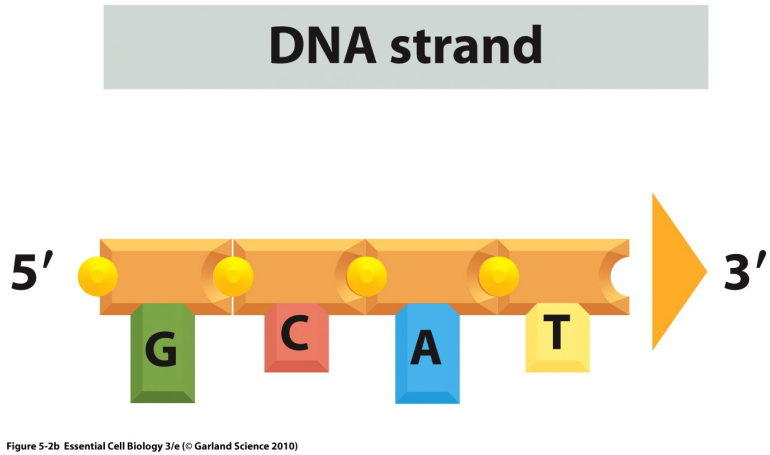
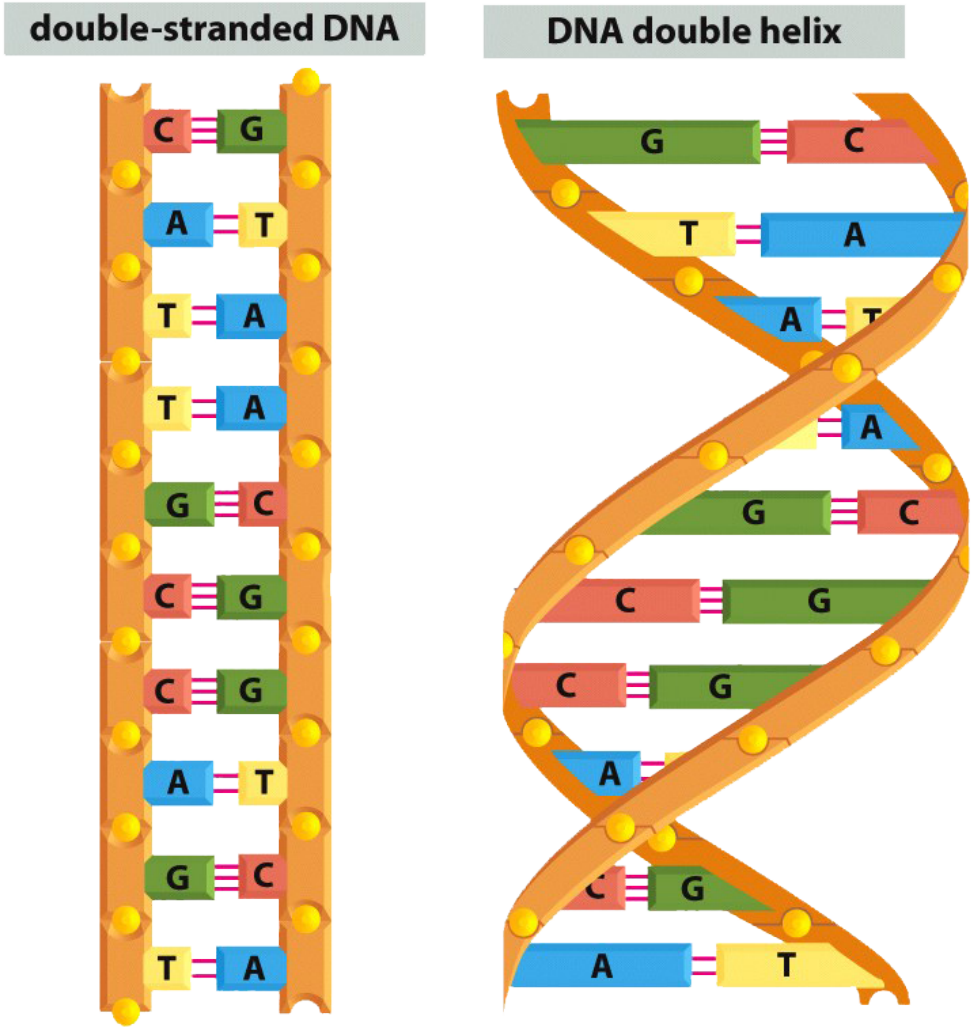


Figure 5-2b Essential Cell Biology 3/e (© Garland Science 2010)

