Module 4
Radiation Chemistry

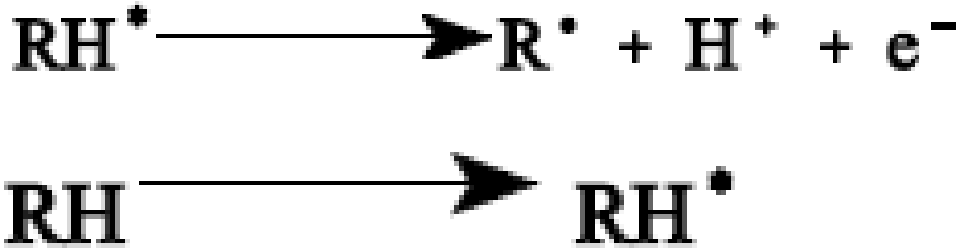
- Radiation causes changes in molecules by both direct and indirect action.
- If the damage is to important molecules in biological systems, the consequence may be severe.
- There are some repair mechanisms for radiation damage to important molecules.

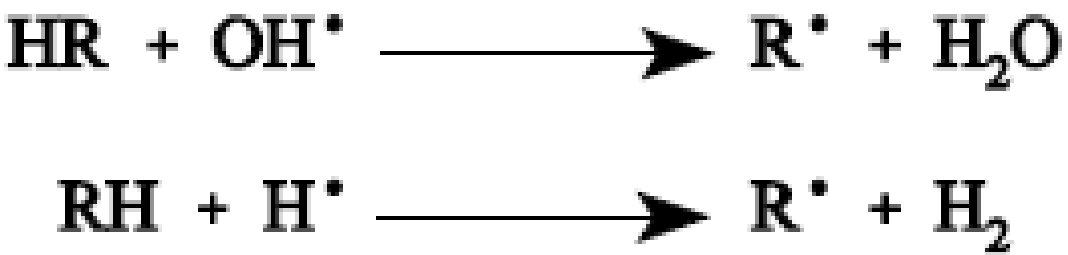
Charged Particle Track

Spur: 6-100 eV
Blob: 100-500 eV
Short Track: 500 to 50,000 eV

Radiolysis Products

Damage to Organic Molecues





Time Scale of Radiolysis

- Initial radiolysis < 10^{-6} seconds
- Recombination ~ 10^{-6} seconds
- Diffusion Controlled process

Direct versus Indirect Action

- Direct Action – the action of the ionizing radiation on the target molecules

- Indirect Action - energy transported by chemical species to cause damage to target molecues

Dose Dependence of Deactivation

$$\varepsilon = \varepsilon_0 e^{-kD}$$

where

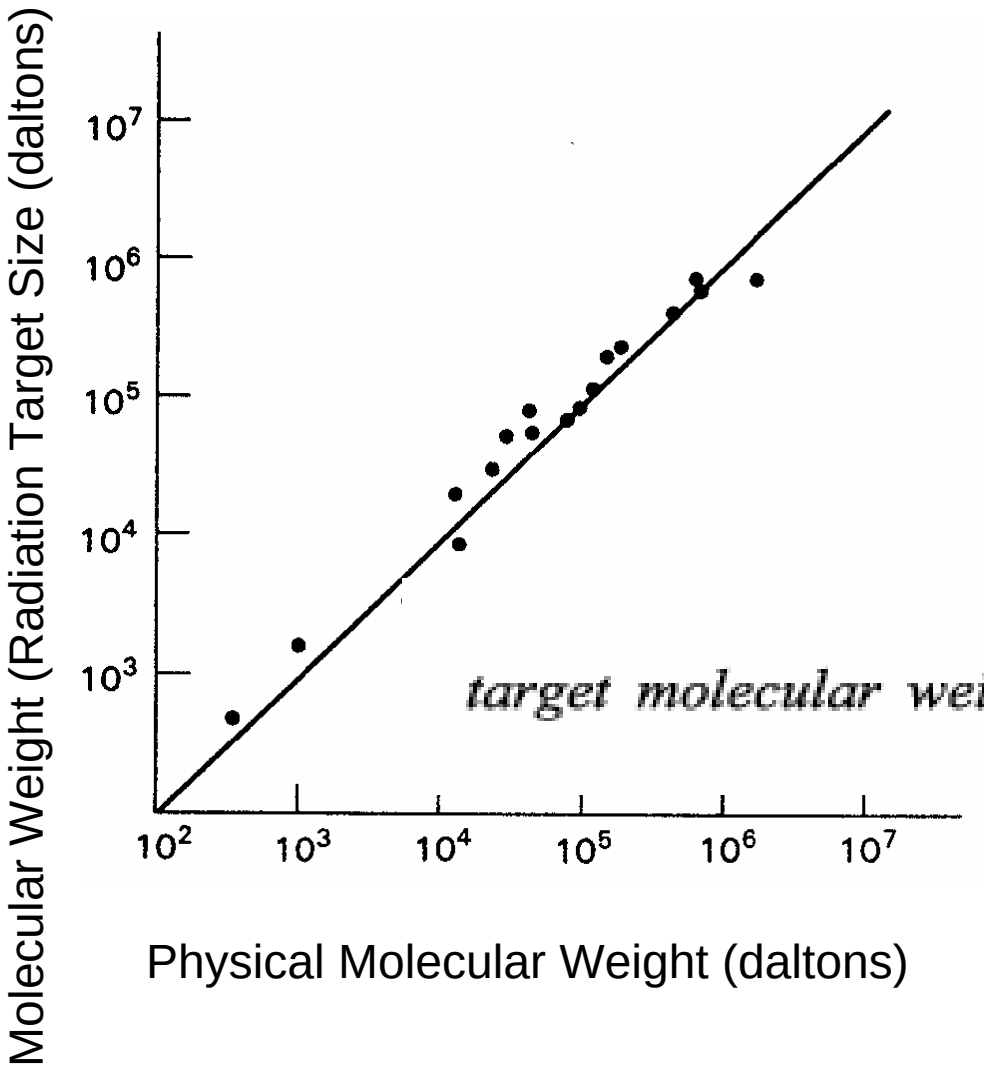
ε_o = undamaged molecules

ε = molecules remaining after dose

k = inactivation constant

D = dose

Dependence of Molecular Size



$$target\ molecular\ weight = \frac{7.28 \times 10^{11}}{D_{37}}$$

What is the dependence on molecular size?

