The Effects of Non-Ionizing Radiation on Biological Systems and the Role of Hemoglobin

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Dedication:

To all those who are suffering and don't know why.

Readership

This paper is intended for readers who are non-expert in science, but also contains sections for those with a deeper knowledge of chemistry, physics and medicine. Depending upon the level of understanding of each reader, he or she may find some sections more comprehensible than others. I make no apology for this. Scientists expecting a top-level concise exposition may be disappointed; this is a result of my efforts to broaden the readership. Some readers may find the text to be unduly wordy. Indeed, I have deliberately repeated some parts of this study - in different ways and contexts. All content is intentional - a decision made in view of the gravity of the message.

The Message

The absorption of non-ionizing radiation by living organisms causes disruption to some physiological functions and genetic damage to cells.

What Does This Mean?

It means that I believe humanity is exposing itself to increased rates of cancer, as well as a number of other sub-clinical but debilitating illnesses. As yet it has not proved possible to convince authorities that action is necessary.

Humanity is sitting on another time bomb of its own making yet seems unable to do anything about it. At least climate change has now become recognised and is being tackled. However the risks to our health by our dependence upon electromagnetic radiation are significant and worsening.

My Motivation

I have no association with any commercial interest in this technology. I am a retired private individual - just another one of a million lone voices crying in the wilderness and without the backing of a heavyweight academic institution. However, unlike many of my fellow complainants, by a strange quirk of fate I do have a good working knowledge and understanding of the theories I am proposing in this work. My fears have been growing over many years since I first heard about leukemias and brain tumours in children living underneath overhead power lines. I thought then that it was a very strange phenomena and was disturbed by the apparent ease with which citizens' concerns were dismissed. I have carried these concerns with me over the decades since, but a recent change to my personal circumstances has caused me to focus my full attention on the issues at stake.

Fact

Non-Ionizing radiation can change the dispositions of electrons within the molecules that make up the human body. Since all chemical reactions result from the electron dispositions in molecules it follows that a proportion of the reactions that occur under the influence of non-ionizing radiation are abnormal and harmful to health. Even if that proportion is statistically very small, it can have a significant effect upon large populations over extended periods.

Summary

Cancer is an uncontrolled abnormal division of cells in a part of the body. Since our entire body is composed of cells, cancer can occur wherever there are cells. The biological growth of cells becomes

uncontrolled because certain parts of the DNA molecule that normally are in control malfunction due to a process called mutation. Changes to the DNA in a human could occur at any time during a life-cycle. It is also possible for faulty DNA to be passed on to a child from one of its parents.

Imagine a robot making specific parts on a car production line. If the robot acquires an error in its programming it could well produce far more of those parts than the production line can deal with. This would cause a severe problem in the manufacturing process for the car. If it went unchecked it could ultimately cause closure of the factory. When DNA coding becomes damaged the result creates a malfunction in the biological process under control and must be repaired if the organism is to survive. Unfortunately we have not been able to repair faulty DNA until recently and medical procedures have concentrated on removal of the unwanted (malignant) cells, i.e. a tumour. Such a treatment is not a cure because the faulty DNA may still be present in nearby cells and the cancer could simply regrow. If the faulty DNA in the cells adjacent can be destroyed, perhaps by radiotherapy or chemotherapy, then we might have a cure. But this is not always possible: in theory, a residue of even one cell with a faulty DNA molecule could result in regrowth of the tumour. In coming decades new processes under the heading of gene therapy will be developed for the repair of faulty DNA. That's great; but what about cancer prevention? None of these arguments or facts provide any evidence about how the DNA originally became damaged. A very great amount of effort is expended today in the diagnosis and treatment of cancer. However, we are making little progress in some areas, especially in the mechanisms that cause it - generally summarised as DNA damage, a process generally called mutation.

It is my opinion that scientists have so far failed to properly recognise the distinction between ionizing radiation and non-ionizing radiation in terms of their chemical effects. Physicists have generally prevailed in the arguments over the causes of cancer because of their deep understanding of the biological damage caused by ionizing radiation, especially in the field of nuclear physics. Our successes in the understanding of nuclear processes, especially applied to medicine, has given us a gross level of overconfidence that we understand all aspects. Health physicists (and government officials acting on their advice) have generally dismissed arguments about biological damage caused by non-ionizing radiation because they have far less understanding of the **chemical** processes involved. The obsession of health physicists that biological damage is only caused by ionizing radiation and that non-ionizing radiation is harmless has led to the serious exposure of humans over many decades and many unnecessary cancer deaths. As we proceed to expand our dependence on technical devices that work by means of Wi-Fi and other electromagnetic radiation (that is non-ionizing), and especially as we bring radiating devices closer to our brains, so we can expect a continuing rise in the incidence of cancer, as well as (I believe) other forms of non-lethal illnesses of the nervous system.

In a society where scientific research depends upon funding from public and commercial sources, it is clear that when a research project does not occupy a place in the mainstream of public interest then it will not be funded. Scientific research into the effects of non-ionizing radiation on human health would have a very significant deleterious impact on society because of our extreme dependence upon technological devices that emit non-ionizing electromagnetic radiation. The effect over decades has been that a failure to recognise a serious risk to human health has been perpetuated. Technology companies who have a vested interest in denial of the health effects of non-ionizing radiation have funded many projects with the aim of disproving the harm caused by it. This is strongly reminiscent of the efforts expended by the tobacco companies in their denial of the harmful effects of smoking. The tide of opinion against acceptance of the harmful effects of non-ionizing radiation has so far proven to be largely insuperable, despite considerable public alarm, regularly expressed.[1]

So why have these harmful effects not been clearly recognised before? There is no doubt that the effect is very small and it is extremely difficult to design satisfactory experiments which give conclusive results. The following pages will make clear the difficulties involved and the many ways in which the harmful mechanisms have clouded analyses of these experiments. In theory, it requires only one DNA molecule to 'go rogue' and then the supreme effectiveness of the human organism ensures the efficient replication of the rogue molecule leading on to the development of tumours, unless it is stopped by one of the body's natural robust self-repair mechanisms. So the extreme inefficiency with which the initial trigger occurs means that the incidence of cancer can be small at first. This is why the statistics have been so easily misinterpreted or disguised and the harmful effects of non-ionizing radiation have not been recognised by authoritative science. There are many obvious parallels with the perceived perils of smoking in society and the denials of the tobacco industry over many decades. However in the case of smoking it is a simple matter for citizens to stop smoking; it is very difficult for citizens to reduce their exposure to non-ionizing radiation; if anything, we are increasing our exposures, not decreasing them. Governments and the wider science community are in denial of the risks as we continue to increase our dose. The effects of non-ionizing radiation on human tissue may be extremely small, but they are proving to have a big impact on society at large and it is a truism to say that even one cancer caused by this mechanism has a devastating impact on an individual and her family.

Like most other humans, I own a cellphone. On two separate occasions, after I have routinely carried my phone in my left trouser pocket, my leg has developed an unpleasant sensation that continues for several weeks. When I first felt the sensation, it was as if the phone in my pocket was ringing in vibration mode. I immediately went to answer my phone and realised that it was not in my pocket - I was not carrying it at all. After much thought I concluded that the muscle in my leg had somehow been sensitized by exposure to the radiation from my phone to which it is in close proximity when in my pocket.

After the first time this happened I resolved not to carry the phone in my pocket, and the sensation eventually went away. However, a year or so later, I started to carry the phone in the same place and the sensation began again.

A scientist might declare a coincidence after the first event and say there is no causal link. However, after the repeat exposure, a coincidence seems less likely. I immediately began telling my friends not to carry their cellphones in their shirt breast-pockets where it would be close their hearts.

Aim

I wish to consider the ways in which exposure to non-ionizing radiation can increase the risk of harmful chemical reactions that may result in:

(1) increased numbers of genetic mutations that, in turn, lead on to cell malfunction and cancer;

(2) damage to nervous systems that may or may not lead on to cancer.

I shall deal with the possible sources of this radiation and the increased risk to which, I believe, most humans are exposed. I shall also present a mechanism of my own invention.

My Experience in the Science of Non-Ionizing Radiation

In 1976, I was awarded a PhD from the University of Leicester.[2] The science I had spent four years studying involved the exposure of chemical substances to non-ionizing radiation and the observation of the ensuing chemistry. This comes under the general heading of photochemistry. The non-specialist reader might deduce that the research involved exposure to light **(that is not ionizing)**, and this is correct. In this context it would be more accurately called the Chemistry of Excited States. The term “Excited States” refers to molecules that have in some way absorbed energy - **they are not ionized**. Light is a very small part of what is called the electromagnetic spectrum (see below). For the lay reader, it is necessary to provide some basic science to move forward and some readers might care to omit some of the sections that follow.

In this work I shall use my own doctoral work to present my thesis that non-ionizing radiation is the source of many cancers and other deleterious health effects, and that the primary mechanism involves absorption of the energy of that radiation by the hemoglobin species, in most cases with the associated presence of oxygen.

Notes

1 The latest is a carefully constructed video focussed on the dangers of cellphones. Mobilize | Cell Phones & Cancer Documentary. https://youtube.com/watch?v=dhlWdHLmfTo&feature=share

2 Trethewey, Kenneth R.: Some Excited State Charge Transfer Interactions, PhD Thesis, University of Leicester (1976). Thesis available on-line from the following:

https://leicester.figshare.com/articles/thesis/Some_excited_state_charge-transfer_interactions_/10126193/1

https://ethos.bl.uk/OrderDetails.do?did=3&uin=uk.bl.ethos.475505

http://hdl.handle.net/2381/33958

Cancer

When The Circumstantial Evidence Is Too Great To Ignore

This section is my own theory. It contains little hard science and few references for ease of reading. The detailed proposal is developed in more detail in the many pages that follow. Circumstantial evidence is never accepted in a court of law and my theory that electromagnetic radiation (EMR) causes deleterious health effects is based upon my own understanding of the way the world works, backed up with some of my own experimental measurements. There are many who will consider these words to define me as a conspiracy theorist - someone to be hated and berated. I present my case here and ask my readers to decide for themselves.

The incidence of cancer is on the increase. However, there are no clear reasons why. Government health authorities say it is because we are all living longer but this is a half-truth.

Cancer could affect every human but some of us are more susceptible to it than others. The complete analysis lies in our DNA. We are now familiar with the word mutation in the context of a virus that can alter its structure to become more dangerous (They can also become more harmless, but it is only the more dangerous ones that survive.) Cancers occur when the DNA of a cell suffers a mutation and cell growth runs out of control. This paper is about what causes these mutations.

Curiously, the incidence of cancer is generally higher in countries where there is more technological development, although the data is skewed where lung and other cancers directly attributed to active or passive contact with tobacco occur in countries where there is less technological development. Some people attribute cancers to certain foods, but diets across the world vary considerably and there is no large-scale correlation of food with incidence of cancer.

I believe the reason for the general trend of increasing incidence of cancers is because of the proliferation, use of and, indeed, dependence on electronic equipment of all types. In the early 20th century our exposure was limited to EMR from first radio and then TV transmitters, but with the arrival of the mobile phone, computers and home networks our exposures have increased greatly. Now we have the imminent deployment of 5G and the electric vehicle, both of which will pose much greater risks to our health in coming years and, I believe, increased likelihood of cancer. As well as cancer there are other deleterious health problems that seem to be more common than ever - dementia, for example. Some of the causes are now being identified, but my theory predicts that EMR can also be to blame. Fibromyalgia is another illness that perplexes the medical profession and is often unfairly attributed to mental issues.

The question is - What is causing all this? Here's my answer.

With each passing year, the human body is exposed to ever greater amounts of electromagnetic radiation - not the nuclear type, but non-ionizing radiation (NIR) from all things that use electricity. It may surprise some readers to know that our bodies work on electricity - tiny signals of electrical charge are constantly pulsing around our bodies through our nerves under the control of our brains. EMR involves both electrical and magnetic effects and we must expect that if we come under the influence of electromagnetic fields from external sources then there must surely be effects of some kind? I am going to look in detail at these effects in the rest of this paper.

If this is true, what would we expect to happen?

The biggest cancer in men is prostate cancer and it is increasing. It could be because of the amount of time a man's phone spends in his trouser pocket, a position no more than 20 cm from the prostate and testicles. In a woman, a phone kept in this position would put her at risk of ovarian cancer. Perhaps the prostate has, for some reason, a particular sensitivity to NIR. Testicular cancer is another risk that statistics might indicate is marginally smaller, but is devastating to those young men who are diagnosed with it. (There is also a curious and unexplained increase in male infertility at present.)

In women the biggest cause of cancer is breast cancer. Here the breasts are significant masses of soft tissue that act like sponges soaking up the radiation. Breasts are complex structures with many elements that could be affected by radiation but it is clear that they have a great susceptibility to radiation-induced cancer especially because of tiny blood vessels close to the skin. The subject is rendered even more complex by inherited DNA effects.

Some of the exposure is from the great and increasing amount of radiation in the atmosphere around us. Most of the rest comes from devices in the home and especially when they are close to our bodies.

In this regard we could expect people with large body mass to be more susceptible to cancer than small people hence the frequent claim that "obesity can cause cancer" I believe has a foundation.

Curiously the numbers of gliomas (brain tumours) are also increasing but are still only about 3% of all cancers.[1] Surely the large mass of the brain would act strongly to absorb radiation? Well, no, because the brain has a very effective bone helmet covering most of it. We note the poor protection at the ear, hence the risk from holding a phone to your ear for long periods.

In children, who have much thinner skulls, we expect to find more brain tumours and this is the case.

In those cases where brain tumours develop quickly I am confident that unusually powerful radiation emitters can be implicated. The well known cases of child leukemias and brain tumours caused by sleeping beneath power lines is still not accepted by the establishment. At particular risk of brain tumours are people who live close to mains transformers in local neighbourhoods.

Lung cancer has often been ascribed to smoking and I am sure this is partly true. However, as smoking decreases in Society we would expect lung cancer rates to be in decline. In the European culture, they are not. In the lungs there is molecular contact where oxygen is transferred to hemoglobin. It seems a likely place for reactive species to initiate cancer.

So how does radiation cause these cancers?

The answer is Blood. Cancer can occur anywhere in the body and there is blood everywhere too.