Full Structure

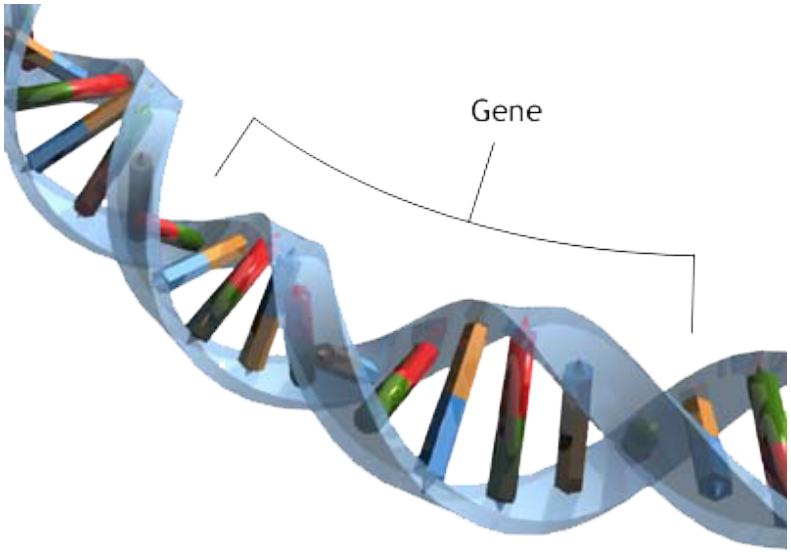


Activity: DNA Modeling

- 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

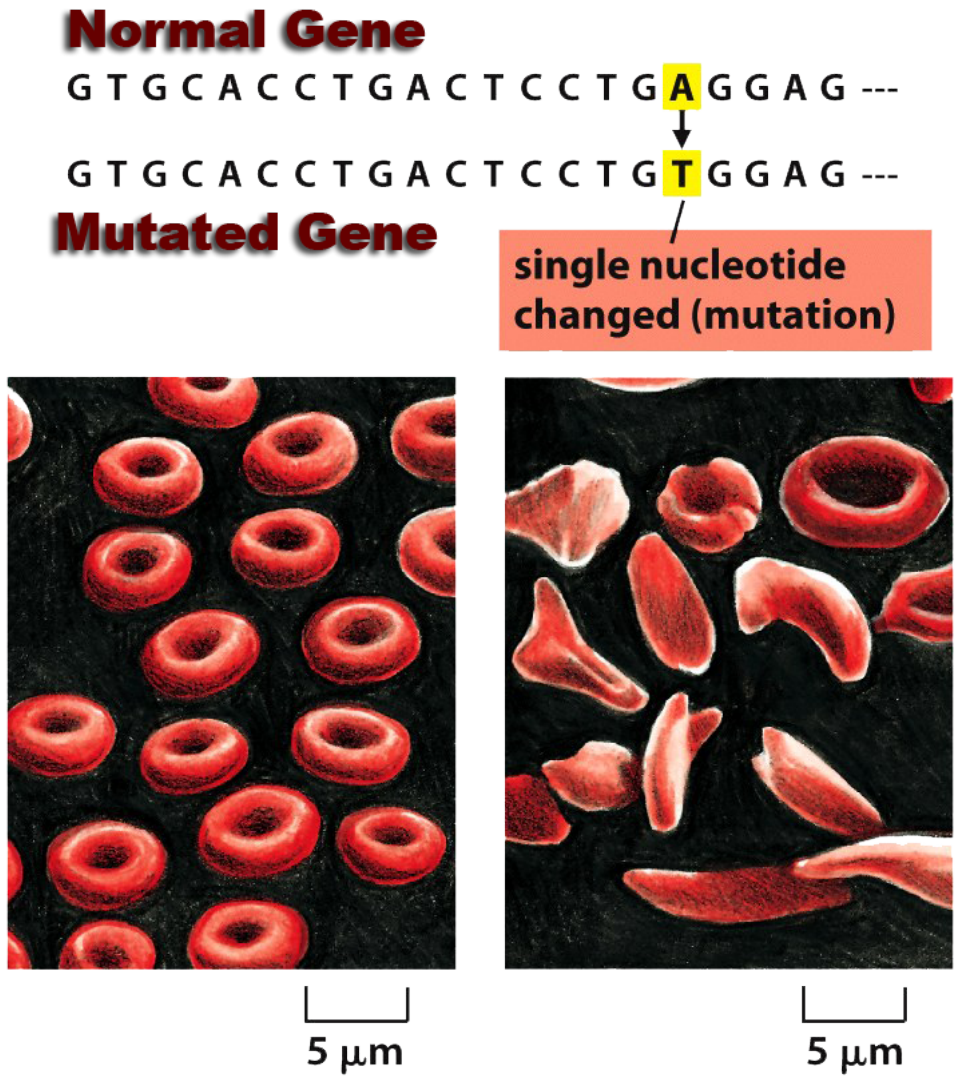
- Groups of bases form genes
- Genes form the "laws" of the cell
- Genes determine physical characterization
  - Eyes: blue vs brown
  - Peas: yellow vs green