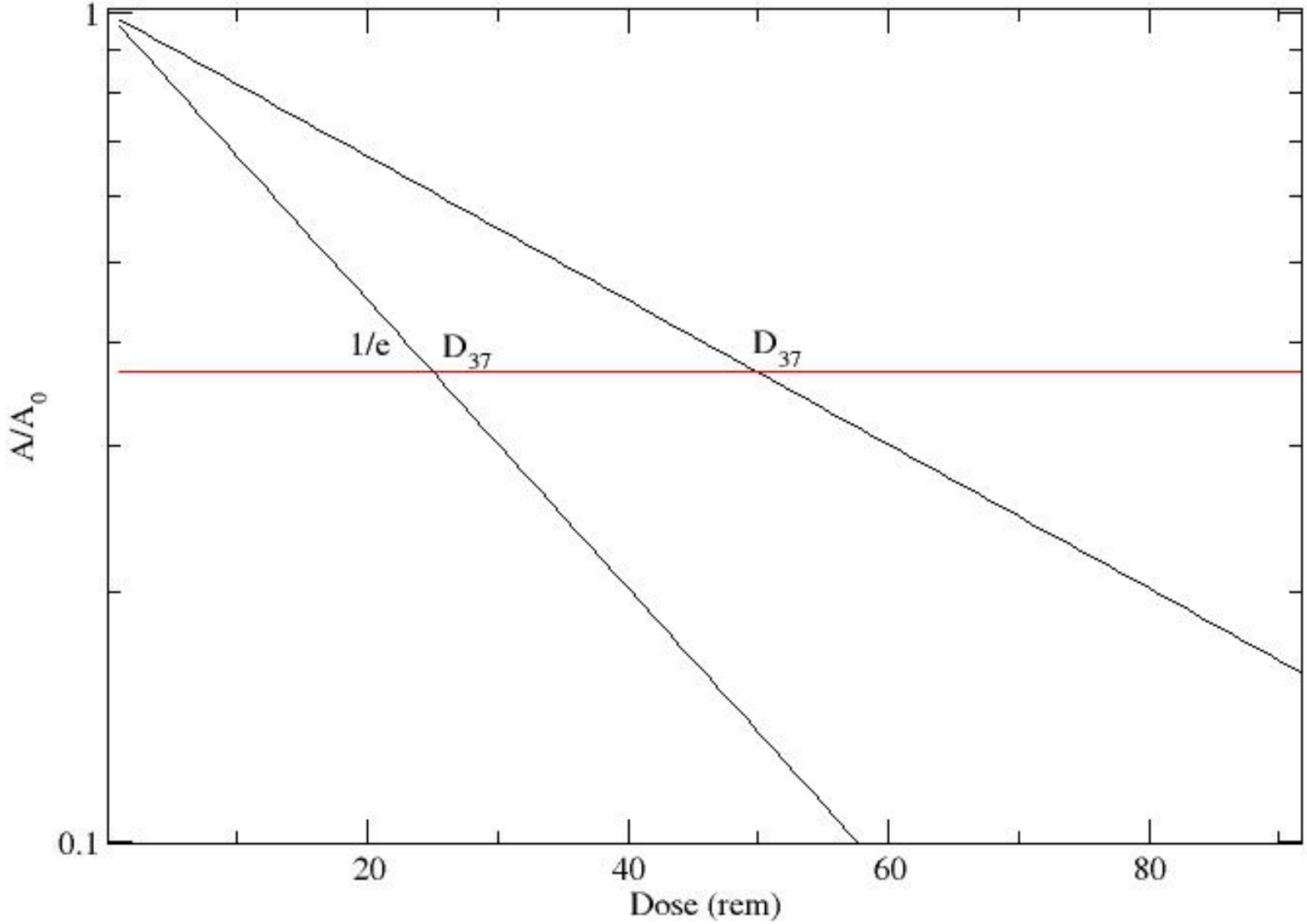
•Consider molecules as having a volume given by the total number of atoms in the molecues.

•The total volume is proportional to the number of atoms.

•This means that for a random choice of energy deposition point the sensitivity is determined by the probability of interaction.

•The response is proportional to the molecular size.

