AN INTRODUCTION TO RADIATION ONCOLOGY

A REVIEW FOR ONCOLOGY NURSES

Nagy Elsayyad, MD DABR MS FACP

AHCI Radiation Oncology

1

DISCLOSURES: NONE

Nagy Elsayyad, MD DABR MS FACP

AHCI

2

Learning Objectives

To understand:

- ***"What"*** **is radiotherapy?**
- ***"How"*** **does radiation act?**
- **Role of radiation therapy in** ***Medicine***
- ***Adverse effects*** **of radiotherapy**

3

What is Radiation Oncology?

That discipline of human medicine concerned with the therapeutic applications of ionizing radiation in the treatment of tumors

Radiation oncology is one of the three primary specialties of the multidisciplinary medical practice of human oncology

4

Part I
A Prelude to Radiation Physics and Chemistry

What is "therapeutic radiation"?

- **Definition of <u>ionizing</u> radiation**
- **Types of ionizing radiation and non-ionizing radiation**

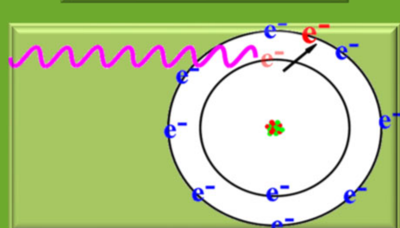
5

What is ionizing radiation ?

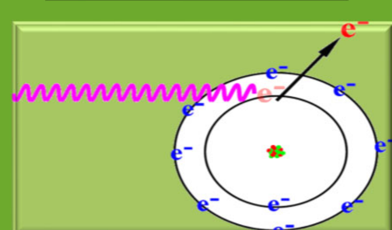
The absorption of energy from radiation in biologic material may lead to: <u>excitation</u> or to <u>ionization</u>.

If the radiation has sufficient energy to eject orbital electrons from the atom or molecule, the process is called ionization and that radiation is said to be "*<u>Ionizing Radiation</u>*

Excitation



Ionization



6

Non-ionizing Radiation

Can cause excitation of atoms (where electrons jump to higher atomic energy levels but are not removed from the atom):

- UV light
- Lasers
- Microwave
- Radio waves
- Infrared Waves

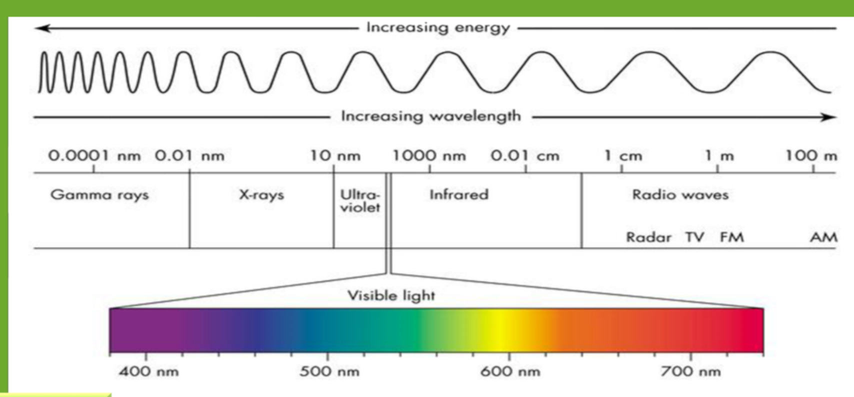
Energy not enough to ionize

What is ionizing radiation ?

- The important characteristic of ionizing radiation is the localized release of large amounts of energy.
- The energy per ionizing event 33 eV enough to break a chemical bond (ex. C=C bond is 4.9 eV).