Mutations

- 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

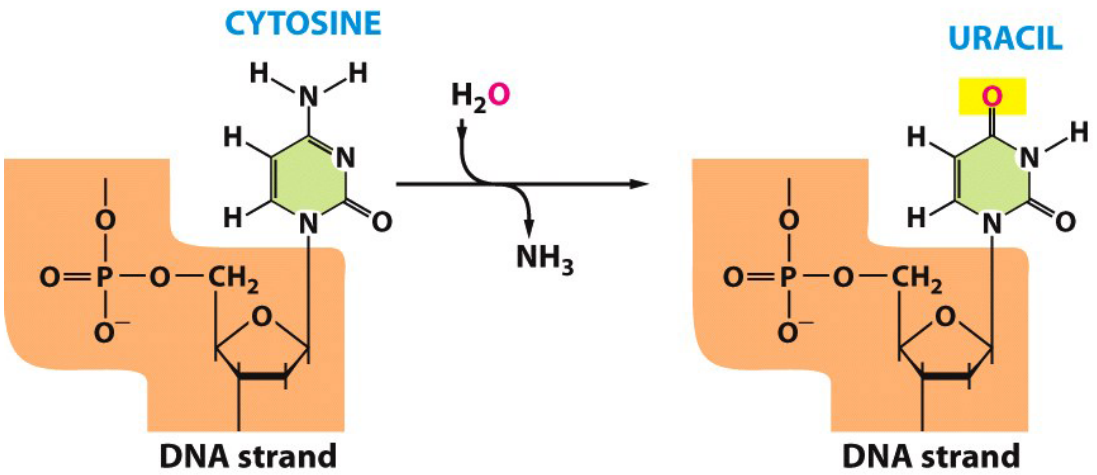
Mutations: Example



Causes of Mutations

- 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



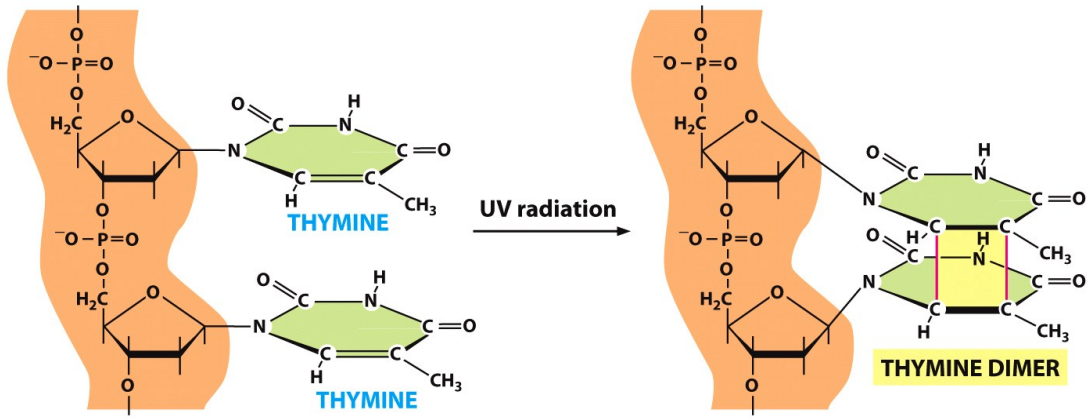


Figure 6-24 Essential Cell Biology 3/e (© Garland Science 2010)

Mutations - Crossover

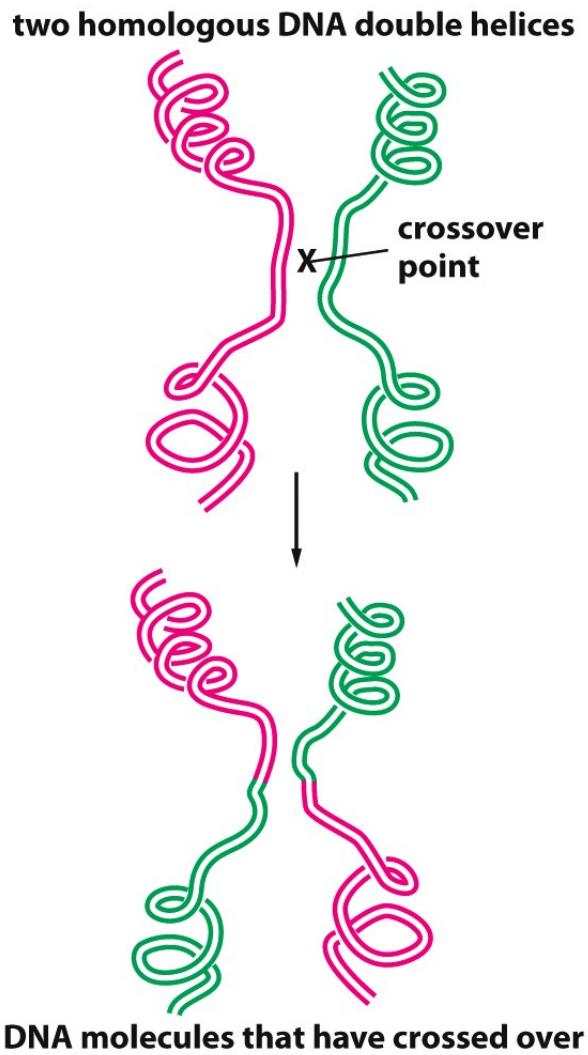


Figure 6-30 Essential Cell Biology 3/e (© Garland Science 2010)

- Moved genes can't be found
- Affects multiple genes at once
- Can destroy entire chromosomes

Chromosome Crossover (Normal)