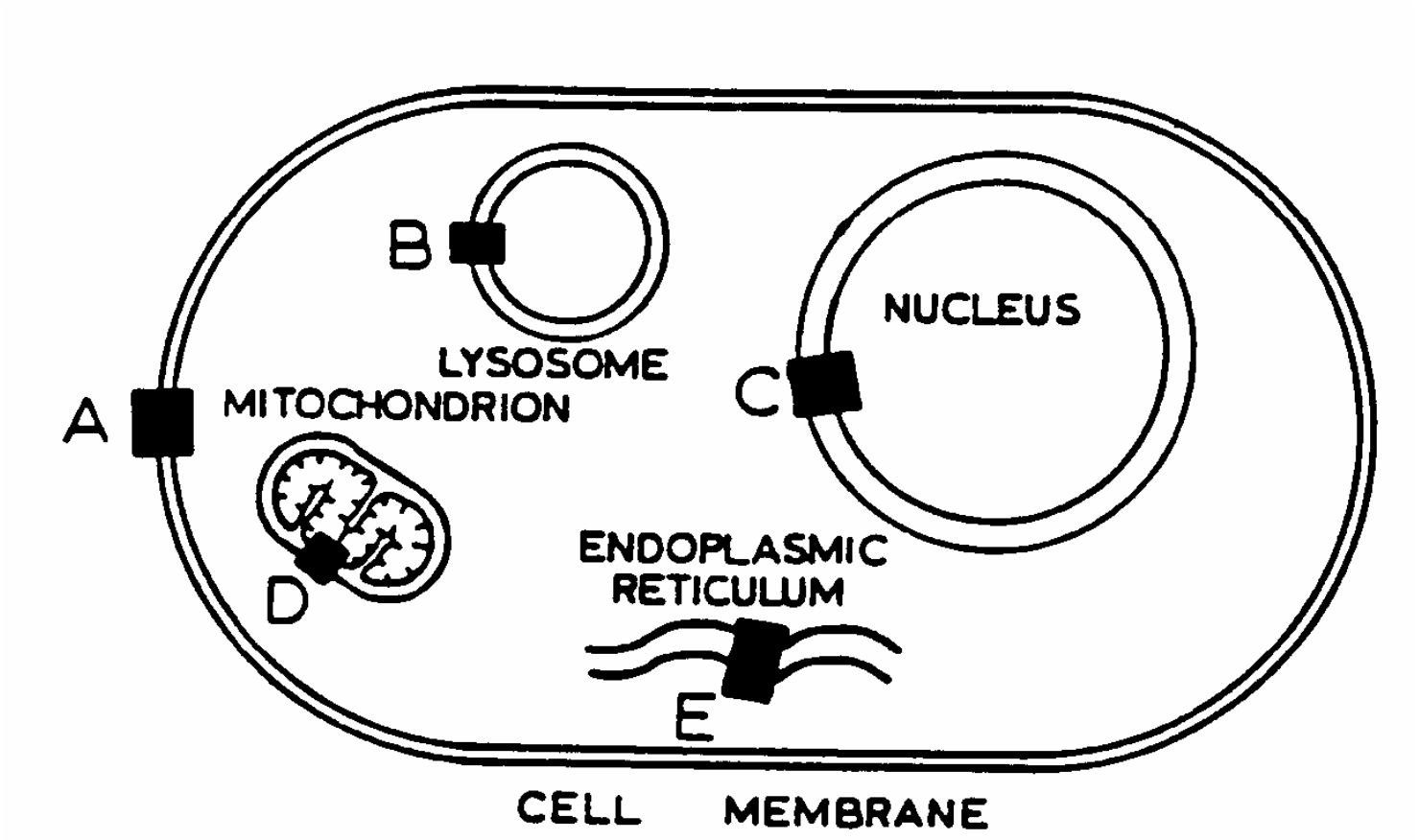
Dose relationship for molecues



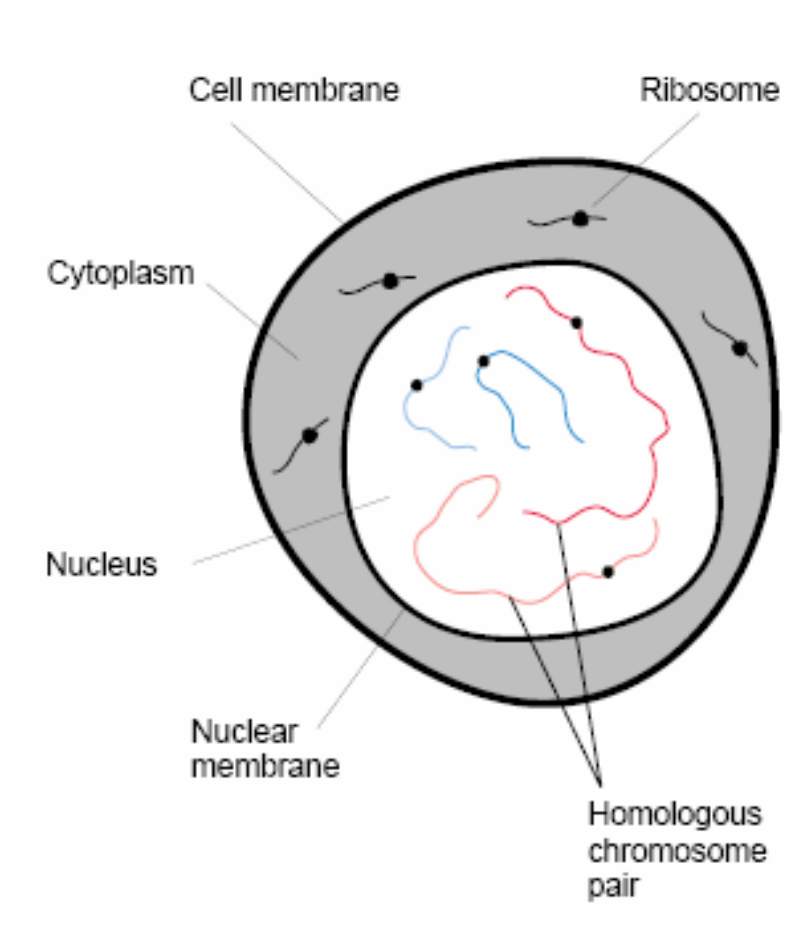
Mammalian Cell Types

- Epithelial tissues
- Connective tissue
- Muscular tissue
- Blood Cells
- Nervous tissue