Radiation is absorbed by hemoglobin and this makes a new species that is much more reactive. It is these new reactive species that make the mutations of DNA in appropriate cells where the end result is a cancer. Lymphoma and leukemia are cancers of the blood. This is when the reactive hemoglobin species do their worst to the blood and lymph cells in these systems.

Blood is about 0.1 mm beneath the skin and therefore the entire body is able to absorb radiation. (Clothes provide no protection against NIR.)

The kind of cancer that develops depends upon where the reactive species are formed in the body. Close contact with the radiation source is important, but when the sources have high power, as many transmissions now do, the effects are felt at greater distances. One of the few effective methods of protection available to us is to get as far away from the sources as possible. The concerns about mobile phones which spend so much time close to our bodies cannot be over-emphasised.

5G technology represents a shift to higher energy transmissions and the transmitters will be far more numerous and much closer to humans than they are now. Plans are afoot to transmit everything currently available by fibre optic broadband, removing the need for these safer cables. The Internet Of Things is already with us and 5G will become the mainstay of this new industry controlling a plethora of new internet-connected devices in our homes. The amount of radiation in the atmosphere will increase enormously. If it still arrives via our domestic broadband, we will have much more powerful home routers that bathe us in strong radiation inside our homes. Fortunately, the frequencies of 5G do not penetrate the walls of our houses as well as the older 4G technologies but this will be compensated for by the telecoms companies persuading us to accept more powerful routers inside our homes. The tendency in households is already to have more powerful or more numerous routers. My prediction is that those of us who choose to wear spectacles powered by 5G wireless signals or spend much time enjoying virtual reality headsets powered by the same means, can expect to have a high risk of brain tumour and/or dementia.

So far there has been no discussion of the health effects of driving electric vehicles. I predict a surge of cancers from the radiation emitted by these high power systems. To achieve the speeds and accelerations we expect it is necessary to generate large currents and voltages. I believe this will result in the driver and passengers being exposed to high doses of non-ionizing radiation.

Why does all this continue to evade awareness amongst our politicians? There is no doubt that the combination of chemistry, physics and biology pose a problem to those without the necessary interdisciplinary skills. The difficulties of carrying out appropriate experiments that satisfactorily replicate the kinds of exposure in humans are immense and have certainly led to false results on both sides of the argument. Other reasons will be discussed below, but the presence of the dark shadow of commercial interest is unhelpful and parallels the resistance of the tobacco industry to the acceptance of responsibility for a very large number of deaths in the past.

The Process of Cancer

Cell + Trigger = Mutation

Repetition X times - mitigation and repair = Tumour

Trigger? BLOOD + NIR (NIR= non-ionizing radiation)

Some Observations

An unidentifiable excited state blood species results from the interaction of hemoglobin (Hb) and NIR. Let's call it HbX. HbX has a finite lifetime, as yet not known. The longer the lifetime, the bigger the distance over which it could react.

Blood passing through the aorta travels at 15 in/sec 380 mm/sec and then slows down as it reaches out into the distant body parts. On average it travels at 3-4 mph - about 20 mm/ sec. Speed is slowest in capillaries where the diameter is least.

If the lifetime of HbX is 1 μs then the distance for reaction to occur is, on average, 20 nm; this is a very short distance, even at molecular scales. It suggests that the reactive intermediate is not a singlet or triplet species but a radical with a much longer lifetime or else something involving secondary reaction with singlet oxygen or other species.

There may be a secondary species that is formed from HbX by transmission of its energy to a third party species and being quenched to its unexcited state, as is the case with chlorophyll in plants.

The secondary chemistry that takes place after HbX has transferred its energy and formed a secondary species will be complex. It is possible that a new configuration of Hb is formed in HbX and, with a longer lifetime, it can create damage with its different chemistry.

The most likely event is a reaction close to where HbX is created. Therefore, when the whole body is irradiated with NIR, HbX could occur anywhere in the body and we have already agreed that cancer can occur anywhere in the body.

Some sites will have better resistance to HbX than others.

This mechanism does not deny other mechanisms. HbX can cause damage other than cell mutations. It may affect nerve processes too, for the NIR can significantly influence electron currents in nerves.

Cancer Statistics

It is well known that statistics can be manipulated to show a desired conclusion. In the field of cancer, statistics are plentiful, but can also be used to show optimism. Governments are especially keen to present good news about the incidence and treatment of cancers.

Worrying questions were raised in 2002 by Hallberg and Johansson[2] who reported that cancer statistics seemed to have been manipulated to hide some real effects, indeed, some data for years around 1955 have, they said, been deliberately kept from public scrutiny. There is no doubt that the incidence of cancer is increasing but this has generally been ascribed to populations living longer.[3] (The last point is another convenient government statistic to demand that people work longer into old age before receiving a public pension. It remains to be seen whether this is indeed the case, given the present big rise in morbid obesity. This is also a less frequently reported cause of cancer. It could be expected that bodies with large amounts of cells are statistically more likely to absorb mutation-enhancing radiation, with women being more at risk than men.[4])

There is no doubt that genetic mutations increase with age, but is this statistic being used to disguise the fact that cancer is becoming more common because of other factors? Hallberg and Johansson correlated cancer rates with the introduction of increasing numbers of broadcast transmission towers both for terrestrial Radio and TV since the 1950s and for phone communications since the 1990s. The authors take a detailed look at data and find a number of irregularities between the statistics and the conclusions presented by government departments. In particular, skin melanoma seems not to correlate with skin directly exposed to sunlight but often occurs on skin that is beneath clothing. Likewise, the authors point out that lung cancer is reportedly increasing despite the reduction in smoking of recent decades. I shall later suggest a mechanism for these observations. The authors conclude that:

> *"There is a common environmental stress that accelerates several cancer forms such, as colon cancer, lung cancer, breast cancer, bladder cancer and malignant melanoma. Every effort should be taken to identify and eliminate this stress."*

Since the paper is a statistical analysis, there is only an indirect association of increases in cancer rate with exposure to electromagnetic fields - more circumstantial evidence, but no proof. This is just one of many papers that raise concerns about a rise in the incidence of cancers being disguised. So far, there have been too many reaching opposite conclusions.

I believe that there are other kinds of debilitating illnesses amongst populations today that are either not well defined by medical science or sub-clinical in nature such that diagnosis is made very difficult. Even if diagnosed, the causes are not currently recognised.

Social and Political Considerations

Is the incidence of cancer rising? It seems obvious to us that we should ask this question. Surely the answer should be obvious given the present high level of scientific activity in the developed world. Evidence shows nothing but unwillingness to accept anything other than the statement that non-ionizing radiation is safe. So does the evidence really show this? Let's begin by looking at the statistics offered by one of the major cancer data on-line sources. In the UK an extensive presentation of cancer statistics is presented on the Cancer Research UK website.[5] A very great number of different statistics are presented. At the top level, data are presented as number of cases, number of deaths, survival rates, and preventable cases. Statistics are also presented in terms of cancer types and variations. It is easy to arrive at the conclusion that great emphasis is being placed upon treatment of cancer, and this is rightly so. However, for those of us more concerned about the causes of cancer and the ways in which cancer could be mitigated the data is less useful.

Because the subject of cancer is so important I would like to focus discussion for the moment on brain tumours. Web pages of the American Cancer Society state:

> *"The cause of most brain and spinal cord tumors is not fully understood, and there are very few well-established risk factors. But researchers have found some of the changes that occur in normal brain cells that may lead them to form brain tumors. Normal human cells grow and function based mainly on the information contained in each cell's DNA. Brain and spinal cord tumors, like other tumors, are caused by changes in the DNA inside cells."* [6]

Accepting that the case is circumstantial, it is known to this author that a worker employed in the maintenance of navigational buoys developed a fatal brain tumour with a few years of close exposure to the fields it generated. Perhaps accepting an element of risk and taking elementary Health & Safety precautions, workers were instructed only to carry out maintenance when the devices were switched off. However my friend admitted to me that he had often, out of convenience, worked on the buoys when they were still switched on.

Of the many different kinds of cancers brain tumours are often reported as being one of the least common. It seems obvious that this is simply because of the protection offered by the skull. We shall see that distance has a significant impact and the diminution of the signal strength by the thickness of bone between the source and the brain offers significant protection. However in situations where the source is powerful, significant exposure of the brain to damaging electromagnetic radiation remains plausible. Dose is the strength of the signal multiplied by the time of exposure. In situations where the body is not protected by a layer of bone and the soft tissue is directly exposed to the source of radiation, then we would expect the incidence of cancers to increase accordingly.

On the Cancer Research UK website, data are presented as 1. Incidence 2. Mortality 3. Survival 4. Risk 5. Diagnosis and treatment 6. Publications. Examination of the incidence information shows no less than 13 headings with many headline statistics. Very little relates to the ways in which brain tumours can occur and very little relates to changes in incidence rate. One heading does indicate that an increase in incidence rates for brain tumours of 6% in the UK to 22 cases per 100,000 people is expected by 2035. This bold statement gives no reason for this increase. Another fact: since the early 1990s, brain tumour incidence rates have increased by 36% in the UK. Rates in females have increased by 47% and rates in males have increased by 25%. These are the only statistics relevant to increased risk to the population. Here is clear evidence that incidence rates of brain tumours are indeed increasing. However, there is a great groundswell of reporting from the scientific community that resists such conclusions and the bad news they bring.

Examination of papers on the subject shows that authors are almost universally unwilling to be controversial. Societal pressure (the threat of cuts to funding perhaps) to avoid bad news seems overwhelming and to have imposed significant nervousness on the scientific community. Whilst reporting increasing evidence of a rise in the incidence of cancer, analyses almost always resort to reluctance to accept the obvious. Uncertainty is always blamed upon changes in diagnosis and reporting, with the conclusion that further work is required. There is a complete vacuum of presentation of any kind of mechanism whereby non-ionizing radiation can cause detrimental effects on human health. Papers seem to be overwhelmed with data which, presented in so many different ways, fail to reach firm conclusions about risks to populations. So many variable or uncertain factors are generally involved as to render firm analyses either very difficult or inaccurate.

One such example of a typical paper is discussed here.[7] It is common in a statement of the prevalence of brain cancer to report that it is rare, as if that is some kind of consolation; to say that malignant tumours of the brain are a rare occurrence accounting for approximately 2% of all cancers in adults is dismissive of the seriousness of the problem. For a cancer which has a very low survival rate beyond five years, and one which has extremely sad outcomes when found in children, it is most disappointing to read such data from scientists purporting to be concerned about human health. According to the paper the overall annual incidence rate of all brain tumours is seven per 100,000 population. This may be a very small number but that is hardly the point.

As to analyses of data, there are common threads that appear time and again in such papers.

> *"There have been reports of increasing incidence of primary brain tumours in recent decades which need to be interpreted with caution."*

This is exactly the kind of statement one finds regularly in these kinds of scientific papers that are shrinking away from direct confrontation of the issue. The typical excuse is that "trends over time can only be considered valid when based upon data collected according to the same definitions and reporting practice. Inconsistencies and changes over time may be the explanation for the observed rises."

Under the heading "childhood brain tumours", again a reluctance to face up to the problem is illustrated by the following. After reporting "what appear to be true rises in incidents over the last three decades", doubt is immediately cast as to "whether this is a real and continuing effect and that it can only be answered by future surveillance using better methods." To end the paragraph by talking about survival of children with brain tumours increasing is once again a refusal to face up to solution of the original occurrence.

Discussion of mobile phones and radio frequency signal impact begins with the statement that the energy levels of these waves are insufficient to damage or disrupt cellular DNA. Once again discussion of the limited number of studies carried out is punctuated with excuses as to why the effects may be misleading. Responsibility for final conclusion is postponed until yet more further studies are conducted.[8]

Discussion of extremely low frequency magnetic fields begins with the statement:

> *"Extremely low frequency magnetic fields are used in domestic and industrial electricity supplies presenting to virtually ubiquitous exposure to the population. The possibility of adverse health effects has generated considerable public concern despite scant epidemiological and biological support in the research literature. There is no consistent research which shows this low energy exposure has any direct effects on disrupting cellular DNA or metabolic pathways."*

Once again the risks perceived by many others are dismissed. Risks from overhead power cables are outlined through mention of early reports in the 1980s, but followed up with dismissal that early reports were not replicated. The final statement says:

> *"Current evidence shows that at levels experienced by the general population, no risk of brain tumours in children appears to be present."*

The overall tone of the paper whilst appearing to be unbiased and analytical creates the impression of typical government response of a calming nature.

The subject of this paper has received a great deal of attention and a summary of the current state of knowledge has been published by the WHO[9], a large and comprehensive review to which readers are referred. The subject popularity waxes and wanes over the years because there is no definitive conclusion to allay peoples' concerns. For example in 2019, the UK Government website hosted a petition that demanded the Government "Launch an independent enquiry into the health and safety risks of 5G." It did not reach the necessary threshold for action, attracting only 32454 voters of the 100,000 needed, and the petition closed on 5 June 2019. The Government's response was:

> *"Exposure to radio waves has been carefully researched and reviewed. The overall weight of evidence does not suggest devices producing exposures within current guidelines pose a risk to public health."*

Calming and dismissive - as expected.

Also in 2019, no less than 26,000 scientists sought action from the WHO because they considered 5G a harmful endeavour. [10]

In the USA, the imminent arrival of 5G technology prompted a major article in Scientific American entitled, We Have No Reason to Believe 5G Is Safe. [11] Even this article in a high profile publication seems to have had no effect.

In 2004, a BBC Panorama programme investigate the perceived growing threat to childrens' health from phone masts in schools.[12] The reception from "experts" could be summed up as a mixture of ridicule and dismissal. There was no action taken by Government.

Of thousands of websites expressing concerns about the effects of non-ionizing radiation, just one example is given here. [13]

I believe that humans are now suffering the consequences of adverse health effects caused by decades of exposure to non-ionizing electromagnetic radiation. As our technological society increases its dependency on non-ionizing radiation, the rates of incidence of these illnesses will rise significantly in coming decades. There are plenty of papers in the scientific literature that conclude that non-ionizing radiation can cause damage to tissue. It is sufficient for readers to consider just some of these papers to realise that they should be concerned. [14] [15] [16] [17] [18] None of these papers provides an adequate mechanism to support the postulate. Despite a great deal of effort, there remains no agreement, as expressed by the WHO, that non-ionizing radiation represents a risk to the development of genetic mutation-induced diseases (cancers), or that exposures may cause nerve damage. There are many reasons for this lack of clarity.