7

Electromagnetic Spectrum



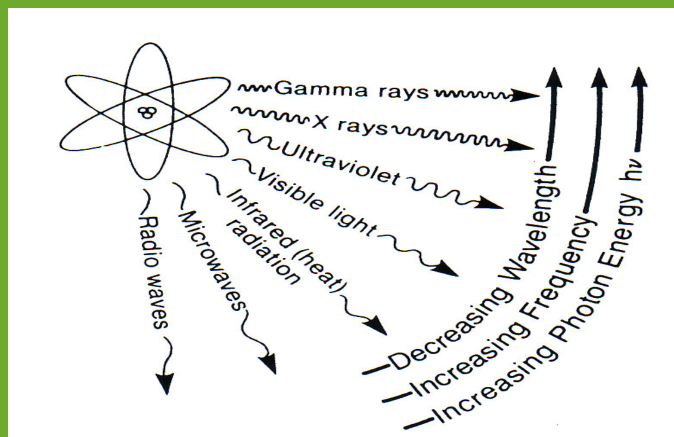
$\lambda \nu = c$

$E = h\nu$

$E = hc/\lambda$

8

Electromagnetic Spectrum



9

Types of Ionizing Radiation of Medical Significance

Particulate

- **Neutral**
  - Neutrons
- **Charged**
  - Alpha (Helium nucleus)
  - Beta (electrons)
  - Protons
  - Pions
  - Heavy Ions

Electromagnetic

- X- rays (artificially produced)
- Gamma- rays (naturally occurring)

10

Radiation Chemistry

What is the biologically most important molecule in the cell that when affected by ionization can effect a change in cell behavior?

DNA

11

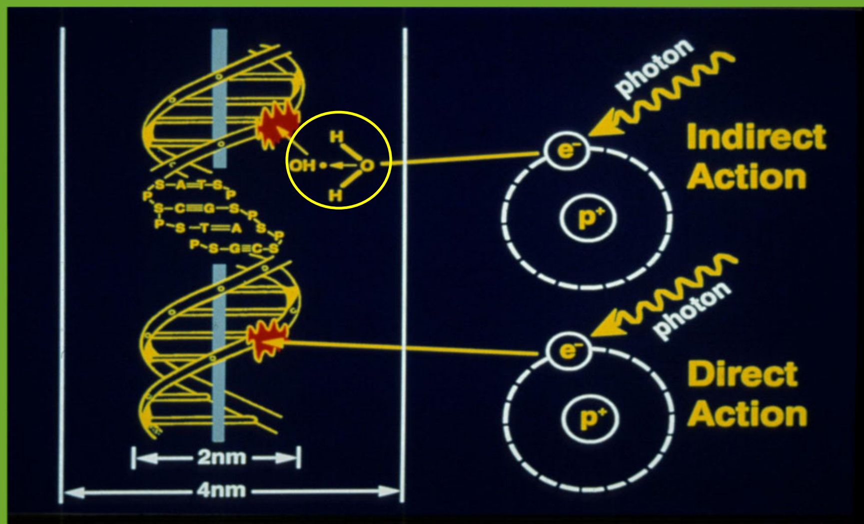
Radiation Chemistry

What is the most abundant molecule in the cell?

Water

12

Direct vs. Indirect Action



13

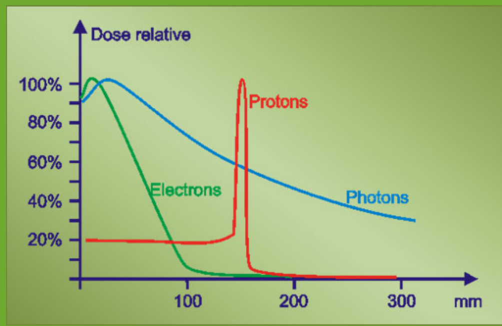
Chain of Events Leading to Radiation Effects

