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EFFECT OF RF RADIATION ON DNA

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Abstract

Problem statement: Ionizing radiation is all around us, and it has been this way since the creation of the Earth. As such, life on Earth has evolved in an environment exposed to ionizing radiation, and has adapted to be able to thrive in its presence. It comes from space (cosmic radiation), the ground (terrestrial radiation), from air, water, and even food. We are also exposed to human-made sources of ionizing radiation such as medical x-rays and CT (computed tomography) scans. When normal repair processes fail, and when cellular apoptosis does not occur, the DNA may be irreparably damaged. Cells with damaged DNA that survive and reproduce can lead to cancer, and failure to correct damage in cells that form gametes (reproductive cells) can result in mutations being passed on to off spring When cells are exposed to ionizing radiation, damage can occur either by direct action or indirect action.

Keywords: Direct damage, Indirect damage, Mutation, Radiation, Sterilization

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INTRODUCTION

DNA damage occurs due to the ionisation of molecules as they interact with radiation. The direct effect of radiation is due to the primary radiation beam interacting with the target molecule, in this case DNA. The indirect effect relies on the secondary radiation generated by the primary radiation to deposit the damage. The ratio of direct to indirect effect varies with different radiation qualities. Alpha particles have a large direct effect whereas photons are more reliant on the generation of secondary electrons and radical ions. The damage caused by ionising radiation includes:

- Damage to bases, repaired through base excision repair. Some base damage is repaired through nucleotide excision repair.
- Single strand breaks, repaired through single strand break repair
- Double strand breaks, repaired through homologous recombination or non-homologous end joining

If radiation interacts with the atoms of the DNA molecule, or some other cellular component critical to the survival of the cell, it is referred to as a direct effect. Such an interaction may affect the ability of the cell to reproduce and, thus, survive. If enough atoms are affected such that the chromosomes do not replicate properly, or if there is significant alteration in the information carried by the DNA molecule, then the cell may be destroyed by “direct” interference with its life-sustaining system.

If a cell is exposed to radiation, the probability of the radiation interacting with the DNA molecule is very small since these critical components make up such a small part of the cell. However, each cell, just as is the case for the human body, is mostly water. Therefore, there is a much higher probability of radiation interacting with the water that makes up most of the cell’s volume. When radiation interacts with water, it may break the bonds that hold the water molecule together, producing fragments such as hydrogen (H) and hydroxyls (OH). These fragments may recombine or may interact with other fragments or ions to form compounds, such as water, which would not harm the cell. However, they could combine to form toxic substances, such as hydrogen peroxide (H_2O_2), which can contribute to the destruction of the cell.

Radiation damage of living cell

High frequency radiation or fast moving particles plow into a living cell with enough energy to knock electrons free from molecules that make up the cell. These molecules with missing electrons are called ions. The presence of these ions disrupts the normal functioning of the cell. The most severe damage to the cell results when the DNA (deoxyribonucleic acid) is injured. DNA is at the heart of the cell and contains all the instructions for producing new cells. The DNA is a complex molecule formed of two long strands that are twisted around each other and linked by chemical subunits. There are two major ways that radiation injures the DNA inside your cells.

1) The water in your body tends to absorb a large portion of the radiation and becomes ionized. When water is ionized it readily forms highly reactive molecules called free radicals. These free radicals can react with and damage the DNA molecule.

2) Alternatively radiation can collide with the DNA molecule, itself, ionizing and damaging it directly. Symptoms of radiation sickness: severe burns that are slow to heal, sterilization, cancer, and other damage to organs. High doses are rapidly (within days or weeks) fatal. Mutations or changes in the DNA can be passed along to off springs. Mutations are generally for the worse. Depending upon the type and severity of the damage caused to the DNA by the radiation, the cell might (or might not!) be able to repair itself as included in Fig. 1.

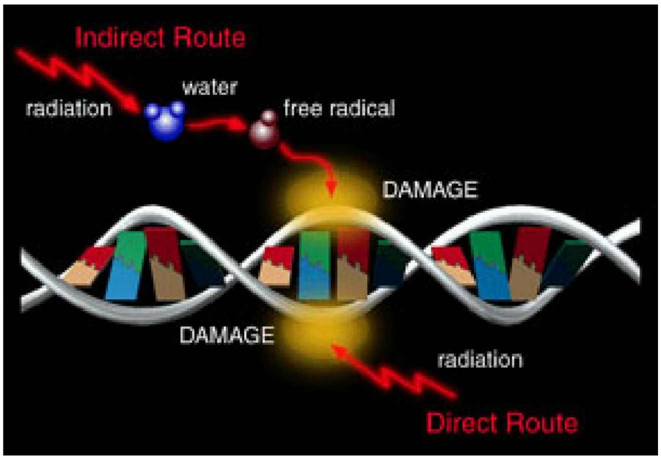

Fig. 1. Damage on DNA cells

There are two main ways of radiation that can damage the DNA inside cells. Radiations can strike the DNA molecules directly, ionizing & damaging it. Alternately, radiation can ionize water molecules, producing free radicals that react with damaged DNA molecules. The UV-photon is directly absorbed by the DNA (left). One of the possible reactions from the excited state is the formation of a thymine-thymine cyclobutane dimer (right). The direct DNA damage leads to sunburn, causing an increase in melanin production, thereby leading to a long-lasting.