Photochemistry is a well-developed academic field, and it is very surprising that there is so little clarity about the possible interactions of non-ionizing radiation with biomolecules. The most common defence that non-ionizing radiation is harmless is meted out on a regular and is summarised by the statement that we are all exposed to non-ionizing radiation (light) all the time and that we do not all die quickly from it. Yet we are all clear that the absorption of light by chlorophyll leads to complicated sequences of reactions in plants that are essential to life and that are driven by electrochemical processes.[2e] Nowhere in this vital part of life on earth is ionizing radiation implicated. It is the opinion of this author that in humans it is the red component of blood, hemoglobin, that provides the link between non-ionizing radiation and subsequent harmful chemical processes. This will be explained below.

So why has definitive proof not been provided? Clear diagnosis of these illnesses has been difficult until the last few decades, and the diagnosis of nerve-damage related illnesses remains haphazard. Cancer patients are generally told what their disease is, but not how they got it. It would seem, that lack of clear evidence and understanding has been the major difficulty in unambiguously relating them to exposure to electromagnetic fields. Nevertheless it is clear that a great number of haematology diseases have occurred over a period of time when the exposure of every citizen to electric fields has also increased exponentially. Scientists would rightly claim that there is no foundation for linking the two. However, this is not a good reason to ignore the possibility when so many severe health risks can result.

Skin Cancer

Oxygen has a common excited state called singlet oxygen[2] which has a lifetime that is long enough to engage in harmful chemical processes with soft tissue. The most important function of hemoglobin is that it absorbs a molecule of oxygen, assisted by the strongly delocalised electron structure and the presence of the central iron atom. In my opinion, there is a strong possibility that the absorption of non-ionizing radiation by hemoglobin could allow or enhance the formation of singlet oxygen. It is very likely that the mechanism by which the oxygen is released from the hemoglobin will have different kinetic parameters if either hemoglobin is in an excited state or if it has passed energy on to the oxygen to form singlet oxygen. All of these events can result in a singlet oxygen creating a genetic mutation which can lead eventually to skin melanoma.

Skin cancers or melanomas are one of the hardest cancers to make conclusions about. Most of the statistics in the open literature exclude melanomas for a variety of reasons, not least of which is the difficulty in recording and reporting the incidence rates. It’s very easy to ascribe a reported increase in melanoma as simply because of increased amounts of leisure time and more time spent on beaches and in sunbathing activities. Indeed, increased exposure to ultraviolet radiation in this way is an undoubted contributing factor. However, it’s quite likely that this would disguise the other main effect which is the absorption of light energy by the hemoglobin in the skin. If this was due to absorption of radiation from artificial electromagnetic radiation sources, increased incidence of melanoma would be completely disguised by the increased rates caused by ultraviolet exposure during sunbathing.

Risk And Probability

At a superficial level the terms risk and probability seem close in meaning. Risk is simply a number having any real value. We might say that the risk of death in an air crash is a million times less than in a car. The risk factor would be a millionth (10^{-6}). If we turn it around and say that the risk of dying in a car crash is a million times greater than in an aircraft, then the risk factor is a million (10^{6}).

Probability, P, takes values:

$$0 <= P <= 1,$$

where 0 indicates it will never happen and 1 tells us that it will certainly happen.

Probability is affected by the size of an influence multiplied by the time over which it takes place. There may also be other exacerbating (and mitigating) factors depending upon the type of event.

Ionizing Radiation And The Risk Of Cancer

In a field of ionizing radiation, the stability of a molecule is greatly reduced and, once formed, the ion seeks to undergo a chemical reaction with a near neighbour. The likelihood is that this reaction is detrimental to the tissue in some way. If the ionized molecule is part of a DNA molecule, for example, it is possible that an important gene function can be changed. Of course, the human body has many inbuilt repair mechanisms so damage is not necessarily permanent. This is a complicating factor for this analysis and I shall put it to one side for now. The requirement for cell malfunction could be just one mutation or it might take many to occur. The logical endpoint of this chain process is that a gene becomes faulty and a cancerous growth process may be initiated. Thus:

ϒ-rays + tissue -> ionization of molecule (gene within DNA) -> gene modification -> faulty process -> cancer

In the sequence above, we could just as well replace ϒ-rays by X-rays, beta particles or alpha particles.

The process summarized above does not happen with 100% certainty every time a ϒ-ray impacts upon human tissue. There is always a probability that a reaction will take place and another probability that a human gets cancer from that reaction. Probabilities are mulitplicative, i.e. if there is a 10% probability of the first, and a 10% probability of the second, then the overall probability is 1%. The probability of exposure to a single ϒ-ray varies with each human. So it is possible that a single human exposed to a single ϒ-ray might develop cancer, but the multiplication of the two probabilities makes the overall probability extremely unlikely. (Again, our body's self-repair mechanisms can mitigate this.)

An increase in the probability occurs with what is known as exposure - again, in simplest terms, the number of ϒ-rays. Most of us know that many of the gallant workers who volunteered to control the meltdown of the reactor at Chernobyl died because they had a great exposure to ϒ-rays. On the other hand many of us are exposed to variable amounts of ϒ-rays (outdoors in some situations, or in industrial environments) in our daily lives, but still live into old age without contracting cancers. Indeed, exposure to ϒ-rays in a controlled way is actually used to kill tumours in the process we call radiotherapy. A breast cancer patient who receives radiotherapy is often subject to a dose of ϒ-rays that would be lethal if it were used on the entire human body. However, the beam of ϒ-rays is focused onto the tumour where, hopefully, only cancerous cells are killed and the rest of the body is not exposed to danger.

In summary, when we talk of ionizing radiation, our risk of contracting cancer is directly dependent upon our exposure: The more we get, the more the risk. In the nuclear industry this is also called **dose**. We might use the same term for non-ionizing radiation, but, because society does not consider non-ionizing radiation to be harmful, we do not.

Effects on the human body

When we consider an environment E that could harm the human body, we can say that f(E), the risk of a harmful event, is directly proportional to the magnitude or intensity of the influence contained in the environment, I, multiplied by the exposure time, t.

Thus:

$$f(E) = k_e \,.\, It,$$

where k_e is a constant that will depend on the type of environment.

For multiple exposures in many environments, each exposure makes a contribution and we could say that the contributions are, at least, cumulative, if not additive. However, there are other complicating factors. For example, there can be a threshold effect whereby an exposure below a certain level has no damaging effect. This seems to be the case for ionizing radiation where exposure is now believed not to be harmful in some situations when the dose falls below the threshold level, possibly due to the self-repair mechanisms. It has even been recently suggested that the stimulation of these self-repair functions can be beneficial.[19]

For most types of exposure, and especially for non-ionizing radiation exposure, intensity is also inversely proportional to the square of the distance but this is a smaller effect in ionizing radiation exposure. For example, exposure to ultraviolet ionizing radiation from sunlight has no distance effect; the probability of skin cancer is simply dependent upon the radiation intensity times the length of exposure.

I intend to consider situations of "intimate contact" where two elements are touching and the distance could be considered as 0 or at least, so small as to be considered touching. Such a situation could be considered to have a 'worst-case' effect. In this article, which primarily concerns non-ionizing radiation, a distance of 1 metre is large and generally sufficient for an influence to be zero. Distance is a very significant factor in the exposure to non-ionizing radiation. As we shall see below, the greatest increases in risk occur from intimate or very close contact between human tissue and an energy source. Conversely, the best method of amelioration (other than source removal) is to increase the distance between tissue and source, e.g. 1 metre. It must be emphasized that this is a severe approximation since if the source of non-ionizing radiation is strong enough, health can still be seriously affected.

Effect of the DNA mutation rate

The probability that a human will die because of illness caused by damage to her DNA can, in the first instance, be represented by two factors. The first is a probability that arises from her DNA at birth, i.e. the degree to which her ancestry has contributed mutations that will ultimately lead to cell malfunction. Quantitatively, this might be considered to be simply a number - expressed as a probability. It is a constant for the individual. At one end of a spectrum of risk, a child might be born with a life-threatening cell malfunction, in which case, the probability is high that she will develop the inherited disease at some point in her life. At the other end of the spectrum is an aged human with a DNA structure that is strongly resistant to cell malfunction. This individual was born with robust genetic constitution and a very low probability of inherited risk of illness. Crudely, the child is likely to get cancer, the old person is not!

Because the inherited risk factor is constant for a given individual, it would seem that any case in which there is an early onset of genetic mutation-induced illness in an individual born with a very small inherited probability factor ought to be investigated thoroughly for evidence that might indicate the source of the mutation - an exposure during her lifetime. A case of childhood or teenage leukaemia must surely indicate an increased risk factor, especially when there is no inherited damage. It may certainly have been triggered by an environmental factor but at present there seems to be little interest amongst the medical community to investigate the possible cause. We are in a position today in which newborn babies could routinely have DNA samples taken to determine their predisposition to later illnesses. If they later fall ill, parents should be carefully interviewed to determine as much as possible how the environment to which the child has been exposed may have contributed to the increased risk factor. Children today are more often in close contact with electromagnetic fields, especially using Bluetooth transmitter/ receiver devices such as wireless and in-ear headphones. Not only is the frequency of use increasing but so is the length of exposure. We should be especially concerned about the risk to children from cell phones for not only is the young brain in constant rapid development but it is much less well protected because of the underdeveloped thickness of the skull.

The second factor is a probability that increases over the human lifetime and is dependent upon the many types of environment to which she is exposed. Taking the inherited genetic factor as G, and the exposed environment factor as E, the probability might be expressed as:

$$P = G \cdot f(E),$$

where f(E) is a function that expresses the complex sum of environments to which the human has been exposed.

To this author, there are many parallels between the effects of ionizing radiation and of smoking tobacco, both situations in which some humans may live to old age being heavy smokers or in mild ionizing radiation environments. Clearly the impact of f(E) on P is very different in different environments and for different humans with different degrees of pre-existing genetic damage.

High Risk Environments

Many efforts have been made to deny that there are harmful effects from exposure to VLF-EMR but the most recent WHO report is unable to reach firm conclusions except in a few limited instances. Meanwhile citizens are continuing to risk situations of high exposure, where the dose is the result of field intensity multiplied by exposure time.

There are many reports in the literature that do suggest harmful effects of non-ionizing electromagnetic fields and that are subject to the denial culture. Most commonly recognized risks are from fields due to overhead power cables, microwave ovens, electric blankets and hairdryers. There is a much increased tendency in modern culture to install microwave ovens at head height especially in kitchens with limited floor space. Those cooking the many varieties of popular microwave meals are exposing themselves to enhanced probability of genetic mutations or nervous system damage when in close proximity to a working microwave oven if that exposure is anything longer than the shortest cooking times.

Another high risk category is the group of people - more female, perhaps, who spend significant periods of time either drying their hair or using other electrically-heated hair tools. Those devices that involve electric heating elements are especially risk-enhancing because of the high voltages they require and the high currents that create the heat. Electric blankets similarly pose a serious risk to those who like to sleep in close contact with these devices when they are switched on.

The ever increasing use of Bluetooth devices is a source of concern. Some examples that have received little attention can be found in the entertainment industry where it is commonplace to attach transmitter/receiver devices in intimate contact with the spinal column and hence the central nervous system. Some professional sportsmen now have wireless performance monitoring devices in their shirts at the back of their necks directly over the central nervous system. In the media world, workers commonly spend much of their day wearing wireless or in-ear headphones in studios where there are banks of electronic equipment. The insertion of ear pieces inside the ear must be a cause of concern, especially the current trend for wireless devices. The present impetus to develop an “Internet of everything” in which all of our household devices are controlled remotely is of especial concern.

A new and possibly worrying development is the introduction of electric vehicles which inevitably function with high voltages and currents. The idea of a driver sitting astride a high-power pack, as we expect to find in an EV, is predictably abhorrent, although it is admitted that there is no data available on this at present.

In the field of communication technology the risks due to Very High Frequency Electric Fields is still subject to unreasonable official denials. This author sees no reason to differentiate High Frequency from Low Frequency fields. One area of great concern in the future is the imminent arrival of 5G communications technology. The proposed hardware installations are known to involve higher field intensity and, because the radiation is less penetrating, requires a much higher density of transmission masts. Inevitably citizens will spend far more of their time exposed to 5G atmospheres, especially using more powerful phones in close proximity to their brains and other soft tissue. The intensity of radiation inside the home will inevitable increase as the demand for increasingly effective Wi-Fi becomes more prolific.

In the brain the density of blood vessels and their proximity to the nerve endings which rely upon the transmission of tiny electron currents is surely a great risk to the body and possible mutations to DNA when exposed to high doses of non-ionizing radiation, just as it is for the ionizing variety. There is a strong current fashion to install complex electric networks at the head of beds where people spend hours with their brains in close proximity. There can be significantly large fields across the width of the bed where human brains lie for eight hours or so. Sitting up in bed for hours and resting your head against the headboard is a significant exposure and, in my opinion, should be avoided. The possibility that many citizens used battery charging devices by their beside at night - or even under their pillows cannot be ignored.

In the case of genetic mutation-initiated diseases such as leukaemia and lymphoma there is sufficient scientific knowledge for great doubt to be thrown upon the safety of our modern electronic environment and I wonder just how long we must wait before action is taken.

The counter arguments, all made by the WHO, are that we simply do not have the statistical data to support the theory that incidence of blood cancers is increasing. Even if it were proven to be true it could be argued that other causes such as food and chemicals could be the cause. Even stress is a frequently suggested cause. Nevertheless there is a sufficiently good scientific mechanism available for the hypothesis that non-ionizing fields have harmful - even fatal - effects to be taken very seriously indeed. But what do those in a position of authority and influence have to say?