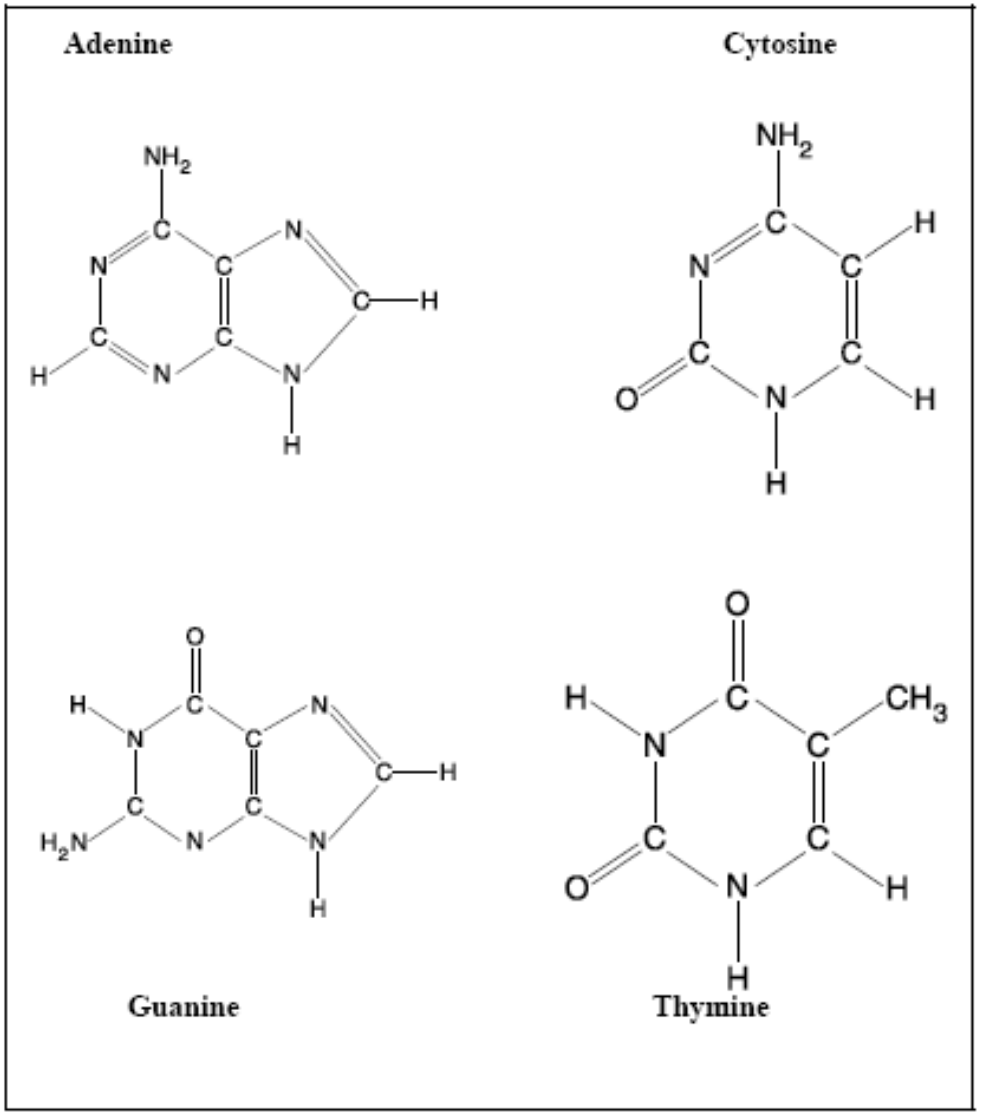
Important Cell Sites



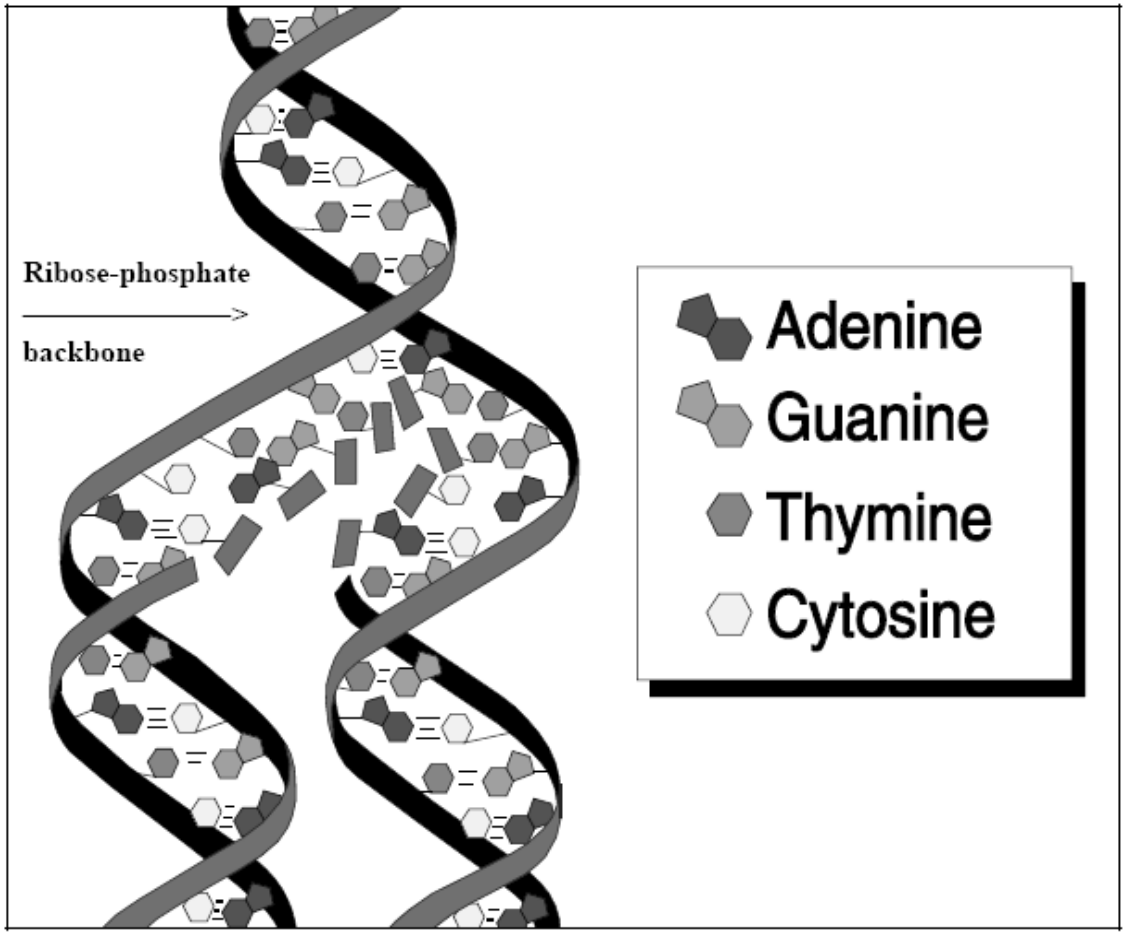
Cell Basics


Cell membrane
Ribosome
Cytoplasm
Nucleus
Nuclear membrane
Homologous chromosome pair