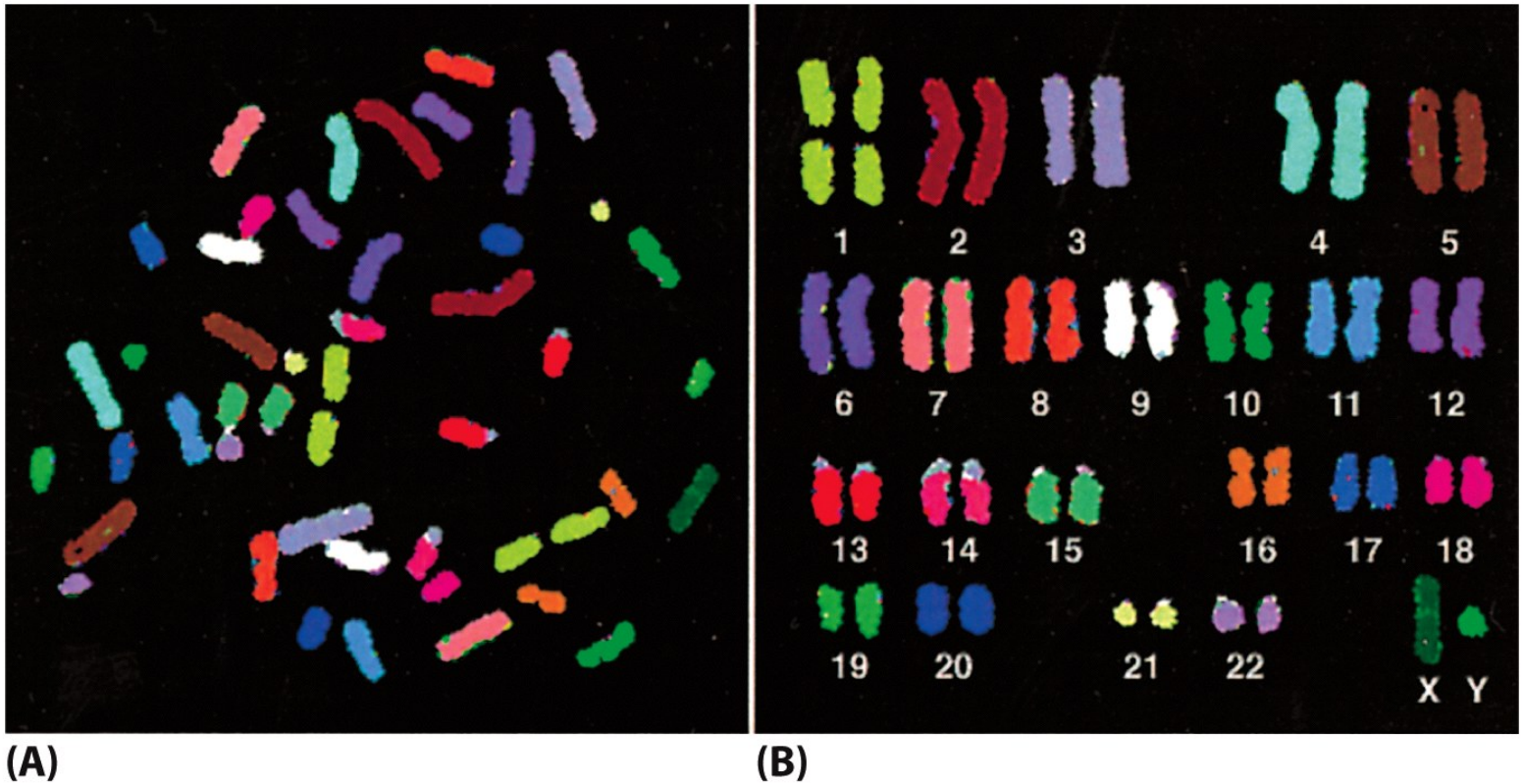


Figure 5-10 Essential Cell Biology 3/e (© Garland Science 2010)

Chromosome Crossover (Mutation)

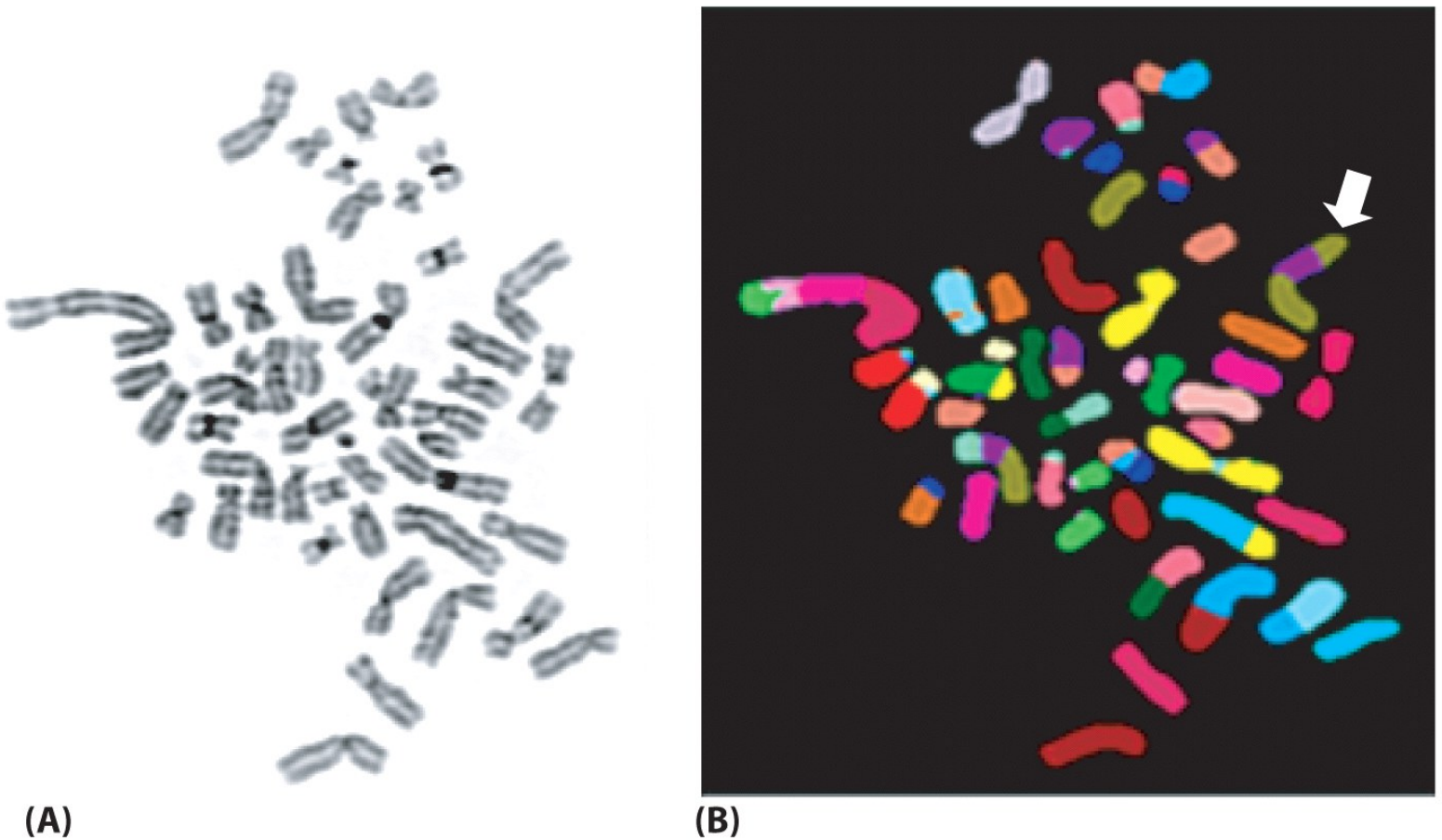


Figure 20-45 Essential Cell Biology 3/e (© Garland Science 2010)