Events	*Timescale*
1. Initial interactions ***Indirectly ionizing radiation*** *(x, γ, ${}^{1}_{1}n$)* ***Directly ionizing radiation*** *(${}^{0}_{-1}e$, ${}_{1}^{1}H$, α, β)*	 **10^{-24}-10^{-14} s** **10^{-16}-10^{-14} s**
2. Physicochemical stage *Energy deposition as primary track structure ionization*	**10^{-12}-10^{-8} s**
3. Chemical damage *Free radicals, excited molecules*	**10^{-7}s - hours**
4. Bio-molecular damage *Proteins, nucleic acids, etc..*	**10^{-3}s - hours**
5. Early Biological Effects *Cell death, animal death*	**Hours-weeks**
6. Late Biological Effects *Cancer induction, genetic effects*	**Years-Centuries**
Coggle, JE, Biological Effects of Radiation , 1983	

14

Ionization for charged particles vs. photons

Photons (X rays, Gamma)	Charged Particles (Electrons, Protons)
Exponential Attenuation *(Energy absorption never reaches zero)*	*Have a "Range"* *(Range beyond which absorption is zero)*



15

How is Radiation Quantified?

Radiation Dose

- Exposure

= Electric charge / Mass of Air

Absorbed Dose

= Energy / Mass

Gy = J/kg
rad=100 ergs/gm = 10^{-2} Gy

16

Part II: Principles of Radiation Biology

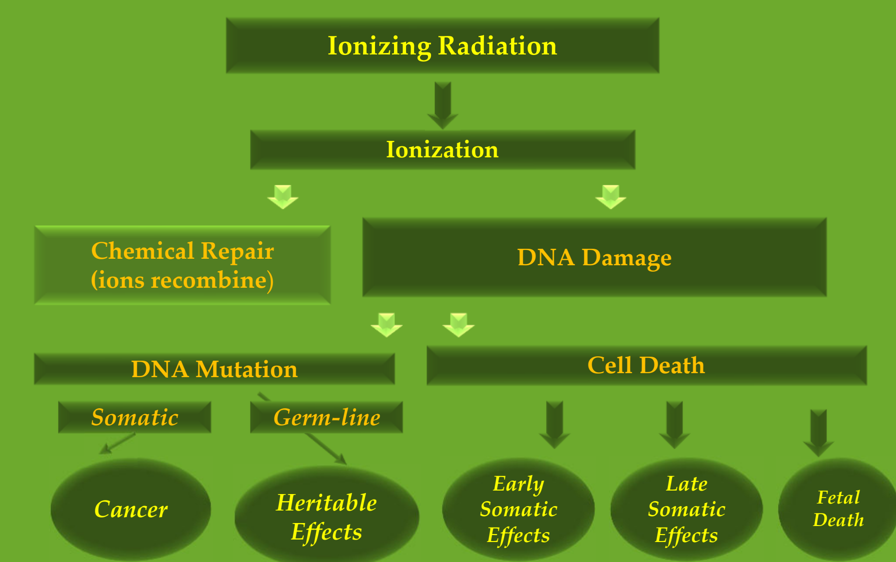
To understand the following concepts:

- Sub-cellular Level: DNA as the target of RT damage
- Cellular Level:
  - Cell death mechanisms in radiobiology
  - The Four "R" s (and more !) of radiation biology

  - *Repair*
  - *Redistribution/Re-assortment*
  - *Re-oxygenation*
  - *Repopulation*

