Remarkably, the error rate, at least in eucaryotic cells, is only 1 per 10^9 nucleotide base pairs. See pages 238 - 254 of MBoC4 for the details.

The error rate in RNA synthesis and in the translation of RNA into protein is 1 part in 10^4. So RNA viruses, like HIV and flu, mutate rapidly.

UV radiation can cause mutations because a single ultraviolet photon has an energy $h\nu = h\frac{c}{\lambda}$

in which $c = 3 \times 10^8$ m/s and $h = 6.6 \times 10^{-34}$ Js is Planck's constant.

UV radiation has $\lambda < 400$ nm.

So a UV photon has energy

$$E = h\nu = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}\ \text{J m}}{\lambda}$$

$$= 2\times10^{-25}\ \frac{\text{J m}}{\lambda}$$

If $\lambda = 400\ \text{nm} = 400\times10^{-9}\ \text{m} = 4\times10^{-7}\ \text{m}$,

then

$$E_{400} = \frac{2\times10^{-25}\ \text{J m}}{4\times10^{-7}\ \text{m}} = \frac{1}{2}\times10^{-18}\ \text{J}$$

$$= 5\times10^{-19}\ \text{J}$$

$$= 5\times10^{-19}\ \text{J}\times\left(\frac{1\ \text{eV}}{1.6\times10^{-19}\ \text{J}}\right)$$

$$= \frac{5}{1.6}\ \text{eV} = 3.1\ \text{eV}$$

which is not quite enough to break

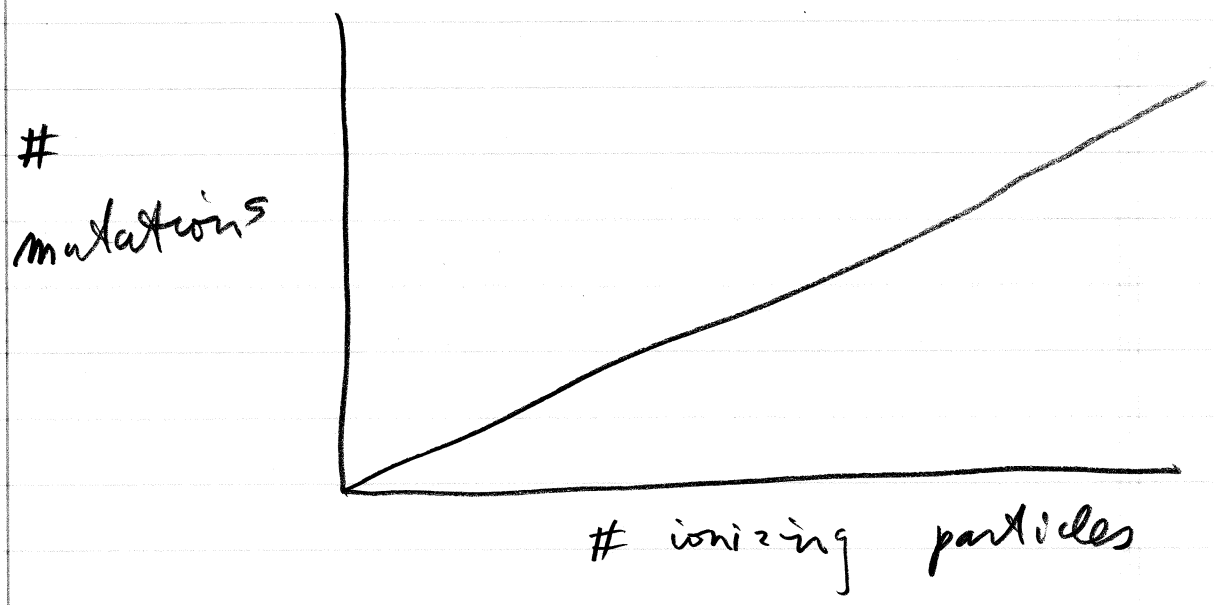
most covalent bonds. But a photon with $\lambda = 40$ nm has 10 times as much energy or

$E_{40} = 31$ eV

which can break any covalent bond I know of.

A charged particle such as an electron or a proton moving at a high speed can also break a covalent bond. Fast charged particles often knock electrons out of molecules and so are called "ionizing radiation." About 10 eV is the lower limit for ionizing radiation.

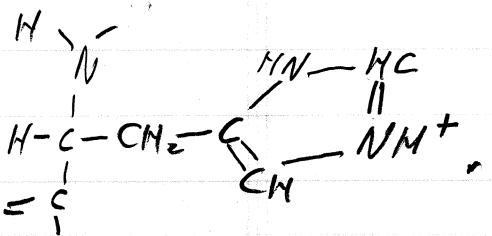
Because a single particle of more than 10 eV or so can break a covalent bond, the mutation rate is linear with the dosage



Healthy cells often can repair the mutations induced by UV radiation. Amazingly, molecular devices inside cells use the energy of UV photons to power their repair of DNA that has been damaged by other UV photons!

A diploid cell has two copies of most of its genes. When these alleles are identical, the cell is a homozygote. When the alleles differ, the cell is a heterozygote.

Some mutations are silent. For instance, because the genetic code uses 64 triplets of bases to code for 20 amino acids and for the start and stop codons, many mutated triplets code for the same amino acids. For example, AGA, AGG, CGA, CGC, CGG, and CGU all code for the amino acid arginine



Some mutations are lethal.

Some are effective but innocent.

Some cause diseases. As cells and animals evolved, each mutation that cause diseases became rare or necessive. An animal that has one healthy copy of a gene (<u>wild type</u>) and one necessive, disease-causing copy of the gene, will be healthy. But if two such animals breed, some of their offspring will be homozygous in the necessive gene and so will be sick. This is why it's illegal to marry brothers with sisters.

It is possible and legal to interbreed mice, however, and some companies have produced strains of mice that have nearly identical genomes. As long as their common genome lacks disease-causing genes, these mice are healthy — until they are consumed in experiments.

Because of epigenetic and environmental factors, purebred mice are not identical. But the descendants of any two pairs of mice will display the same distribution of phenotypical properties — heights, colors, weights, etc.