Outline

Tumors

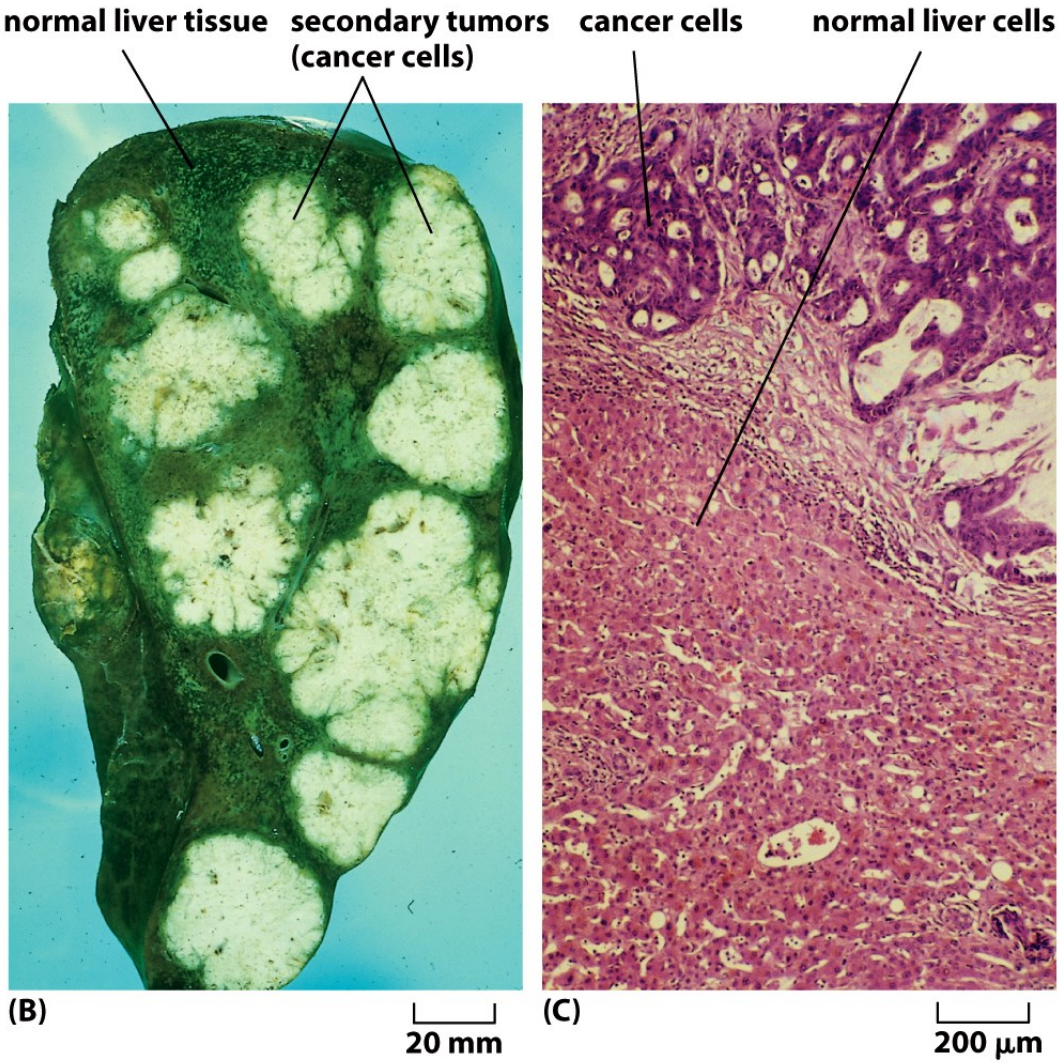


Figure 20-44bc Essential Cell Biology 3/e (© Garland Science 2010)

Cancer Cells

- 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

Oncogenes

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

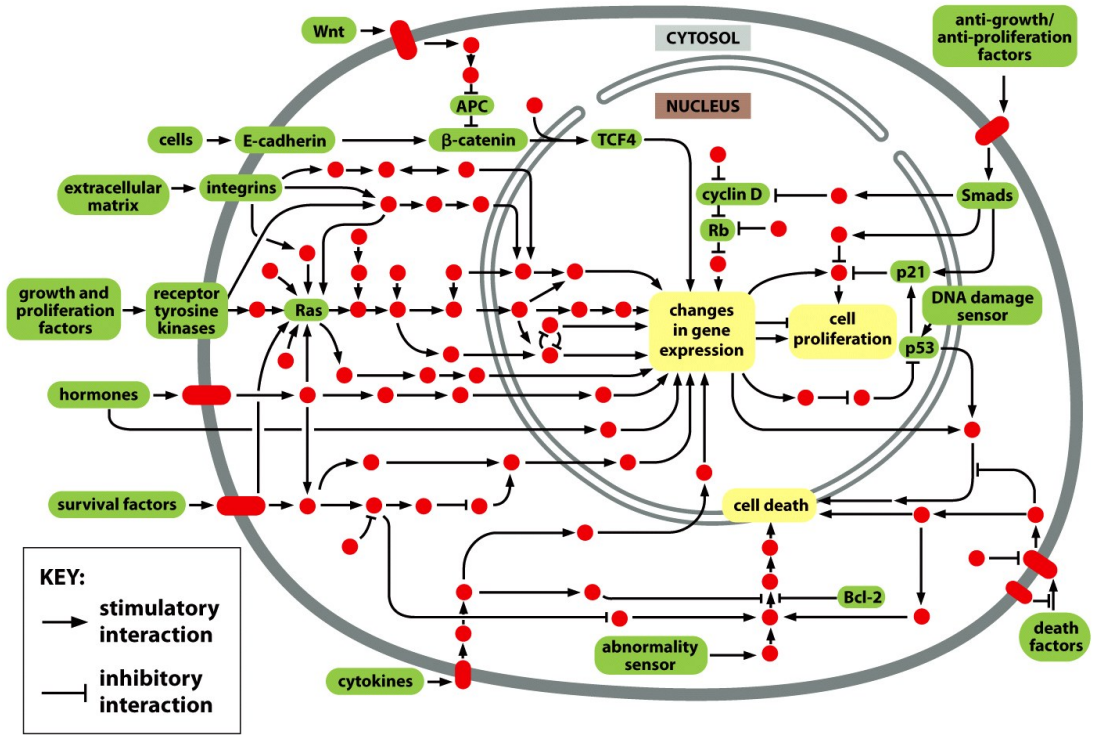


Figure 20-49 Essential Cell Biology 3/e (© Garland Science 2010)

Specificity

Why certain people?