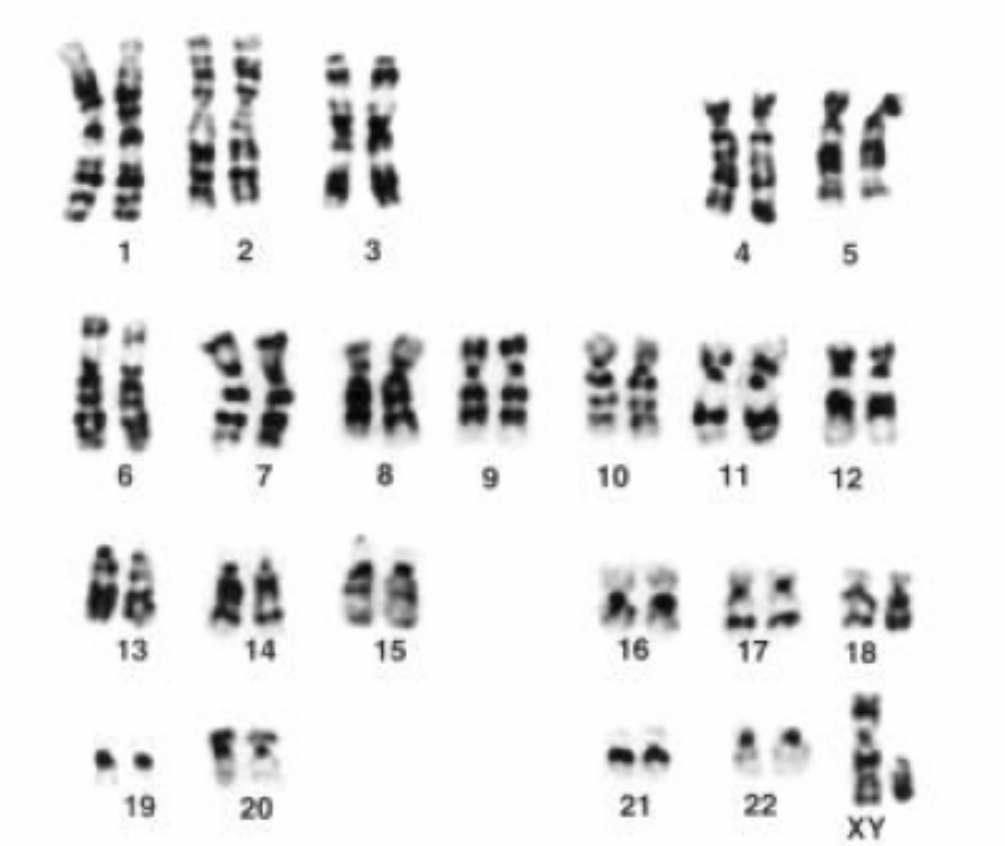
Nucleic Acids



DNA Structure



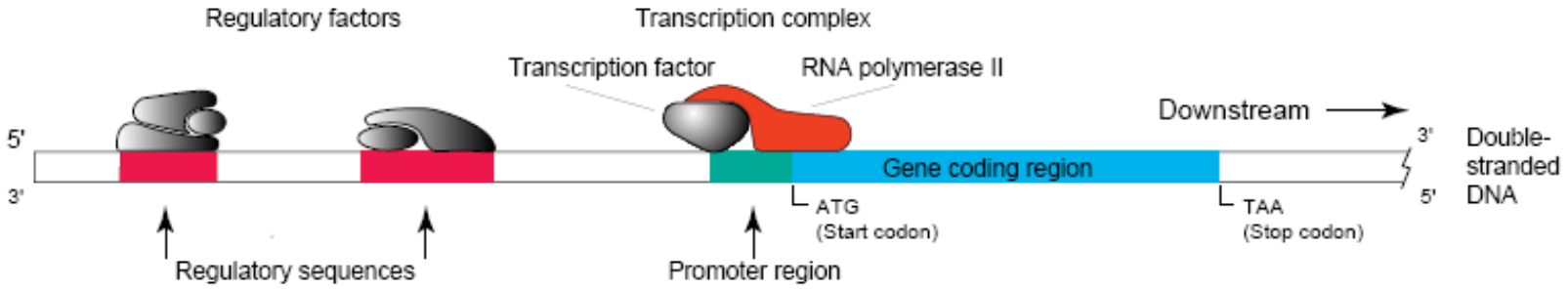
Human Chromosomes



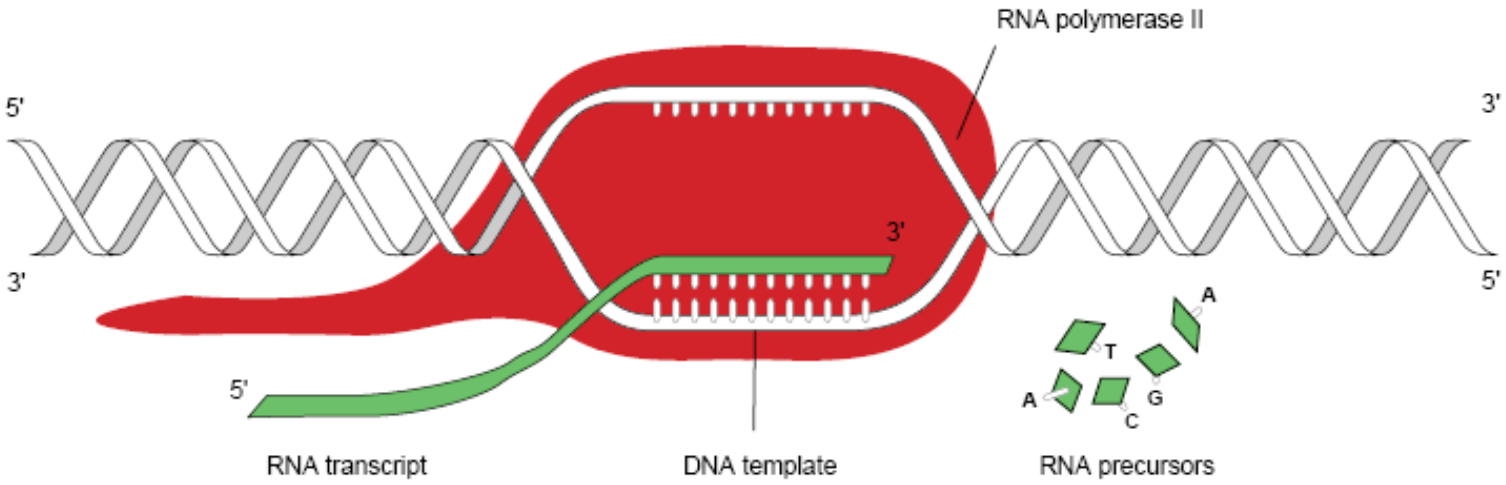
Damage to DNA

- Altered functional group of Purine or Pyrimidene.
- Loss of Purine or Pyrimidine
- Free radical transfer causing the loss of base and chain breakage.
- Single strand breakage
- Double strand breakage