Effects Of Electric Fields On The Nervous System

The greater part of this study has focused on health conditions that are generally life-shortening. However, there are also a large number of possible deleterious health effects from exposure to non-ionizing radiation that are not lethal. The topic in which we try to make sense of many as-yet undiagnosable or poorly diagnosed illnesses is fraught with complexity. Those illnesses that involve DNA mutations are clearly very serious, but there seem to be a great number of people who suffer badly from other health problems that could be placed under the general heading of mental illnesses or of the nervous system.

I have discussed brain tumours at some length as this is a most devastating problem, but in a situation where we are concerned with impact upon the brain and the central nervous system in general we should also take serious note. Only now are the problems of footballers suffering from early dementia being associated with brain damage caused by heading footballs in their youth. Yet we have now seen that unwanted chemical interactions are initiated by exposure to electromagnetic radiation. Perhaps these problems too will take years to become obvious and thus provide us with evidence today that studies ‘proving’ mobile phone usage is safe are erroneous?

I believe it is entirely possible for electrons taking part in the transmission of minute pulses of electricity through the nervous system can be affected by spurious chemistry caused by the absorption of non-ionizing radiation by hemoglobin and associated oxygen. Such mechanisms could explain the great rise in dementia, fibromyalgia and other such problems in the brain and central nervous system. GPs have struggled to agree on the diagnosis of many of these issues and patients are suffering from severely debilitating issues with no understanding of the reason or of any suitable medication to mitigate the problems. It could also be the case that such problems eventually lead on to produce cancers. Here we are moving into the realm of speculation, but the mechanisms that I have outlined above present us with plausible explanations for many other problems than cancers alone.

Let us consider an individual who is born with a genome that is relatively free from mutation (ie no family history of genetic mutation-induced disease). This individual is in the fortunate situation of having a pseudo-resistance to genetic damage, insofar as it could take a great number of mutations before a cell malfunction is initiated. We know that it is the total sum of risk factors to which the individual is exposed during her lifetime that determine whether she gets a mutation induced disease. Such an individual who is diagnosed with such a disease at an early age might be considered to have suffered a large or acute exposure to mutation-initiating conditions. A detailed analysis of the lifetime environment should be made with respect to exposure to electromagnetic fields. A person who in old age is diagnosed with the same illness might have suffered genetic damage for other reasons by virtue of her longer life but still the risks should be explored. This paper is also proposing that the nervous system exposed to electromagnetic fields undergoes changes according to the increased risk and probability explained above in a progressive way such as:

Field exposure + healthy human -> sub clinical effects -> mild symptoms -> severe symptoms -> death

The typical symptoms - which may or may not affect different people according to the dose received are:

- Forgetfulness
- Difficulty of recall of names
- Erratic behaviour
- Fatigue, ranging from mild to severe
- Fibromyalgia
- Early onset dementia
- Alzheimer’s
- Brain tumour

It seems unscientific to deny that electric fields affect nerve activity. There are today many nervous complaints that seem to confound the medical world, not least of which is fibromyalgia. Those who claim to suffer from fibromyalgia present a great variety of symptoms that range from mildly inconvenient intermittent pain to disabling unremitting pain. Patients presenting with symptoms of fibromyalgia are most often unsympathetically prescribed basic pain relief and/ or rest. Some patients receive counselling but others find solace in support groups and networks. Almost all have no idea why they have developed the symptoms. To this author, at least, it seems that the most likely mechanism is some kind of change within the nervous system and it seems that exposure to harmful fields is a likely suspect for the initiation process. It is too easy to ascribe these most unpleasant effects to various mental conditions in patients or to the stress of modern life. Modern life might certainly be to blame, though not especially because of stress. All nervous functions must surely be affected to a greater or lesser degree by electric fields that influence those electrons taking part in those functions. The increased probability of suffering these symptoms will depend upon the same factors as those previously described. The fact that the symptoms at present seem to be irreversible is significant, implying that permanent damage is involved. As long as the exposure has not been too severe, there may be a small element of reversibility involved in that removal of the fields removes the symptoms, but it is clear from the steady deterioration of patients over time that the effects are mostly irreversible and exacerbated because the patient has no idea what is causing the effect in the first place. Dementia and Alzheimer’s are presently being linked to the build-up of certain proteins in the brain, but we are still in the dark as to whether these unwanted changes are initiated by exposure to fields. The intimate association of tiny blood vessels with brain cells should ring warning bells in our minds.

An interesting observation made by this author concerns a patient who suffered from both fibromyalgia and lymphoma. During the period when the patient was receiving intense chemotherapy, all symptoms of fibromyalgia disappeared. Once the patient was in remission, the fibromyalgia returned. The possibility that chemotherapy caused a change to the parameters for fibromyalgia should offer a clue for further research. The apparent increase in the occurrence of fibromyalgia amongst the population could be ascribed to increased diagnosis - a common explanation when other explanations are unavailable. However, when there is a good explanation available it is negligent not to investigate it further. It seems obvious that an increase in occurrence of fibromyalgia might be a result of the increased risk created in modern hi-tech environments. The reason why it is so difficult to prove the link is because environments and exposures are so complex and occur over long time periods. Scientists investigating the links have so far been unable to produce unequivocal evidence in support of the theory.

Notes

1 Brain Tumours: Are they increasing?

This article says there is no evidence...

Geoffrey Kabat: Are Brain Cancer Rates Increasing, And Do Changes Relate To Cell Phone Use?

https://www.forbes.com/sites/geoffreykabat/2017/12/23/are-brain-cancer-rates-increasing-and-do-changes-relate-to-cell-phone-use/#1a8c821d25b4

“A lesson in how easy it is to be misled. Little is known about the causes of brain cancer and brain tumors. Exposure to ionizing radiation (X-rays) and certain rare genetic syndromes have been identified as causes, but these account for only a small proportion of cases.

“Since the early 1990s the possibility that exposure to radiofrequency (RF) radiation from wireless communications devices may be causing an increase in brain cancer has become a public concern, and this possibility was given credence in 2011 when the International Agency for Research on Cancer (IARC), an arm of the World Health Organization, classified cell phone RF energy as a “possible carcinogen.”

“In addition, a research group in Sweden has been publicizing results that appear to indicate that long-term cell phone use is associated with a 2-3-fold increased risk of brain cancer.   These results contrast with the vast majority of epidemiologic studies, which show little evidence of an association. However, the frightening results from this single group tend to get much more attention than the much larger body of studies which show no association.

“In this situation, a crucial question is: Has the incidence of brain cancers – and of specific types – been increasing over recent decades – as the use of cell phones has surged? This would appear to be a simple question, but, as I explain below, it is anything but.”

This article suggests there is...

Alasdair Philips, Denis L. Henshaw, Graham Lamburn, and Michael J. O’Carroll : Brain Tumours: Rise in Glioblastoma Multiforme Incidence in England 1995–2015 Suggests an Adverse Environmental or Lifestyle Factor. (2018)

https://www.hindawi.com/journals/jeph/2018/7910754/

Objective. To investigate detailed trends in malignant brain tumour incidence over a recent time period. Methods. UK Office of National Statistics (ONS) data covering 81,135 ICD10 C71 brain tumours diagnosed in England (1995–2015) were used to calculate incidence rates (ASR) per 100k person–years, age–standardised to the European Standard Population (ESP–2013). Results. We report a sustained and highly statistically significant ASR rise in glioblastoma multiforme (GBM) across all ages. The ASR for GBM more than doubled from 2.4 to 5.0, with annual case numbers rising from 983 to 2531. Overall, this rise is mostly hidden in the overall data by a reduced incidence of lower-grade tumours. Conclusions. The rise is of importance for clinical resources and brain tumour aetiology. The rise cannot be fully accounted for by promotion of lower–grade tumours, random chance or improvement in diagnostic techniques as it affects specific areas of the brain and only one type of brain tumour. Despite the large variation in case numbers by age, the percentage rise is similar across the age groups, which suggests widespread environmental or lifestyle factors may be responsible. This article reports incidence data trends and does not provide additional evidence for the role of any particular risk factor.

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Evidence from the UK:

Preventable cases 3%; Brain and other CNS tumour cases are preventable, UK, 2015; Caused by obesity 2%; Brain and other CNS tumour cases caused by overweight and obesity, UK, 2015; Caused by radiation <1%; Brain and other CNS tumour cases caused by ionizing radiation, UK, 2015; Older age is the main risk factor for cancer. This largely reflects cell DNA damage accumulating over time. Damage can result from biological processes or from exposure to risk factors.

Evidence from the USA:

Brain cancers are rare. In the US, the incidence (that is, the number of newly diagnosed cases per year per 100,00 population) of all brain cancers is 6 cases per 100,000. (By contrast, the incidence of breast cancer is 125 per 100,000, and that of prostate cancer is 120 per 100,000). (2017)

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Caldarella A1, Crocetti E, Paci E.: J Neurooncol. 2011 Sep;104(2):589-94. doi: 10.1007/s11060-011-0533-5. Epub 2011 Feb 17.

Is the incidence of brain tumors really increasing? A population-based analysis from a cancer registry.

Abstract: Recently, an increasing incidence of brain tumors has been reported from multiple studies. Brain tumors diagnosed in the period 1985-2005 were identified through the Tuscan Cancer Registry, a population-based registry active since 1985 in the area of Florence and Prato. Age-standardized incidence rates and average annual percent change (APC) was calculated for the entire period from 1985 to 2005 for sex and behavior. A total of 4,417 brain tumors was registered, 1,900 (43%) in male and 2,517 (57%) in female patients. Malignant and benign tumor incidence rates were 8.3 and 4.1, respectively, among males and 6.4 and 7.2, respectively, among females. The age-adjusted annual incidence rate of all brain tumors was 13.9, with a statistically significant increasing rate throughout the period (APC: +3.2, CI 2.2-4.2). The annual incidence rate remained stable for malignant brain tumors but increased significantly for benign brain tumors (APC: +6.2, CI 4.5-7.9). In our population-based study, the incidence of brain tumors increased from 1985 to 2005 overall and for benign tumors, but not for malignant tumors. Part of the temporal variations may be attributed to improvement in diagnostic imaging techniques and, particularly for benign tumors, in changes in registration practice.

2 Orjan Hallberg and Olle Johansson: Cancer Trends During the 20th Century. Journal of Australian College of Nutritional & Environmental Medicine Vol. 21 No. 1; April 2002: pages 3-8.

3 Cancer Research UK: Cancer Statistics for the UK. https://www.cancerresearchuk.org/health-professional/cancer-statistics-for-the-uk

4 15% of the body is bone, 30-40% of the body is muscle. Then there is fat… The mean percentage body fat in women is 30-40% and for men is 25-30%

5 Cancer Research UK: www. cancerresearch UK.org

6 What Causes Brain and Spinal Cord Tumors in Adults? https://www.cancer.org/cancer/brain-spinal-cord-tumors-adults/causes-risks-prevention/what-causes.html

7 McKinney, PA, "Brain Tumours: Incidence, Survival, and Aetiology", Journal of Neurology Neurosurgery and Psychiatry, British Medical Journal, Volume 75, (2004).

8 Independent Expert Group on Mobile Phones (IEGMP), Stewart, Sir William: Mobile Phones and Health (2000); National Radiological Protection Board, Chilton, Didcot, Oxom, OX11 0RQ. The report points out that the balance of evidence does not suggest mobile phone technologies put the health of the general population of the UK at risk. There is some preliminary evidence that outputs from mobile phone technologies may cause, in some cases, subtle biological effects, although, importantly, these do not necessarily mean that health is affected. There is also evidence that in some cases people's well-being may be adversely affected by the insensitive siting of base stations. New mechanisms need to be set in place to prevent that happening. Overall, the report proposes that a precautionary approach be adopted until more robust scientific information becomes available and that the subject be reviewed again in three years time, or before if circumstances demand it.

In 1998 the International Commission on Non-Ionizing Radiation Protection (ICNIRP) published its own guidelines (paragraphs 6.27–6.31) covering exposure to RF radiation. These were based on essentially the same evidence as that used by NRPB, and for workers the limits on exposure are similar. However, under the ICNIRP guidelines, the maximum levels of exposure of the public are about five times less than those recommended for workers. The reason for this approach was the possibility that some members of the general public might be particularly sensitive to RF radiation. However, no detailed scientific evidence to justify this additional safety factor was provided.

Para 1.16 stated that there is little scientific research and new technology has had so little time for health effects to become manifest. "There is, however, some peer-reviewed literature from human and animal studies, and an extensive non-peer-reviewed information base, relating to potential health effects caused by exposure to RF radiation from mobile phone technology." The balance of evidence to date suggests that exposures to RF radiation below NRPB and ICNIRP guidelines do not cause adverse health effects to the general population (Chapter 5, paragraphs 6.33–6.42). Para 1.18: There is now scientific evidence, however, which suggests that there may be biological effects occurring at exposures below these guidelines (paragraphs 5.176–5.194, 6.38). This does not necessarily mean that these effects lead to disease or injury, but it is potentially important information and we consider the implications below. Gaps in our knowledge suggest a precautionary approach.

9 World Health Organization; Extremely low frequency fields (2007) (Environmental health criteria; 238); ISBN 978 92 4 157238 5 (NLM classification: QT 34); ISSN 0250-863X

10 26000 scientists agree 5G will prove devastatingly harmful

https://principia-scientific.org/petition-26000-scientists-oppose-5g-roll-out/

11 Joel M. Moskowitz: “We Have No Reason to Believe 5G Is Safe. The technology is coming, but contrary to what some people say, there could be health risks”, Scientific American, October 17, 2019. https://blogs.scientificamerican.com/observations/we-have-no-reason-to-believe-5g-is-safe/

12 Scientists reject Panorama’s claims on Wi-Fi radiation risks; Laptop and phone mast comparison is criticised; Programme spokesman defends methodology; by James Randerson, science correspondent, Mon 21 May 2007

“An investigation into the possible dangers of Wi-Fi technology - wireless computer networks - by the BBC documentary programme Panorama has been rejected as ‘grossly unscientific’ and a ‘scare stor’” by leading scientists. The programme will claim that the radiation given off by a Wi-Fi laptop is ‘three times higher than the ... signal strength of a typical phone mast.’ But the experiment carried out by the programme did not take into account a ‘basic’ scientific concept and presented a bogus comparison, critics say.