Why certain organs?

Activity: Mutations

- 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
  - Rate of mutation is high

Activity Rules:

- Each cell gets a turn
- Then all cells roll the mutation dice
- On a turn you do one of the following:
  1. Fix DNA (costs 1 nutrient) (if mutated)
  2. Divide (costs 1 nutrient) (must be free space adjacent)
  3. Take 1 Nutrient
  4. Die, if you have 4 nutrients

GENES

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

- **B**roke (can't fix DNA)
- **M**ove (don't need to be on substrate)
- **F**ood (always take nutrient at beginning of turn)
- **I**mmortal (never dies)

Outline

Methodology

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

Choosing Treatment

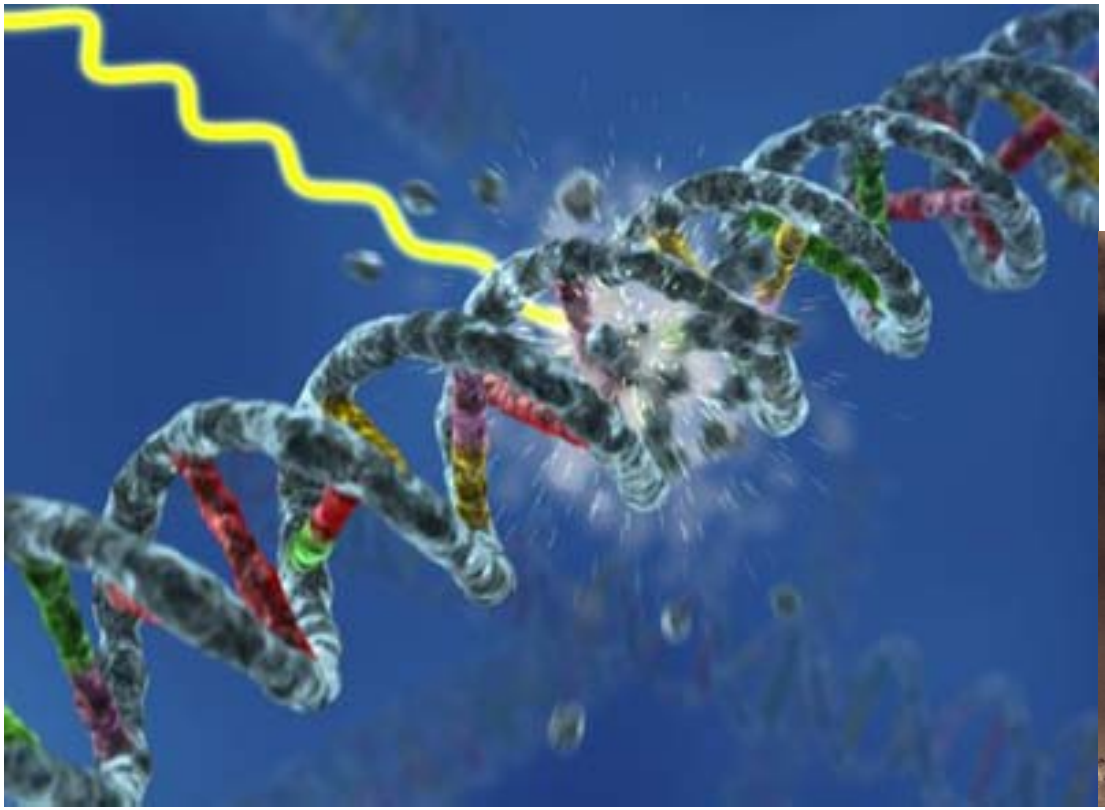
- Cancer type/behaviour
- Individual health considerations
- Some can be tested ahead of time on biopsies
- Facilities available, doctor speciality
- Health Insurance

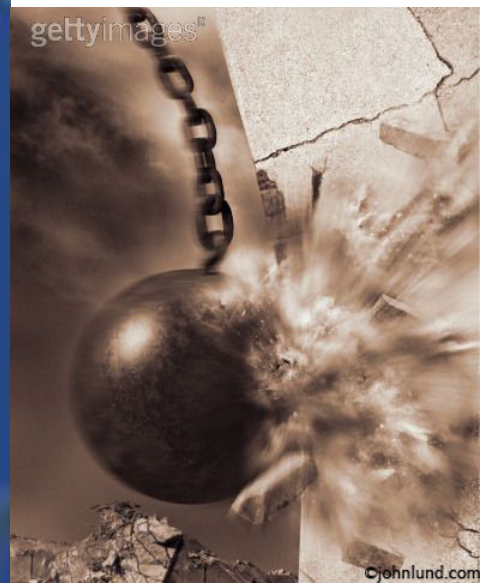
General Considerations

- Sparing healthy tissue
- Risks
- Complete Eradication
- Killing cells
  - Chemically tell them to die
  - Block essential proteins
  - Damage DNA

Outline

DNA Damage





ACTIVITY

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

Targeting Tumor

- Geometrical localization
- Biological traits
  - Rapid Division
  - Growing new blood vessels
  - Certain cell markers

Outline

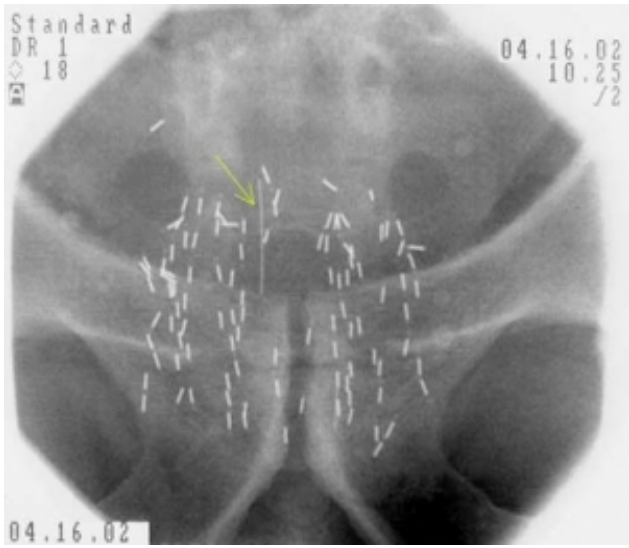
X-Ray/Gamma Therapy

- Can be from
  - X-ray tube
  - Radioactive source
- External to the body.
- Radiation strongest at skin, weaker as you move in
- First done months after discovery of x-rays