DNA Transcription



RNA Transcription



mRNA Translation to Protein

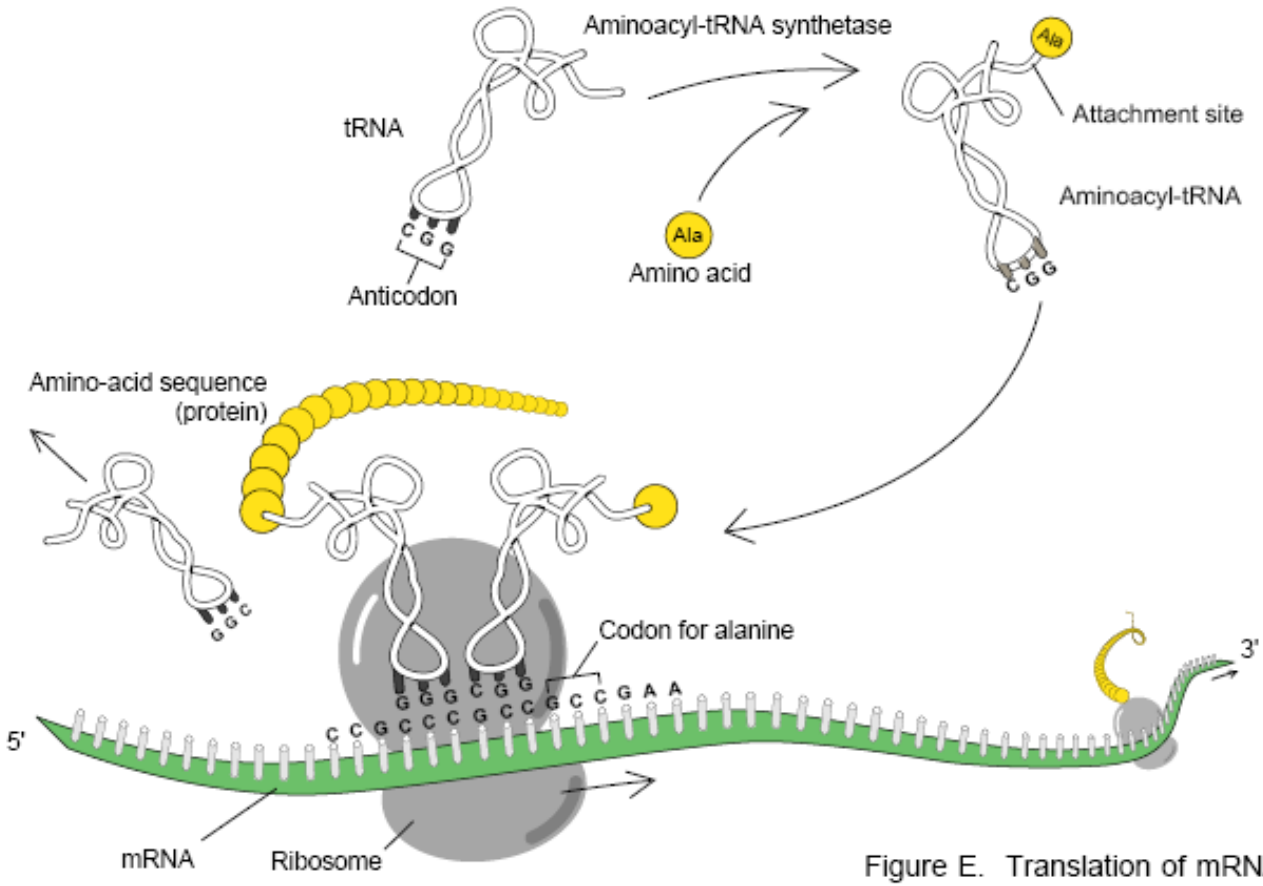