DNA damages

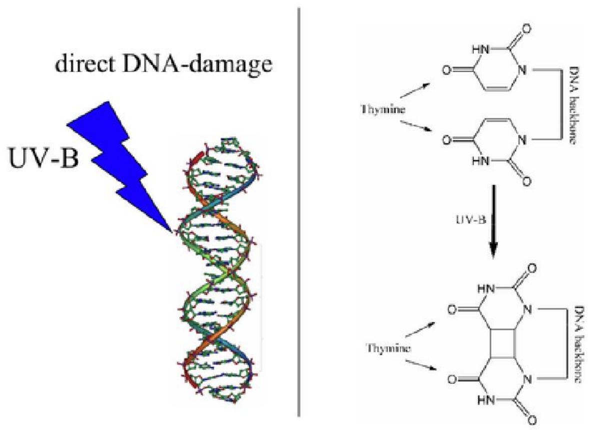

Fig. 2. Direct DNA damage

It can occur when DNA directly absorbs a UVB photon, or for numerous other reasons. UVB light causes thymine base pairs next to each other in genetic sequences to bond together into pyrimidine dimers, a disruption in the strand, which reproductive enzymes cannot copy. It causes sunburn and it triggers the production of melanin. Due to the excellent photochemical properties of DNA, this nature-made molecule is damaged by only a tiny fraction of the absorbed photons. DNA transforms more than 99.9% of the photons into harmless heat (but the damage from the remaining < 0.1% is still enough to cause sunburn). The transformation of excitation energy into harmless heat occurs via a photochemical process called internal conversion. In DNA, this internal conversion is extremely fast, and therefore efficient. This ultrafast (sub pic second) internal conversion is a powerful photoprotection provided by single nucleotides. However, the Ground-State Recovery is much slower (picoseconds) in G·C−DNA duplexes and hairpins. It is presumed to be even slower for double-stranded DNA in conditions of the nucleus. The absorption spectrum of DNA shows a strong absorption for UVB radiation and a much lower absorption for UVA radiation.

Since the action spectrum of sunburn is indistinguishable from the absorption spectrum of DNA, it is generally accepted that the direct DNA damages are the cause of sunburn. (Maes *et al.,* 1997) While the human body reacts to direct DNA damages with a painful warning signal, no such warning signal is generated from indirect DNA damage (Malyapa *et al.,* 1997). The chromophore absorbs UV-light (*denotes an excited state), and the energy of the excited state is creating singlet oxygen ($^1O_2$) or a hydroxyl radical (•OH), which then damages DNA through oxidation. Indirect DNA damage occurs when a UV-photon is absorbed in the human skin by a chromophore that does not have the ability to convert the energy into harmless heat very quickly. Molecules that do not have this ability have a long-lived excited state. This long lifetime leads to a high probability for reactions with other molecules - so-called bimolecular reactions. Melaninand DNA have extremely short excited state lifetimes in the range of a few femto seconds (10^{-15}s).

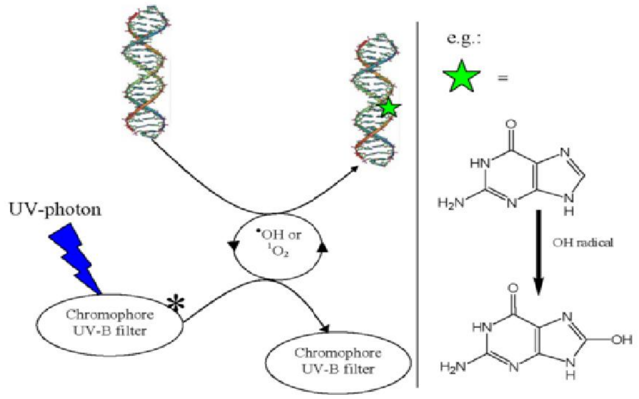

Fig. 3. Indirect DNA damage

The excited state lifetime of these substances is 1,000 to 1,000,000 times longer than the lifetime of melanin, and therefore they may cause damage to living cells that come in contact with them. The molecule that originally absorbs the UV-photon is called a "chromophore". Bimolecular reactions can occur either between the excited chromophore and DNA or between the excited chromophore and another species, to produce free radicals and Reactive Oxygen Species. These reactive chemical species can reach DNA by diffusion and the bimolecular reaction damages the DNA (oxidative stress). It is important to note that indirect DNA damage does not result in any warning signal or pain in the human body (Malyapa *et al.,* 1997).

$(\text{chromophore})^* + {}^3O_2 = \text{chromophore} + {}^1O_2$

Conclusion

Although electronic devices and the development in communications makes the life easier, it may also involve negative effects. These negative effects are particularly important in the electromagnetic fields in the Radio frequency (RF) zone which are used in communications, radio and television broadcasting, cellular networks and indoor wireless systems. Along with the widespread use of technological products in daily life, the biological effects of electromagnetic waves have begun to be more widely discussed. The general opinion is that there is no direct evidence of hazardous effects on human health incurred by low-frequency radiofrequency waves. Studies at the cellular level, which uses relatively higher frequencies, demonstrate undesirable effects. In recent years there are a lot Electromagnetic Waves and Human Health of studies about effects of EMF on cellular leve l; DNA, RNA molecules, some proteins, and hormones, intracellular free radicals, and ions are shown.

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