“Nearly half of UK primary schools and more than 70% of secondary schools are fitted with Wi-Fi networks. Campaign groups and some scientists are concerned that the expansion of the technology has happened without adequate research into the effects of Wi-Fi radiation. But most scientists argue that there are no grounds for thinking that Wi-Fi radiation at the power generated by a wireless router or a laptop would have harmful effects. The World Health Organisation says there are “no adverse health effects from low-level, long-term exposure”.

“Paddy Regan, a physicist at the University of Surrey, criticised the experiment at the heart of Panorama’s claims because the measurements of signal power had not been made at equal distances from the mobile phone mast and the Wi-Fi laptop. A spokesman for the programme told the Guardian that the “three times higher” comparison was based on measurements taken one metre away from the laptop and 100 metres away from the phone mast, although material sent to journalists promoting the programme did not make this clear. Dr Regan said: ‘It’s a basic fundamental of science measurement, that if you are trying to compare things you have to take into account the so-called inverse square law.’ To make a fair comparison between two radiation sources the measurements should be taken at the same distance away. The levels measured by the Panorama investigation were 600 times lower than levels considered dangerous by the government. ‘It does sound like a scare story to me,’ said Dr Regan.

“The programme’s evidence was criticised as ‘grossly unscientific’ by Malcolm Sperrin, director of medical physics and clinical engineering at Royal Berkshire hospital. ‘It’s impossible to draw any sort of conclusion from the data as presented there.’

“Panorama’s spokesman defended the methodology by saying the phone mast measurement was ‘at the point at which the beam was at greatest intensity where it hit the ground.’

“Scientists generally believe that wi-fi ought to be safer than mobile phone radiation because Wi-Fi devices transmit over shorter distances and so can operate at lower power. The Health Protection Agency says a person sitting within a wi-fi hot-spot for a year receives the same dose of radio waves as a person using a mobile phone for 20 minutes.”

13 “For decades, some scientists have questioned the safety of EMF, but their concerns take on a heightened significance in the age of ubiquitous wi-fi routers, the Internet of Things, and the advent of wearable technologies like the Apple Watch and Fitbit devices, which remain in close contact with the body for extended periods.

‘Cellphones, among the most studied emitters of electromagnetic radiation, remain the standard for judging health risks. The federal Centers for Disease Control and Prevention maintains that “we do not have the science to link health problems to cell phone use.’ In a 2012 review of all available research, Timothy Moynihan, a doctor with the respected Mayo Clinic, concluded that ‘there’s no consensus about the degree of cancer risk—if any—posed by cell phone use.’

“The WHO, on the other hand, classifies radio-frequency electromagnetic radiation (the type emitted by wi-fi routers and cellphones) as ‘possibly carcinogenic to humans’ based on limited evidence associating cellphone use with an increased risk for glioma, a malignant type of brain cancer. ‘The conclusion means that there could be some risk,’ Dr. Jonathan Samet, a medical professor at the University of Southern California and chair of the WHO panel that made the determination, explained in 2011, ‘and therefore we need to keep a close watch for a link between cell phones and cancer.’

“Studies since then have highlighted the need for caution. Last year, French researchers found an almost three-fold increase in the incidence of brain cancer in people with more than 900 hours of lifetime cellphone use. Then, in March, Swedish researchers reported that the risk of being diagnosed with brain cancer increased by a factor of three in people who’d used cell or cordless phones for at least 25 years. “

https://www.motherjones.com/environment/2015/05/cellphone-emf-wifi-health-risks-scientists-letter/

14 Nahed S. Hassan and S.A. Abdelkawi: International Journal of Environment ISSN: 2077-4508 Volume : 05, Issue : 01, Jan-Mar, 2016 Pages: 1-8.

15 Feychting, M.: Health effects of static magnetic fields –a review of the epidemiological evidence. Prog. Bioph. Mol. Biol. 2005; 87: 241.

16 Aziza A. El Saeid and Mona A. Mohamed: Effects of Whole Body Exposure to Extremely Low Frequency Magnetic Field (ELF- MF) on Physical and Biological Parameters in vivo Rats.

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Sherif Abdelmottaleb Moussa, Mohamed Anwar K. Abdelhalim and Hisham A. Alhadlaq, 2009. Evaluation of Electrical Conductivity of Hemoglobin and Oxidative Stress in High Fat Diet Rabbits. Journal of Applied Sciences, 9: 2185-2189.

Electrical conductivity of Hb in control rabbits found to be 44 uS cm-1

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Zhang XY1, Shao J, Jiang SX, Wang B, Zheng Y. : Structure-dependent electrical conductivity of protein: its differences between alpha-domain and beta-domain structures. Nanotechnology. 2015 Mar 27;26(12):125702. doi: 10.1088/0957-4484/26/12/125702. Epub 2015 Mar 4.

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Schwan HP: Electrical properties of blood and its constituents: alternating current spectroscopy. Blut. 1983 Apr; 46(4): 185-97.

Abstract: The electrical properties of blood and its constituents are reviewed over the frequency range from less than 100 Hz to nearly 100 GHz. The conductivity and dielectric constant display strongly dispersive behavior with three distinct relaxation regions. Mechanism responsible for this behavior are stated and possible applications indicated.

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H. Pauly And H. P. Schwan : Dielectric Properties And Ion Mobility In Erythrocytes. Biophysical journal Volume6 1966 Pp 621-39

Erythrocytes conductivity (red blood cell) were measured at between 1 and 6 mmho/cm at 20C. Higher values were observed at 1 GHz.

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Nahed S. Hassan and S.A. Abdelkawi: Changes in Molecular Structure of Hemoglobin in Exposure to 50 Hz Magnetic Fields. Nature and Science 2010;8(8): 236-243]. (ISSN: 1545-0740).

Abstract: The rapid development of new technological applications of static magnetic fields such as security systems, power plants and in medical practice as magnetic resonance imaging –MRI affects the human population. In certain occupations, clinical patients are exposed to over magnetic field strengths. The aim of this work is to elucidate the biological effect of short duration exposure, (one hour / day for a period of four consecutive days) to moderate and intense static magnetic field in the range of (0.5, 1.0 and 1.5T) which equivalent to that emitted from common sources of static magnetic field as (MRI) systems on the absorption spectra of hemoglobin (Hb) molecules and on its electric conductivity. In addition, the protein content and the electrophoresis mobility were measured for the plasma from the control and exposed albino rats, about 2 months age. The results indicated that, exposure of the animals to moderate and strong static magnetic fields resulted in changing in the absorption spectra and conductivity measurements of Hb molecules. Moreover, the total protein of the plasma increased and the electrophoretic mobilities also changed. It was concluded from the results that exposure to either diagnostic or interventional (MRI) may be hazardous for patients and more hazardous for machine operators.

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Feychting has studied the cancer risks of static magnetic fields (SMFs) on health, in both occupational and non-occupational environments.

Feychting, M., Health effects of static magnetic fields –a review of the epidemiological evidence. Prog. Bioph. Mol. Biol. 2005; 87: 241.

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Dini, L. and Abbro, L., Bioeffects of moderate static magnetic fields on cell culture. micron. 2005; 36: 195.

SMFs weak <1 mT; moderate 1 mT to 1 T; strong 1-5 T; ultra strong >5 T

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In Feychting:

"Henrykowska et al. (2009), indicated that exposure to 50 Hz magnetic field of 10 mT induced oxidative stress and free radicals generation in human blood platelets producing a number of adverse effects within the cell and thus may lead to systemic disturbances in the human body."

Henrykowska, G., Janskowsk, W., Pacholsk, K., Lewicka, M., Śmigielsk, J., Dziedziczak-Buczynska, M., Buczynsk, A. The effect of 50 Hz magnetic field of different shape on oxygen metabolism in blood platelets: in vitro studies International Journal of Occupational Medicine and Environmental Health 2009; 22(3): 269 – 276.

"Some results indicated that working near a 1.5T (MRI) system or while seated close to the bore of the field (where the field strength was less than 0.7T) may lead to neurobehavioral effects (De Vocht et al., 2003) and neuro- cognitive function adverse effect (Chakeres and de Vocht, 2005)."

Chakeres, D.W. and de Vocht, F., Static magnetic field effect on human subjects related to magnetic resonance imaging systems. Phys. Mol. Biol. 2005; 87 (2-3): 255.

"Recent studies found a high relation between exposure to non-ionizing radiation and acute childhood leukemia (Calvente et al., 2010). Feizi and Arabi (2007), concluded that the presence of high-voltage overhead power lines within 500 m of residential areas should be considered a risk factor for acute childhood leukemia."

Calvente I, Fernandez MF, Villalba J, Olea N, Nuñez MI. Exposure to electromagnetic fields (non-ionizing radiation) and its relationship with childhood leukemia: A systematic review . Science of the Total Environment 408 (2010) 3062–3069.

Feizi, A.A. and Arabi, M.A. Acute childhood leukemias and exposure to magnetic fields generated by high voltage overhead power lines: a risk factor in Iran. Asian Pac J Cancer Prev. 2007; 8(1) :69–72.

The authors were unable to find conclusive evidence of damage in short term exposures from CT and MRI scans.

"The available evidence from epidemiological studies on blood is not sufficient to draw decisive conclusion about potential health effects of moderate and strong static magnetic field exposure at the levels encountered in the environment or at work places."

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Aziza A. El Saeid and Mona A. Mohamed : Effects of Whole Body Exposure to Extremely Low Frequency Magnetic Field (ELF- MF) on Physical and Biological Parameters in vivo Rats . International Journal of Environment ISSN: 2077-4508 Volume : 05, Issue : 01, Jan.-Mar. (2016) Pages: 1-8

Magnetic field exposure results in deleterious morphological changes in the different parts of the brain. A focal hemorrhage in the meninges, nuclear pyknosis and degeneration of the neuronal cells of the subiculum are signs of brain tissue injury that leads to to gliosis. Gliosis is the universal response of the CNS to tissue injury and occurs as a result of many acute conditions such as trauma, ischemia, and stroke. Gliosis in any form entails an alteration in cellular activity that has the potential to create widespread effects on neurons as well as other non-neural cells, causing either a loss of normal functions or a gain of detrimental ones (Sofroniew & Vinters, 2010 and Hamby & Sofroniew, 2010). Glioma is a malignant tumour in the nervous system tissue

18 Nature and Science 2010; 8(8); Changes in Molecular Structure of Hemoglobin in Exposure to 50 Hz Magnetic Fields

19 Wade Allison: Radiation and Reason - The Impact of Science on a Culture of Fear (2009), p63-6. ISBN: 9780956275615.

Background Science

The Physics of Light

Light can be pure energy; it can also act like particles (bullets, say). I propose not to descend unnecessarily into quantum physics at this point, so some readers will need to bear with my rather simplified physics.

Light travels from place to place at an absolutely fantastic speed - 300,000 kilometres per second or 186,000 miles per second! There is nothing that can travel faster than light: nothing of "normal" size can even approach this speed. For everyday purposes, on Earth, we say that light travels "instantaneously" from one place to another.

Another property of light is that, for all general purposes, it travels from one point to another in a straight line. This is a very important property that we will use extensively in our discussions later. There are circumstances in which light can bend. Light is affected by gravity, and bends when it passes through strong gravitational fields, but this is of interest only to astrophysicists and cosmologists and is beyond the scope of our discussions here.

We all know that light has colour; this is shown in below. Thus, white light is made up of a wide range of different coloured light, but it is only a very small part of the **electromagnetic spectrum** shown in full in Figure 1. In simple terms we think of white light as being made up of the colours of the rainbow. A rainbow occurs in nature when the rays of sunlight pass through water droplets in the air; rainbows occur when the sun comes out immediately after a heavy shower of rain and when you, the observer, are looking into the rain shower with the sun at your back.

The Electromagnetic Spectrum

The electromagnetic spectrum is a key part of the understanding of these issues. All electromagnetic radiation (EMR) falls across a spectrum energy from extremely high to extremely low. In Figure 1, the wavelength of the radiation increases towards the right, and the frequency increases towards the left. We express the relationship between frequency, wavelength, and speed of light as:

frequency (f) x wavelength (l) = speed of light (c)

Because the speed of light is always constant, as the wavelength gets bigger, the frequency gets smaller and *vice versa*.

Visible light is just a small part of the EMR spectrum and is shown roughly in the middle as the narrow band of colour. At one end of the visible spectrum, red light has long wavelength and, at the other end, violet light has short wavelength. Conversely, red light spans lower frequencies than violet which occurs at higher frequencies. At longer wavelengths than red we feel the infra-red as heat from the sun, whilst at shorter wavelengths than violet we are exposed to damaging ultraviolet rays from the sun and these may lead to skin cancers. The ultraviolet light is **ionizing** EMR; the infra-red is **non-ionizing** EMR.