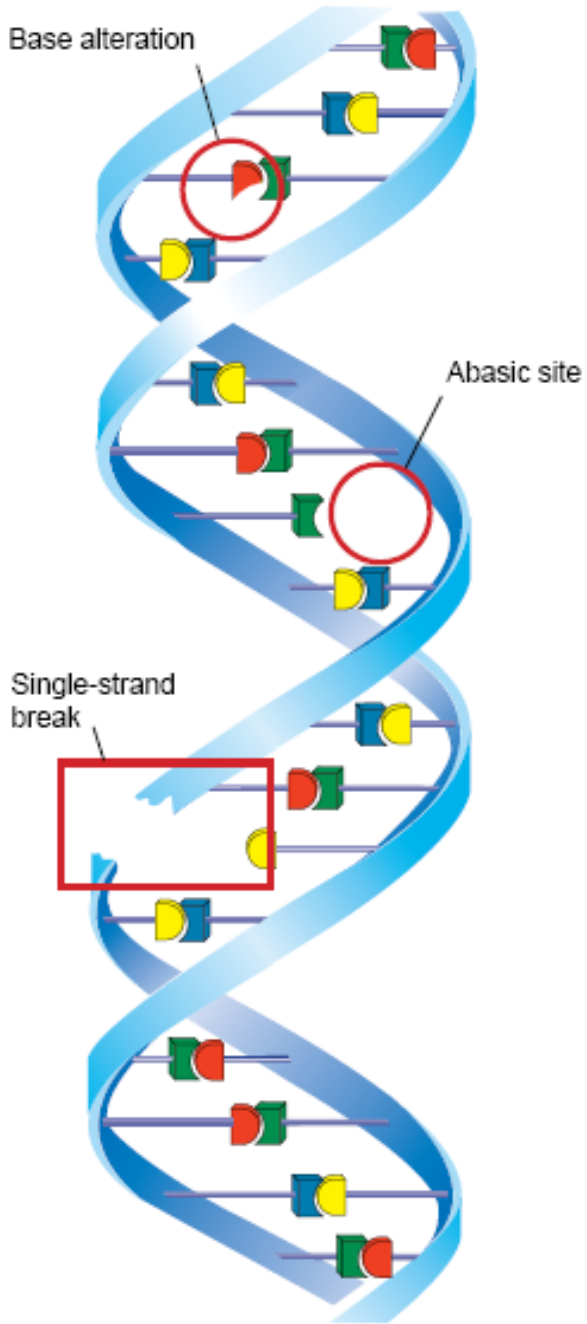
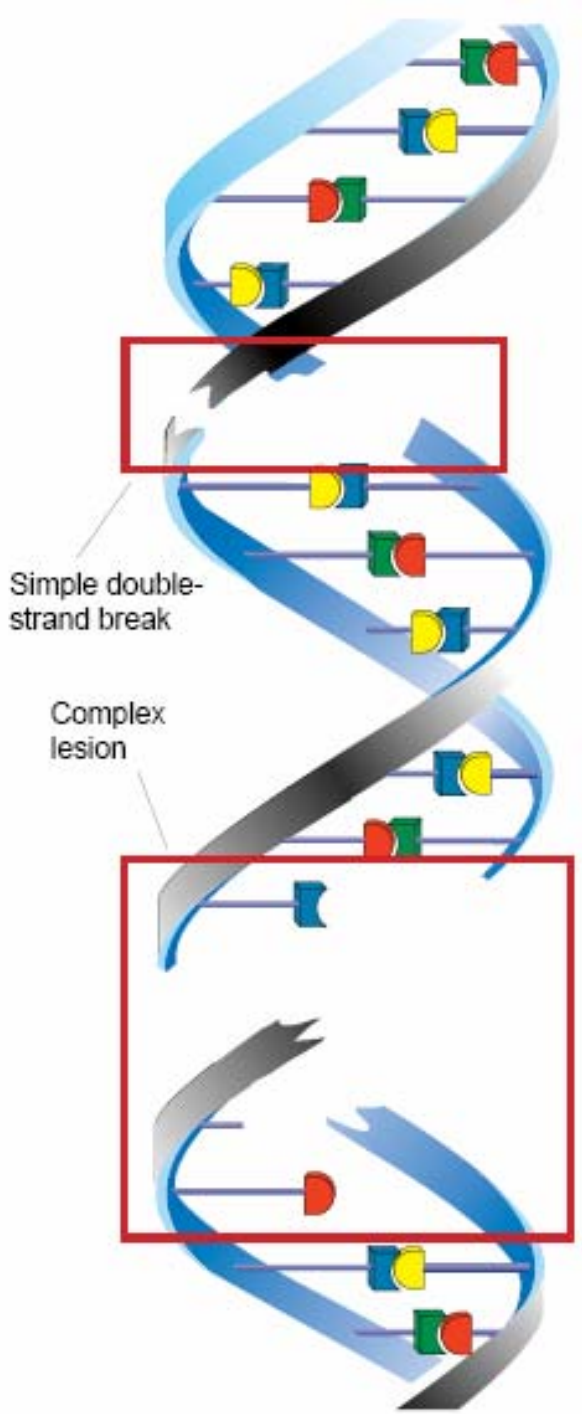