Brachytherapy

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

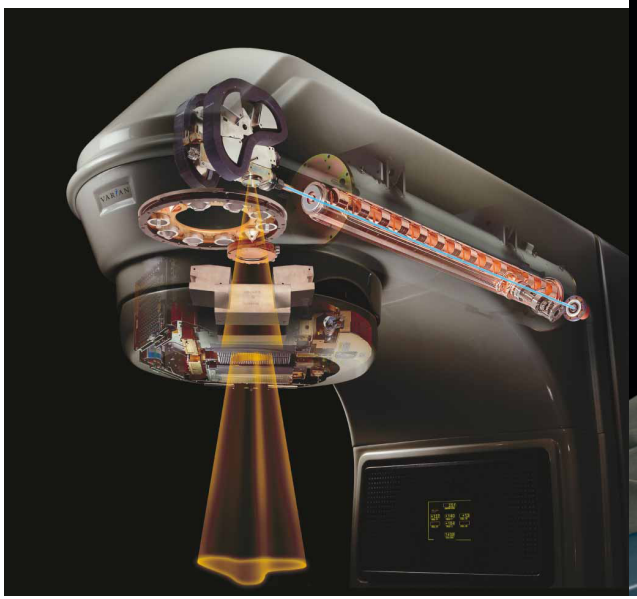
Brachytherapy



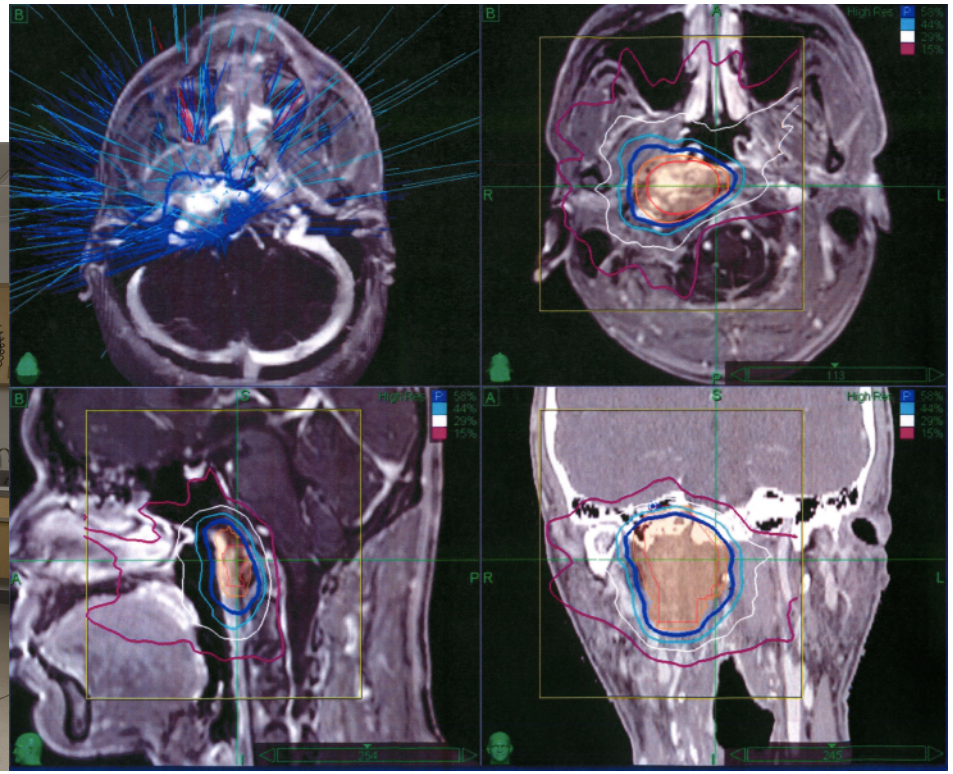
Accelerator Therapy

- Different Particle Types
  - Higher energy photons
  - Protons
  - Ions
- Different Beam Patterns