A second crucial relationship is called Planck's Law. This says that:

energy (E) = Planck's constant (h) x frequency (f)

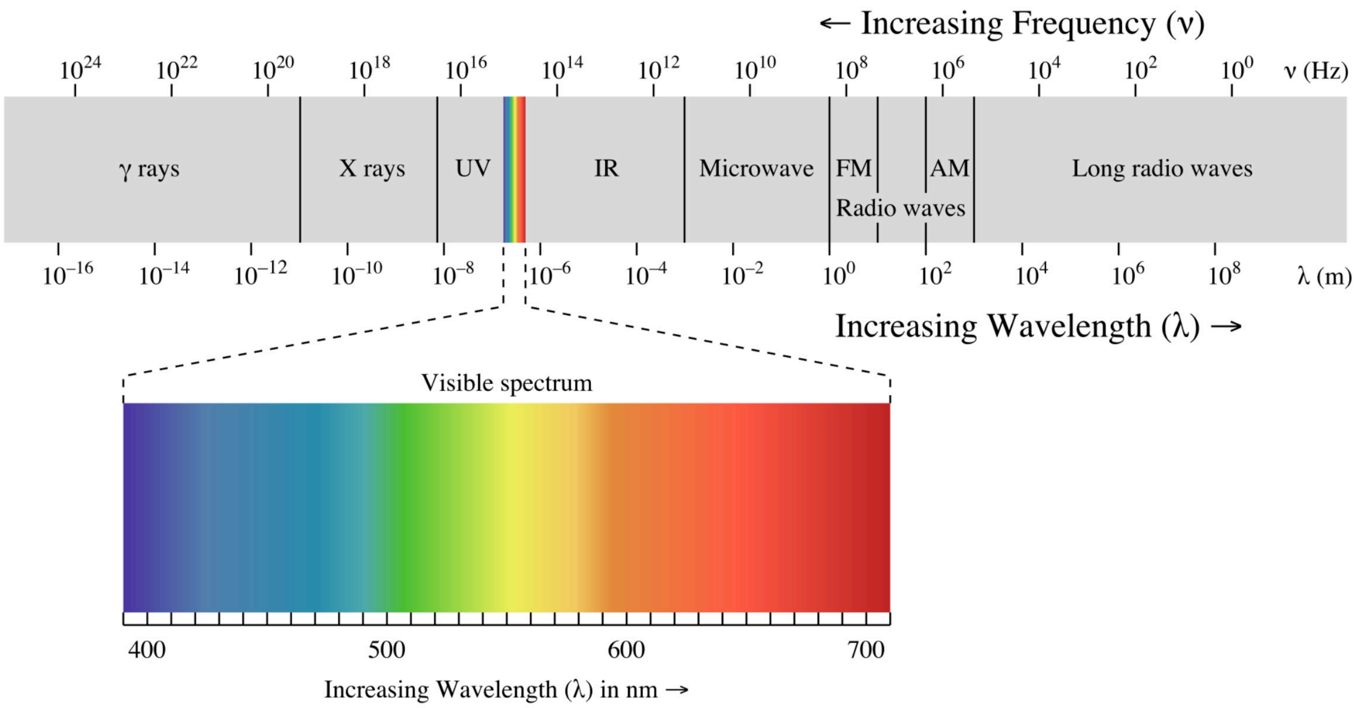
It tells us that, with Planck's constant simply a (very small) number, as the frequency increases so does the energy of the radiation. This is also a most important equation.

In this technological era we tend to focus on the frequency of the radiation and we see that very high frequency is equivalent to very high energy. A big distinction occurs between whether the radiation is ionizing or not. This is well understood. Ionizing radiation (I-EMR) has frequencies that are greater than violet, i.e. in the ultraviolet range and above - to the left of Figure 1. Through the visible frequencies and below, the radiation is non-ionizing. Because life on Earth have evolved over so many millions of years it is clear that visible light is safe and therefore all other non-ionizing radiation (NI-EMR, which has even less energy) is safe too. The key error in this assumption is that it takes no account of the **quantity** of non-ionizing radiation - the level of exposure, or what we will call the **Dose**. More will be said of this below.

The two cases of subjecting molecules to radiation is summarized by these two expressions:

Molecule + Ionizing Radiation -> electrons + New Reactive Molecular Species

Molecule + Non-Ionizing Radiation -> New Reactive Molecular Species



The electromagnetic spectrum. Note that 5G frequencies occur at around 10^{11} Hz which is at the high energy (frequency) end of the microwave region, close to infra-red but well less than the visible range.

Ionizing radiation has enough energy to impact on a molecule and knock an electron out of it. New chemistry then is possible because a new chemical species results that may quickly react with other molecules close by. This is often damaging to biological systems. The difference with non-ionizing radiation is that there is not enough energy in the radiation to remove an electron from the molecule. Simplistically, it is assumed that this is not damaging. **This is wrong**.

The molecule can still absorb the non-ionizing radiation and become changed into a new reactive molecular species that can undergo potentially damaging chemistry. The molecule chlorophyll is a perfect example. It absorbs the perfectly safe radiation from daylight (and makes plants appear green in so doing). The new reactive molecular species created then set off a series of processes in the plant that are vital to the sustenance of life on Earth. Electrons are absolutely involved in this process but the chlorophyll is not ionized. Hence there is a great deal of chemistry that takes place when molecules are exposed to non-ionizing radiation and it is quite wrong to assume that this is always harmless. This will be explained again at length in another chapter.

Energy

Everything that takes place in chemical reactions depends upon energy. A simple way to think about energy content is to consider its temperature. Put simply, the hotter something is, the more energy it has. If all of the energy could be removed from a molecule it would be at the absolute zero of all temperature, -273.16 C. Physical laws prevent this from ever being attained, but scientists have come very close.

If we give a molecule increasing energy, its temperature rises. As temperature rises, solids turn to liquids and then gases (they may catch fire!) and in the extreme, at the highest temperatures, the electrons are lost as the gas turns to plasma. (Very high temperatures are ionizing- think of the Sun.) The extreme of energy or temperature represents a total breakdown of molecules and the atoms from which they are made. Of course this is a gross simplification.

Besides temperature, there are other ways in which energy is distributed in atoms and molecules. We can name four easily:

1. Translational energy is the energy of motion in a straight line. (Faster = more energy.)
2. Rotational energy - energy that causes a molecule to rotate and tumble in space. Naturally these

two are most applicable to gaseous molecules that are not held in fixed positions like those in a solid.

3. Vibrational energy is available to cause atoms to vibrate about a mean position in a molecule and to allow complex molecules to bend and flex in complex modes.

4. Electronic energy is the energy of electrons that are fundamental in all chemistry.

The ways in which electrons interact with atoms and molecules underpin everything we know about the material world. Electrons can have variable energies and undergo a variety of processes that do not involve them leaving the bonds in which they are located within the atoms and molecules. If the electron (having a negative electric charge) does leave its location (in an intermolecular interaction), then it leaves behind an ion (a charged atomic or molecular species) and the process is called ionizing. However, in many intramolecular processes (the electrons move about within the molecule), it is not necessary to invoke the creation of ions and therefore these processes are called non-ionizing.

Ionizing And Non-Ionizing Radiation

Scientists and engineers tend to distinguish between energy that is either ionizing or non-ionizing. Remember, ionizing radiation is to be found on the left of Figure 1, non-ionizing radiation on the right of the visible spectrum, but it should be emphasized that there is no clear dividing line between them. Ionizing radiation is energy that results in the outright removal of electrons from atoms or molecules leaving behind a charged species called an ion. We generally consider four types of ionizing radiation - ϒ-rays, X-rays, beta particles and alpha particles. The last two, being particles rather than pure electromagnetic radiation will not be considered here, but are harmful nevertheless in different circumstances, when, acting as bullets, they can knock electrons from their bonds in molecules and initiate harmful biological processes. However, we saw earlier that ultra-violet and even visible light can be ionizing.

Ionizing radiation involves option 4 above and it is generally considered that non-ionizing radiation only involves options 1 to 3. I believe it is the failure to appreciate that there is no clear delineation of 4 from 1, 2 and 3 that leads to the conclusion that non-ionizing radiation is harmless. It is the insistence on distinguishing ionizing from non-ionizing radiation that leads to this unfortunate paradigm. We should consider **all** radiation, whether affecting options 1, 2, 3 or 4, as being potentially harmful.

According to the authorities, cellphones operate with non-ionizing radiation, which is generally assumed to be safe. Ionizing radiation is mostly dangerous to organic tissue and the dangers are well recognized in modern Health and Safety Legislation.[3] The simplistic assumption that non-ionizing radiation is safe seems to have worked for us up to now, but we need to take another look at this subject, especially in view of changes that are imminent in society - 5G phone systems, electric vehicles, etc.

Electromagnetic Fields

What is a field? It is a difficult concept for many of us to grasp. A field occupies space and contains energy. A popular explanation goes like this: “A particle makes a field and a field acts on another particle. Electromagnetism is considered by physicists to be one of four fundamental forces. It is created by the movement in space of electric or magnetic particles and its effects cause changes to other electric or magnetic particles.” [1] Generally the energy content of an electromagnetic field is proportional to the magnitudes of the potential (volts) and the current (amperes). Clearly, power transmission lines have the most energy since the voltages and currents are very large. Any domestic mains power line creates a field with a lot of energy when, in Europe, voltages are around 220 V and currents can be up to 13 A. In industrial situations, 440 V is common and even higher currents are possible. Hence close contact with a power line, no matter how well insulated, places your body in a large electric field. Thus, for example, it is dangerous to sleep on an electric blanket that is switched on; this is not because there is a risk of electrocution, although it is possible when the blankets have been mistreated by folding, say, and the insulation around the wires is damaged. No, it is simply because of the high field from the cables being so close to the human body, and over a large area too. These situations are considered to be exposures to low frequency (LF) or, indeed, VERY low frequency (VLF) non-ionizing radiation because the frequency of mains supplies are of the order of 50-60 Hz. What about all our other devices around the home?

Frequency is another parameter that plays a role largely because of the way it is generated. Low frequency (LF) is associated with high power equipment in which coils of copper are rotated (at 50-60 Hz) in magnetic fields. HF, VHF and UHF are generally associated with communications equipment and may have values as high as 10^{15} Hz. Bluetooth devices are becoming increasingly popular around the home. They operate in the region of 2.4 GHz (2.4 x 10^9 Hz) and create significant fields. Popular smart speakers create fields that are typically 50-70 V/m when in an active mode.

Historically there has been a clear engineering demarcation between LF and HF with LF being thought of as high power and HF as low power. Simply think of all the power cables attached to your devices in the home. These days, most of them are chunky plugs because they have inbuilt transformers that convert the mains supply from 220 V down to 12, 9, 6, or even lower voltages. They generally consume much less power and are thought to be much safer compared to products running off the full mains voltage such as electric blankets, kettles and other electric heating devices. There is no doubt that they ARE much safer in the sense that we can not be electrocuted by these devices. However, we have not considered the frequency used for their function and this is where we are failing to appreciate the risks from the fields they create.

The Chemical Mechanism For Genetic Damage

It is generally agreed that ionizing radiation causes genetic damage when high energy particles or electromagnetic radiation of ultraviolet frequencies or above, cause the ejection of electrons from their molecular bonds. This is a well known mechanism in chemistry that results in the formation of ions (charged species) or free radicals (reactive chemical species that do not bear charge but have unpaired electrons). Both ions and radicals can be significantly reactive to adjacent chemical species and may have lifetimes that are long enough to allow genetic mutations to occur. This is how it is generally agreed that ionizing radiation causes genetic mutations leading to tumours and cancer.

The intimacy of contact between blood and nerve tissue is at its greatest in the human brain. However, there are many other situations in human physiology in which nerves and blood vessels are in very close proximity.[2] The size and mass of a brain ensures that it will strongly interact with energy from electromagnetic fields according to the mechanisms discussed here and that deleterious energy transfer processes will be initiated.

What does the magnetic component of EMF do?

Some readers may be aware that the principal focus of this study has been on electrons in molecules and the electric fields. It should be evident that electromagnetic radiation has both an electric and a magnetic component. However, we all know about the extraordinary magnetic properties of iron, an atom that is vital to life because of its role in hemoglobin, yet found in few other organic molecules in the human body. So what might the role of the magnetic component - rather than the electric component - be? Sadly, there is much less published material concerning this aspect of excited state reaction chemistry and we can only make some general judgments based upon standard chemistry theory.

The explanation for the great magnetic properties of iron is generally explained as due to a large number of unpaired electrons in the atom, and these are retained in the electronic structure of hemoglobin. We would predict that the iron atom would render the molecule very sensitive to magnetic fields because of these unpaired electrons; there are 4 unpaired electrons when the molecule is without O_2 and 2 unpaired electrons in oxyhemoglobin. We also predict therefore that the magnetic behaviour of oxy- and deoxyhemoglobin and hence their reactivities will be very different. The mechanism proposed in this paper remains unproven and it is possible that the deoxyhemoglobin with more unpaired electrons plays a greater role in the generation of singlet oxygen by some other kind of energy transfer process, as outlined in my other published work.

Magnetic fields have figured significantly in discussions from time to time. Just one example was reported on the Fox News website in 2017:

> *"In 2002, the International Agency for Research on Cancer classified extremely low frequency magnetic fields (ELF-EMF) as possibly carcinogenic to humans. The classification was based on studies that showed a two-fold increase in childhood leukaemia among children with exposure to high levels of magnetic fields in the home (above 0.3 to 0.4 μT)."* [3]

It would seem that this investigation led to the adoption of the safe level of 0.4 μT that is used in some applications. As an example, with a simple inexpensive meter, it is easily possible to measure values of 2 to 3 μT in public spaces. For people casually walking past such installations we could reasonably expect no danger. However, devices emitting strong magnetic fields are situated close to spaces where people spend a lot of time, especially at night, this situation should be regarded as unacceptable.

Notes

1 Wikipedia: Field (physics), retrieved 20190530

2 Blood vessels in the skin come to within 0.1 mm of the surface - the thickness of a sheet of paper.

3 https://www.foxnews.com/health/can-living-near-power-lines-cause-cancer.

The report went on to say the following:

“The possible EMF-cancer link has been debated since the 1980s, said Dr. Boffetta Paolo, a medicine professor at the Icahn School of Medicine at Mount Sinai in New York.

“In the late ’80s, there were a few studies on childhood leukemia, a type of cancer which is common in children, that showed an association with very high exposure to EMFs,” Boffetta told FoxNews.com. “However, this was [from] a very high exposure, which is only present in about one percent or less of the population, and most people, even those living near power lines, have much lower level of exposure.”

“Boffetta, also an associate director for Cancer Prevention at the Tisch Cancer Institute at Mount Sinai, said after these early reports, new studies were conducted with better methodology that did not confirm the association between cancer and heavy, very high exposure to EMFs.

“Several international and national agencies, including the World Health Organization, have reviewed the entire body of evidence and concluded that, under most circumstances, there is really no risk from exposure to EMFs,” he said. “The high exposure was mainly coming from the wiring configuration within the home, not really from outside the home.”

“Boffetta said more research would be needed to confirm the merit of earlier studies’ findings under exceptional circumstances.

“Although scientists are still studying how EMFs may influence cancer risk, experts like Santella and Boffetta argued home owners currently living near power lines should not be concerned.”

Excited State Chemistry

The Excited State

The following is an important argument because it is at the root of the considered difference between ionizing and non-ionizing radiation.