Figure E. Translation of mRNA to Protein

DNA Damage



Major Damage to DNA



Effects on Macromolecule

- Carbohydrates undergo degradation
- Lipids experience oxidation by chain reaction.
- Proteins suffer breakage of hydrogen bonds which can result in change in primary and secondary structure. This also causes loss of function.
- Nucleic acids have change/loss of a base, single strand breaks and double strand breaks,

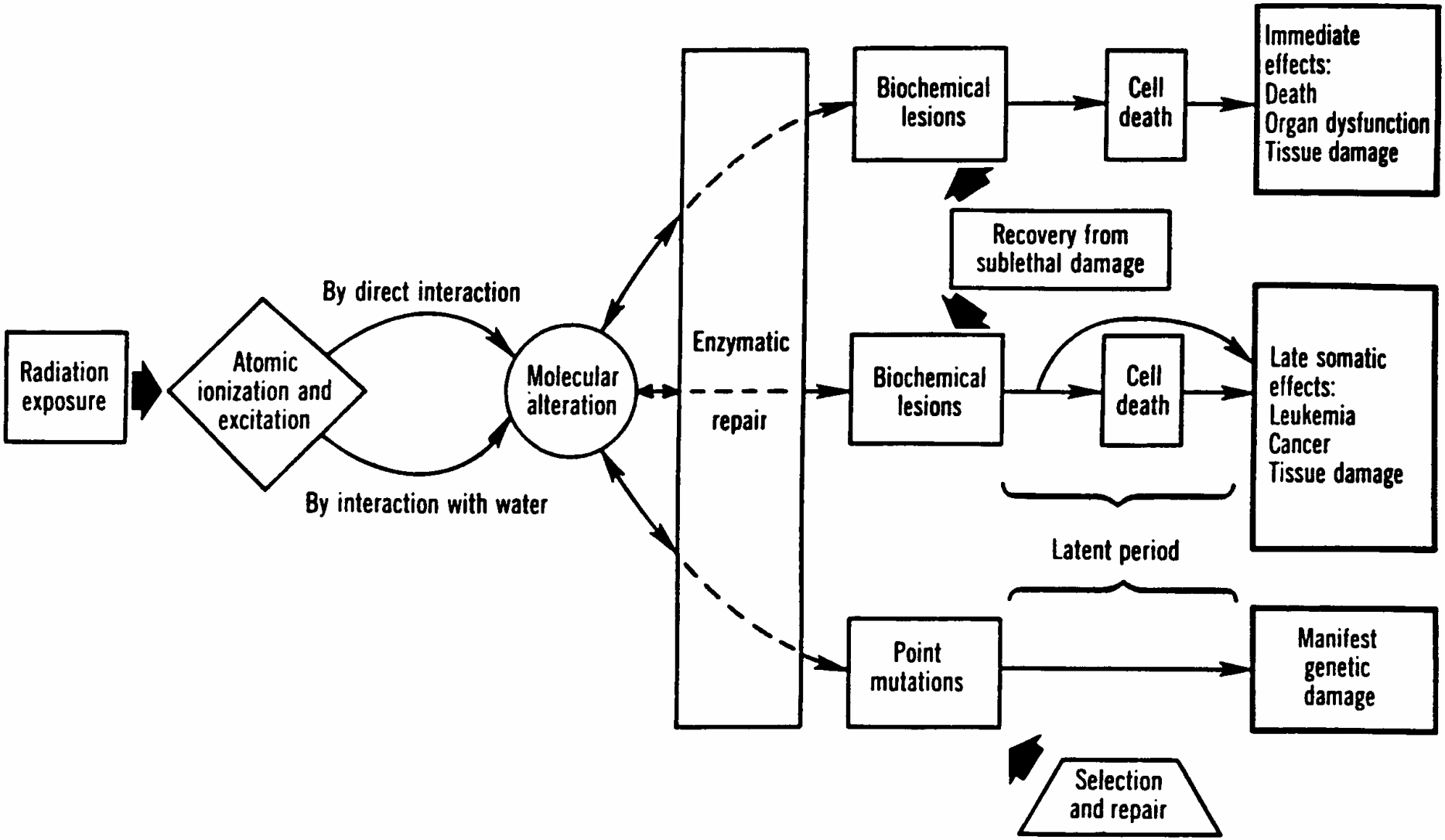

Radiation exposure
Atomic ionization and excitation
By direct interaction
By interaction with water
Molecular alteration
Enzymatic repair
Biochemical lesions
Cell death
Immediate effects:
Death
Organ dysfunction
Tissue damage
Recovery from sublethal damage
Biochemical lesions
Cell death
Late somatic effects:
Leukemia
Cancer
Tissue damage
Latent period
Point mutations
Manifest genetic damage
Selection and repair

Table 4-1. Some of the types of mammalian radiobiological damage	
Level of biological organization	**Important radiation effects**
Molecular	Damage to enzymes, DNA, RNA, and biologically important molecules
Subcellular	Damage to cell membranes, nucleus, chromosomes, mitochondria, and lysosomes
Cellular	Inhibition of cell division; cell death
Tissue; organ	Disruption of central nervous system, hemopoietic system, epidermis, induction of cancer
Whole animal	Death; "radiation life shortening"
Populations of animals	Changes in genetic characteristics due to gene mutations in individuals
Based on Table 1.4 in J. E. Coggle's, Biological Effects of Radiation, (Wykeham Publications, London 1977).	