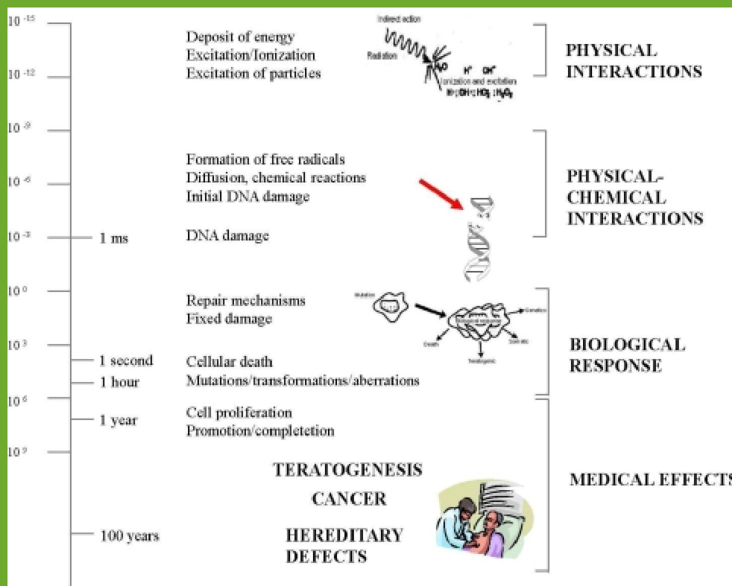
17

Classic Paradigm of Radiation Injury



18

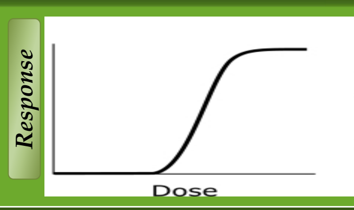
Classic Paradigm of Radiation Injury

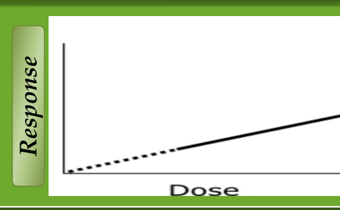


19

Biological Responses to Radiation

Stochastic vs. Deterministic Effects





Deterministic	Stochastic
Threshold dose below which there is no response	No threshold
Severity of effect is dose dependent	*Probability* of effect increases with dose but *severity* of effect is independent of dose
Can be scored	Cannot be scored
Somatic effects	Mutagenesis and carcinogenesis

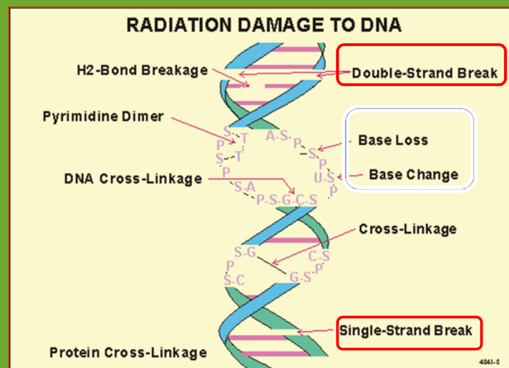
20

Sub-cellular Target of RT: DNA damage

RT induced DNA damage is heterogeneous

Cancer cells:

- **High proliferative potential**
- **Defective DNA repair**



21

Radiobiological Definition of Cell Death

Reproductive cell death

Loss of unlimited reproductive capacity (even if cell appears morphologically and metabolically unaltered)

- **Applies only to "clonogenic cells"**
- **Relevance: explains early and late tissue effects**

22

RT-induced Cell Death

Types of Cell Death after RT

RT-induced Cell Death	Examples of normal tissue that display the specified type of cell death in response to RT
Mitotic cell death	All irradiated cells are at risk
Apoptosis *(cell death by suicide)*	Depends of cell type Lymphocytes Parenchymal cells of salivary glands Crypt cells Glial cells
Necrosis *(cell death by accident)*	Toxic doses in normal tissue
Senescence	Fibroblasts
Autophagy	

23

Clinically Measureable Biological Determinants of Response to RT

The "4 R s" or "5 R s" of radiation response

Classic "R"s
*R*epair
*R*epopulation
*R*eoxygenation
*R*edistribution/*R*e-assortment
*R*adiosensitivity (intrinsic)

24

24

The Four "R" s of Radiotherapy

Repair

- **Better in normal tissues vs. cancer**
- **Can occur if the dose is divided over several fractions thus giving a advantage for normal tissues to recover better than cancer cells (fractionation)**
- **However, the full magnitude of repair will not occur unless sufficient time is allowed between fractions**

25