Any species in its “natural” state - that is, entirely unaffected by external influences, has an energy that we call the **ground state**. If the species then comes under the influence of an external effect, it may absorb energy from that external source and become what is known as an **excited state**. Because the excited state contains more energy, there is a natural tendency (the second law of thermodynamics) to lose that energy and revert to the ground state once more. We say that, while it exists, the excited state has a particular **lifetime**. Lifetimes can be extremely short, but also significantly (in molecular terms) long. The rules governing lifetimes are generally understood but can be greatly influenced by local environmental conditions.

Readers might ask how the energy is held in the species whilst it is in the excited state. There are four possibilities:

(1) The species may increase its speed through space - this is called an increase in **translational energy, E_{trans}**

(2) The species may increase its speed of rotation about an axis - this is called an increase in **rotational energy, E_{rot}**

(3) The species may vibrate more vigorously - this is called increasing its **vibrational energy, E_{vib}**

(4) The electrons in the bonds of the molecule may accept energy and become excited - this is called an increase in **electronic energy, E_{elec}**

The four possibilities listed above occur at different magnitudes of energy according to the following:

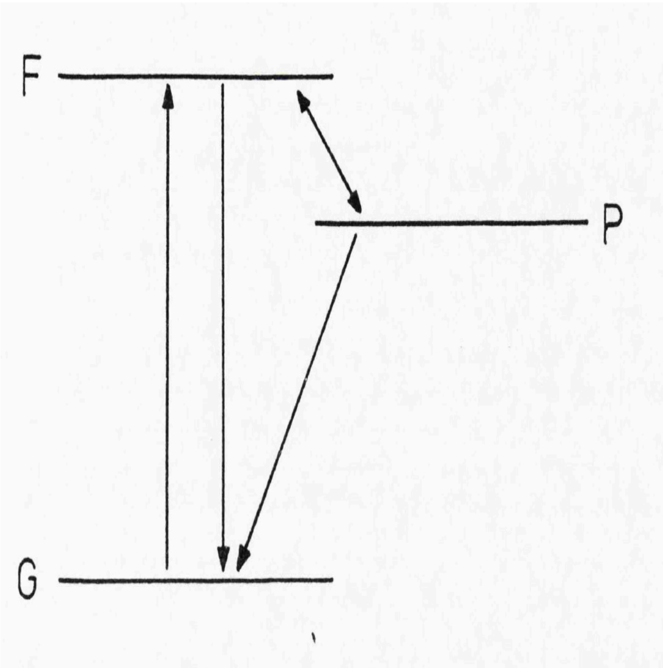
$$E_{trans} < E_{rot} < E_{vib} < E_{elec}$$

In the ground state, the atom or molecule can have all kinds of motion - translational, rotational, vibrational whilst the electrons are in action too - all of which, when summed, makes the total ground state energy of the species. Small variations will occur in any or all of the components as its thermodynamic energy (temperature) changes in its environment. However, when it is subjected to non-ionising radiation, any or all of these components will change more than usual, creating excited states that may lose that energy harmlessly or indulge in new forms of chemistry that damage tissue and/or interfere with physiological functions. The greatest amounts of energy are absorbed into the electrons of the molecule and since it is the electrons that determine how the molecules behave within the system, it is these excited states of molecules that can give rise to new chemistry.

We should remember the following at this point. First, we are almost always referring to more than one atom, bound to other atoms in molecules. In the kinds of biological systems we are considering here, the molecules are present in complex systems and may or may not be able to move through space. They may also be very restricted from rotating. However, increases in vibration are certainly possible - the molecules can vibrate significantly without affecting their location inside the system. This effect is how we define its temperature, so if the vibrational energy increases its temperature goes up.

If the energy absorbed is great enough, an electron is emitted from the molecule. This will occur when the molecule is subjected to **ionizing** radiation. The species that remains after the electron has been lost is a completely different chemical species and will undergo an entirely new range of chemical processes. (Example: A sodium atom is a metal that violently reacts with water; when it loses an electron, it becomes a sodium ion that we sprinkle liberally on our food!) This chemistry is well understood and is often damaging to biological systems. The risks are incorporated into Health and Safety codes that are well established. Despite some voices to the contrary, they are implicit in the safe functioning of the entire nuclear industry.

However, if the energy absorbed by the molecule is not sufficient to cause the emission of an electron,



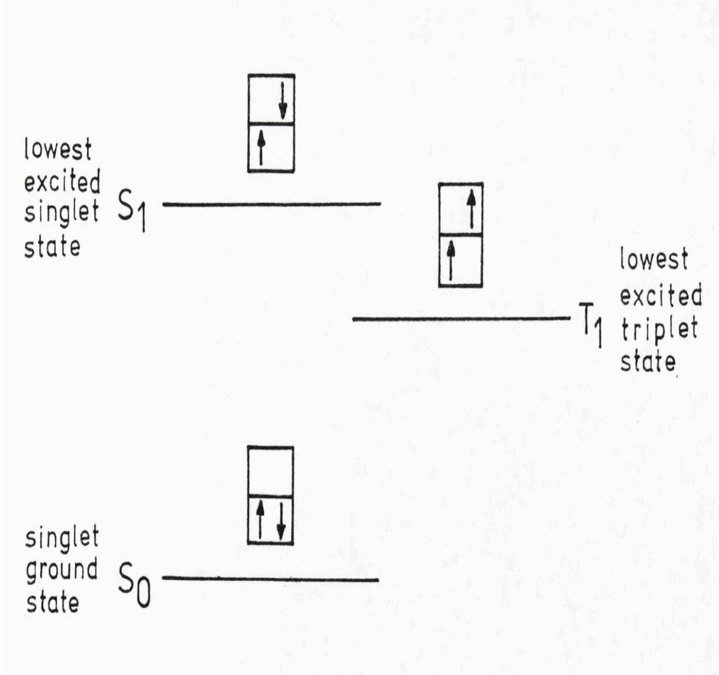


Figure 1 (left): Electronic states - G = ground state; F = fluorescent excited state; P = phosphorescent excited state.

Figure 2 (right): Electronic states - S_0 = singlet ground state; S_1 = lowest excited singlet state; T_1 = lowest excited triplet state. Singlet states have arrows (electron spins) pointing in the opposite directions (spins paired); triple states have arrows pointing in the same direction (spins parallel).

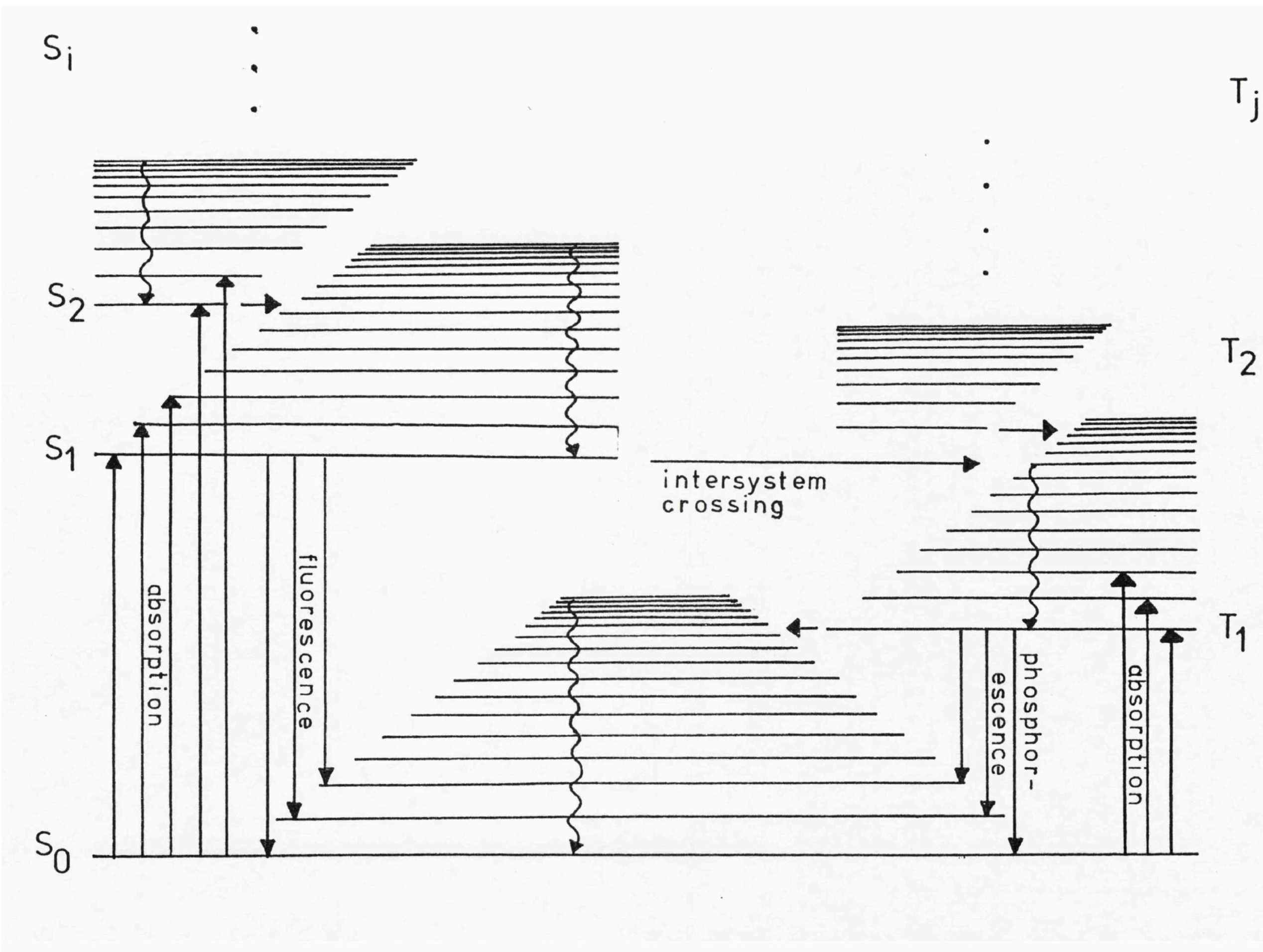


Figure 3: A more complete version of the processes shown in Figures 2 and 3 above. Processes with straight arrows pointing upwards absorb radiation; Processes with straight arrows pointing downwards emit radiation. Processes represented by "wiggly" arrows do not emit radiation.

then the molecule is said to have been exposed to **non-ionizing** radiation. The electrons will have absorbed the energy nevertheless and the species will be in an excited state. Because this is not the usual ground state configuration, the molecule may or may not take part in new chemical reactions which may or may not be deleterious to our biological systems. This is the aspect of chemistry that is not well understood and has led to great arguments among scientists. In the absence of agreement, there have been very few successful attempts to generate Health and Safety codes.

The Role of Singlet Oxygen

The key idea being presented in this paper is that some kind of chemical species interacts with DNA to create a mutation. An argument supporting the harmless effects of non-ionising radiation is that if it were dangerous, our bodies would suffer badly from the effects of exposure to daylight. Biology has evolved in such a way that life is prolific and not affected in this way under normal circumstances, but we note that evolution did not take place under irradiation by non-ionizing radiation of the kinds we increasingly experience today. The safe environment in which evolution took place is no longer benign when a common chemical species in that environment absorbs energy. We have been considering hemoglobin, but what of the other species that is vital to life - oxygen?

It is well known that the oxygen molecule in the air we breathe is in a stable, low energy triplet state. You should now know that this means that the molecule has two unpaired electrons. An oxygen atom has four electrons that occupy three p orbitals, which means that two are paired in one of the p orbitals and the other two electrons occupy each of the remaining two p orbitals. Of course, gaseous oxygen exists as a molecule with two atoms bonded together, as shown in the right hand structure in Figure 7.

However, when exposed to non-ionizing radiation, the electrons change their dispositions within the molecule and two new short lived species are obtained. The most important of the two, for our purposes, is the one on the left of Figure 7 that is called **singlet oxygen**. This new more energetic species is far more reactive than its lower energy form. Singlet oxygen is very likely to take part in unwanted chemical reactions such as are necessary to trigger DNA mutations. At the present time, we cannot discount the possibility of a serious role for singlet oxygen in the initiation mechanisms for cancer. The excited state chemistry of oxygenated hemoglobin can not, so far, be properly understood by the scientific community or others would perhaps have already proposed these ideas before me. When scientists come close to recognizing this possibility they use the expression **oxidative stress**[1] whilst never offering a deeper explanation.(Cynically, my own criticism is that the term is too often used when the user has no idea of the mechanism involved.) There are many opportunities for the oxygenated hemoglobin molecule to absorb non-ionizing radiation and generate the kinds of long-lived intermediate species with the ability to cause genetic mutations.

It is well understood that oxygen binds to hemoglobin in the lungs and is then transported around the body to fuel the various biological mechanisms that keep us alive and with our cells functioning properly. However the exposure of oxyhemoglobin to radiation that is non-ionizing is likely to create a reactive species that is quite capable of causing mutations to DNA. Even accepting the fact that this process might be very small - indeed, it may even be exceedingly unlikely - but still enough to result in a trigger for cancer. I believe this mechanism has been grossly ignored for decades.

Molecular Orbital Theory - Singlet and Triplet States

Building upon the ideas shown in Figures 1 to 3, we now consider Figure 4. Chemical molecular orbital theory deals with the changes to the distribution of electrons in the bonding orbitals in molecules rather than atoms. The theory describes how molecules change in shape and reactivity depending upon their energy content. Quantum chemistry requires the assignment of ids to each electron in an atom; no two electrons may have the same quantum id. Spatially, electrons are distributed very differently around the nucleus of an atom, ranging from being tightly bound and close to it, to being more loosely bound and much more distant from the nucleus. Generally it is only the outermost atoms that are involved in chemical processes as are being discussed here. These are the electrons that create real substances and hold the molecules together in bonds.