Trilogy

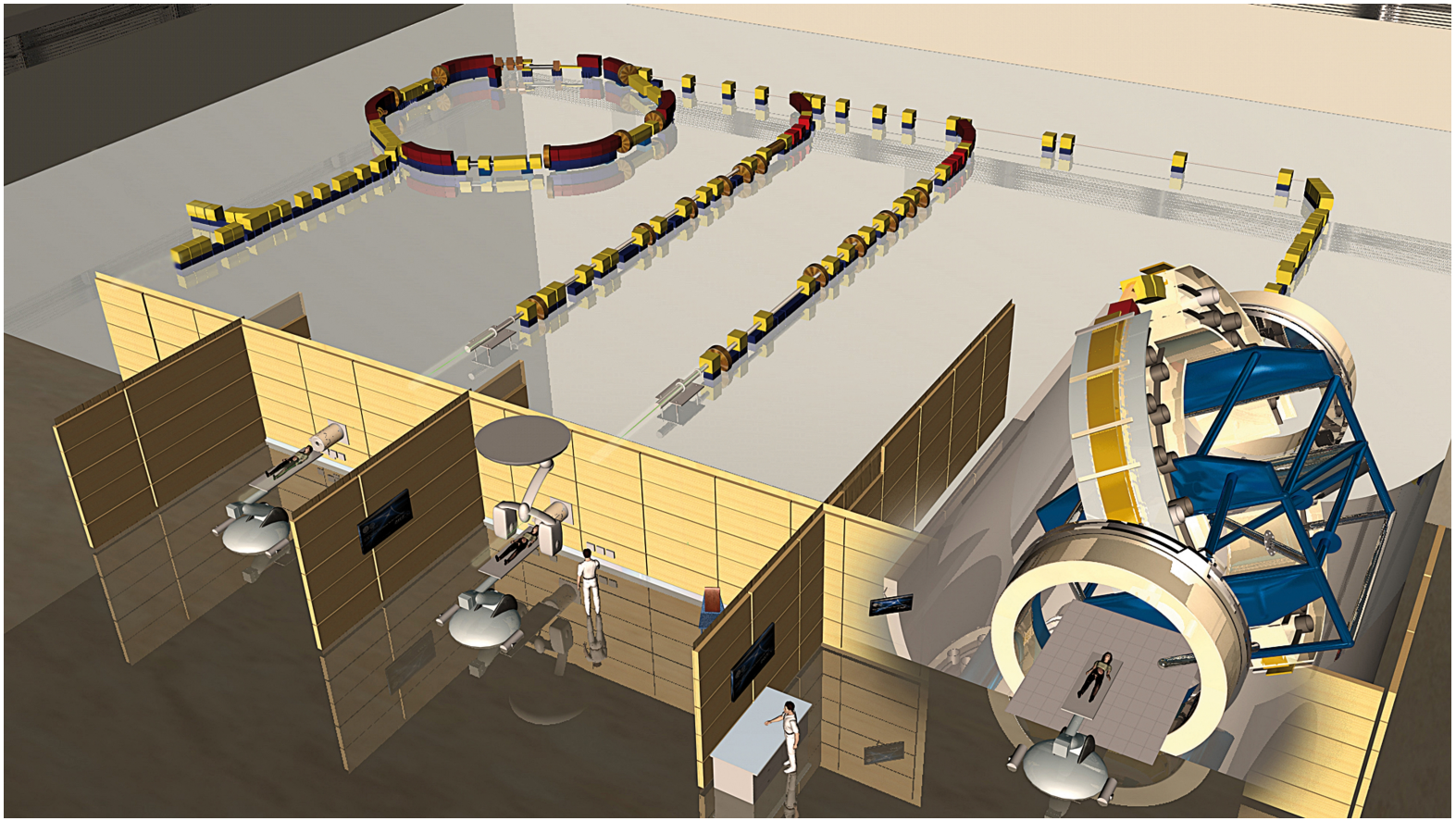


Cyberknife

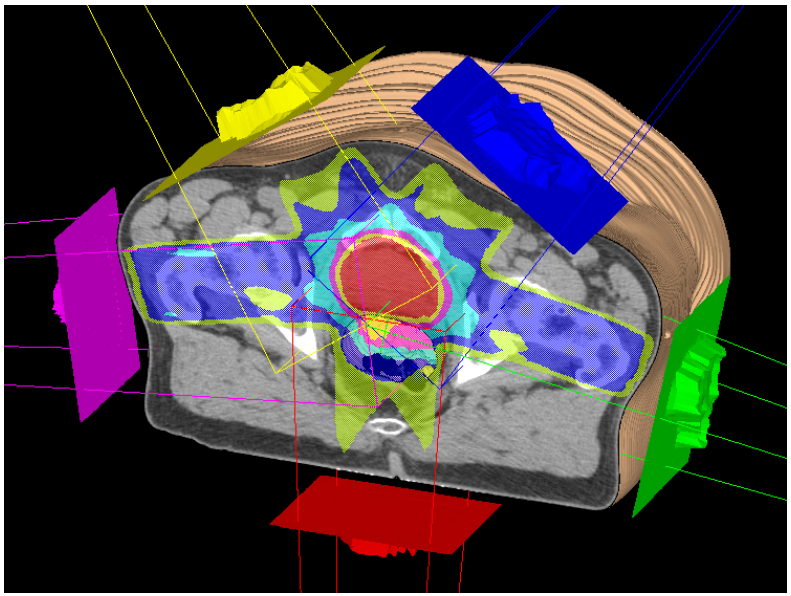


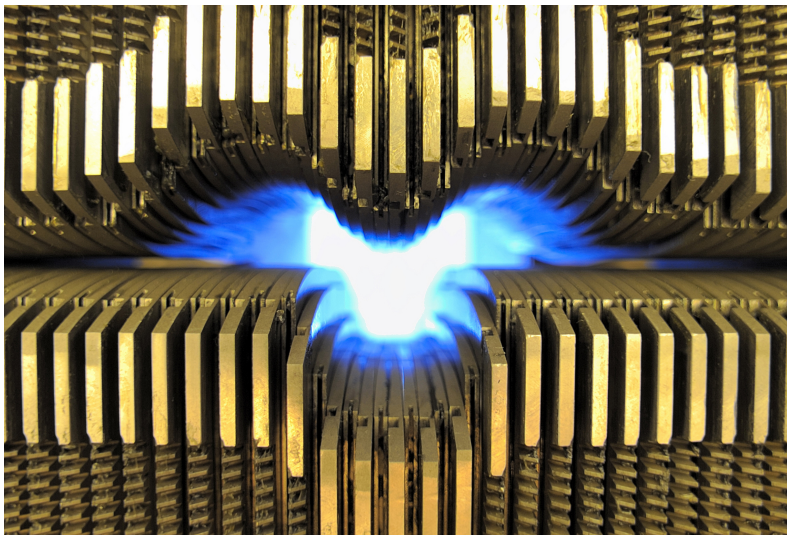
Proton Facility

Ion Facility



Shaping





Outline

Motion

- Breathing (etc)
- Increases risk to neighboring organs
- Constant monitoring vs. increased restraint

Pediatric

- Children have higher risks for certain cancers
- Lower tolerance for long-term risk
  - Secondary cancers
  - Fertility risk
- Cell division high throughout body

Conclusions

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