Electrons occupy space around the nuclei called **orbitals** and these can be identified as s, p, d and f orbitals. Inside each orbital there can be 0, 1 or 2 electrons and, having a property called **spin** (with two

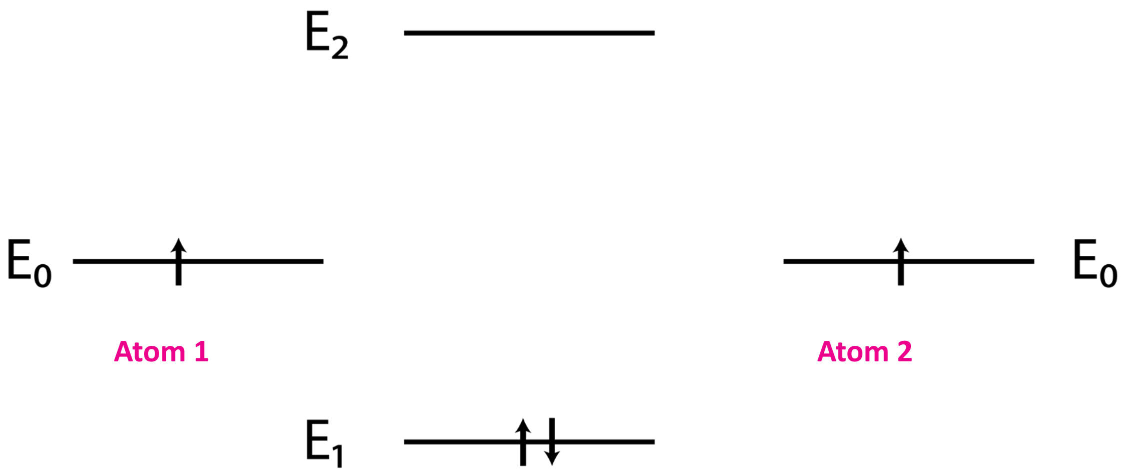


Figure 4: Molecular Orbital Theory: Two atoms having a single unpaired electron (arrow up) in an orbital E_0 join to make a molecule having one ground state orbital E_1 in which the two electrons occupy space with spins paired (one arrow up and the other down). The excited state E_2 is available but empty (no arrows). When energy is absorbed by the bond, an electron can become excited (it jumps from E_1 to E_2) and occupies half of the available space in the excited state, E_2.

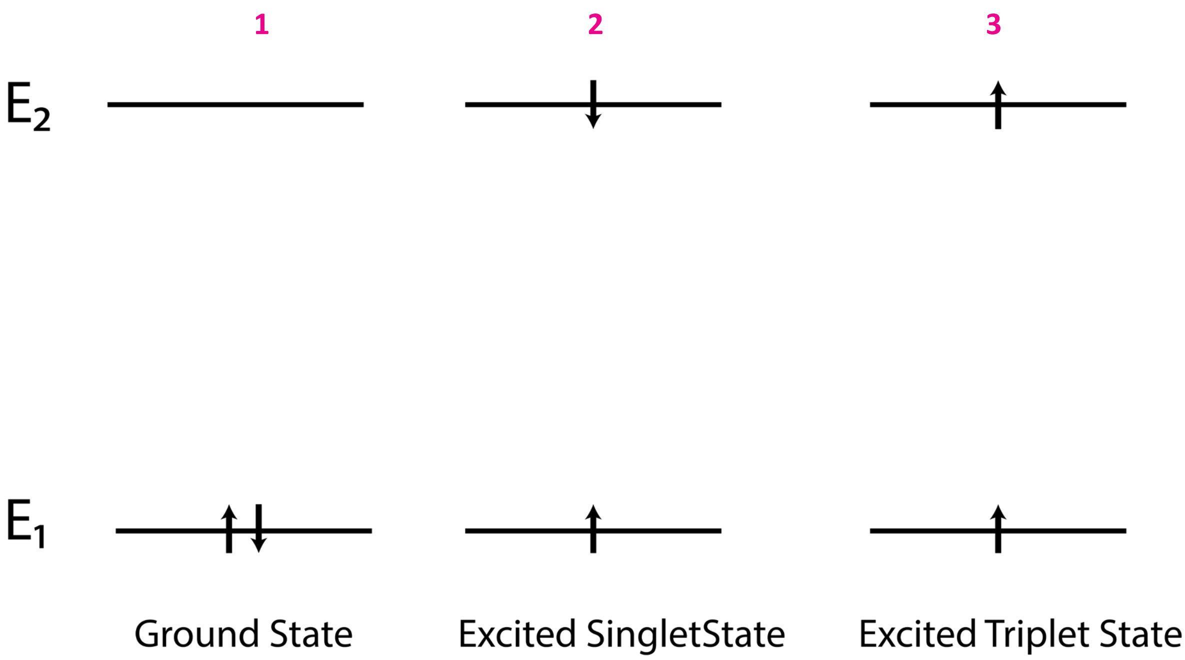


Figure 5: Molecular Orbital Theory: 1. Electrons in the ground state orbital, E_1,can absorb energy such that one electron is promoted (jumps up) into the excited state, E_2. 2. If one electron has spin +1/2 (arrow up) and the other has spin -1/2 (arrow down) then it is called an excited singlet state. 3. If both electrons have spins up (or both spins down) as shown, then it is called an excited triplet state.

values of either +1/2 or -1/2). They must have spins paired, with one +1/2 and the other -1/2 when in the same orbital. Each bond or orbital has an energy that is usually a fixed quantity for the given configuration.

When multiple s or multiple p orbitals of, say, two atoms interact in molecular bonds, new orbitals are created. For example, in Figure 4 we have Atom 1 and Atom 2 each with a single electron in energy level (orbital) E_0. When brought together from a remote distance, these two orbitals interact. The total number of orbitals (in this case 2) remains the same before and after the interaction. The result is one new orbital E_1 and another E_2 where $E_2 > E_0 > E_1$.

The level E_1 is called the ground state molecular orbital and E_2 the excited state molecular orbital. Generally, before interaction, there will be one electron in each orbital and so the two electrons occupy the ground state, E_1, with spins paired. (Although I show the electrons in Atom 1 and Atom 2 both with spins up, they are not allowed to retain these spins in the new ground state - one of them must change to become paired with the other.) This now represents the chemical bond between the two atoms. The original levels E_0 are typically midway between the E_2 and E_1. If an amount of energy equivalent to (E_2-E_1) is available in the environment, such as from an electromagnetic field, then one of the two electrons in the ground state can absorb the energy and be "promoted" (raised) from E_1 into the excited state E_2. We say that the molecule is in the excited state because it has acquired extra energy in addition to that which it had in the ground state.

We now consider electron spins. The single electron that was prompted to the level E_2 by the absorption of energy may retain its original spin (which was opposite to the electron still in the ground state, level E_1). Because the spins remain paired the state is an **excited singlet state**. However, the electron in the excited state E_2, may flip its spin such that it is the same as the electron in the ground state E_1. In this case, either both electrons have spin +1/2 or both -1/2. We call this an **excited triplet state**. Singlet states are known to have very short lifetimes compared with triplet states. If a molecule reaches a triplet state because of absorption of radiation, its lifetime may be long and it may have a much greater time in which to undergo chemical reaction. However, if the molecule is in the singlet state its lifetime is generally very short and therefore there would be little time available for a reaction to take place. Most of the time excited states are singlet states and this is used as an explanation for why non-ionizing radiation might be considered harmless to chemical species: the lifetime is too short for it to undergo chemical reaction leading to harmful effects.

The argument used in the past to support the thesis that non-ionizing radiation does not cause deleterious health effects is that the lifetime of the excited singlet state is too short for it to be involved in intermolecular (molecule-to-molecule) chemical processes, i.e. of the order of 10^{-14} s or less. This is far too simplistic. I believe there are many situations in which excitation of molecules into singlet states by absorption of energy can lead to chemical reaction without the requirement of conversion to the triplet state. There has not been sufficient consideration of situations in which either the singlet lifetime is much longer than would be expected or the energy gap (E_2-E_1) between the ground state and the excited state is significantly reduced for some reason yet to be investigated.

Multiple Atom Molecules

Now consider Figure 6. If n orbitals of energy E_0 interact, the result is two new sets of orbitals, one set lower in energy than E_0 and the other set higher in energy than E_0. The lower set occupies a range of energies, E_i , where E_i ranges from E_3 to E_4. This is again called the ground state but the set of orbitals is called a **band**. Bonding electrons occupy all of these ground state levels in pairs (with opposite spins) from E_3 to E_4. When the starting atomic orbitals are p orbitals, the resulting molecular orbitals are called pi (π) orbitals. The upper set of available levels occupies a range of energies, E_j , where E_j ranges from E_5 to E_6. This is called the excited state band of orbitals and is normally empty of electrons because all of the electrons are paired up in the ground state. The molecule can absorb energy corresponding to the energy gaps that exist between the molecular orbitals, E_i and E_j . In the case where two p orbital electrons have created the bond, the energy (E_2-E_1), if absorbed, can raise an electron from the ground state to the excited state. In its excited state, the molecule is very much more reactive and the probability of a chemical interaction with an intimately associated molecule is increased. In a molecule with these pi band orbitals a much broader range of energies can be absorbed. Not only that but smaller energies can now cause excitation because the energy gap (E_5 - E_4) is smaller than the (E_2 - E_1) energy gap in Figures 4 and 5. Overall,

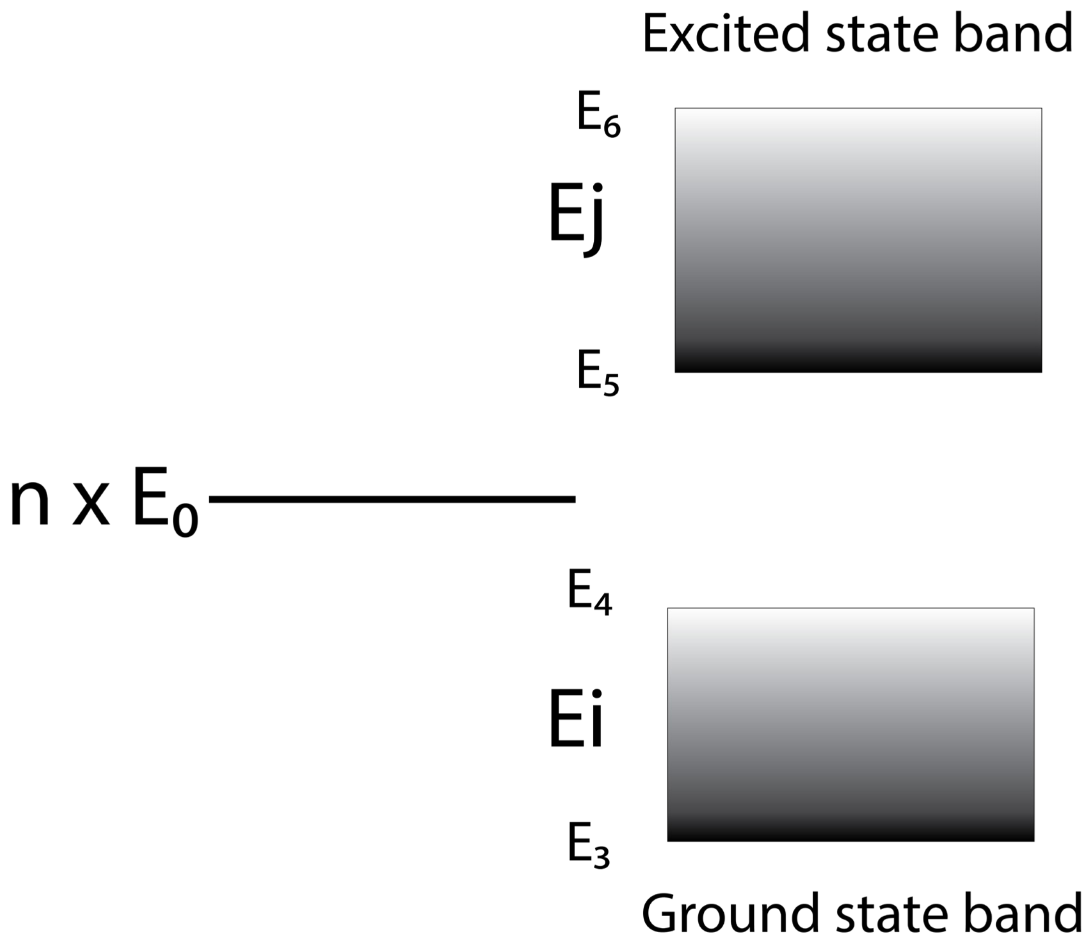


Figure 6: Molecular Orbital Theory: When there are many of the same orbitals in a molecule, i.e. n orbitals each of energy E_0, they interact in such a way as to form bonds that have bands of energy. Thus, the ground state band has orbitals E_i, where the range is E_3 to E_4. The excited state band, Ej , has a range from E_5 to E_6. If there was one electron in each of the starting E_0 orbitals, then the ground state band is half full and the excited state band is empty. Electrons can easily hop up and down within the ground state band, probably by simple changes in temperature. At any time quantum theory allows electrons to occupy levels at the top of the ground state band (E4) from where it requires only an absorption of the amount of energy (E_5 - E_4) to raise it into the excited state band. It is essential to realise that an electron at the top of the E_i band needs only to absorb the energy (E_5 - E_4) to reach the excited state. This is much less energy than is needed in the previous case where the energy required was at least (E_2 - E_1). Thus, in complex biological molecules such as chlorophyll and hemoglobin where there is extensive delocalization of electrons in pi-bonds it is much easier for these molecules to absorb energy and produce excited state chemistry.

the probability of creating excited states is significantly increased, and so is the probability of a chemical reaction with intimately associated molecules. It is usually the case that the species lifetime is significantly lengthened too, which enhances the probability of excited state charge transfer reactions that could be deleterious to health.

Now we arrive at one of the most crucial aspects of this entire argument. Both hemoglobin and chlorophyll are large molecules with many pi bonds caused by overlap of p orbitals. We know for sure that non-ionizing radiation is absorbed by chlorophyll to generate the life-supporting chemical reaction of carbon dioxide into oxygen. I say again - here is chemistry of crucial importance that is brought about by a molecule absorbing non-ionizing radiation. My conclusion is that hemoglobin is very good at increasing the amount of energy absorption and therefore increasing the risk of charge transfer between molecules. Photosynthesis is a natural process, but absorption by hemoglobin is not. The probability of creating genetic mutations is enhanced by such non-ionizing processes in these large, complex molecules that have greatly delocalized electrons in pi-bonds. Indeed, this is part of the reason why we are alive at all because hemoglobin has the ability to react with oxygen - the mechanism that allows us to breathe...

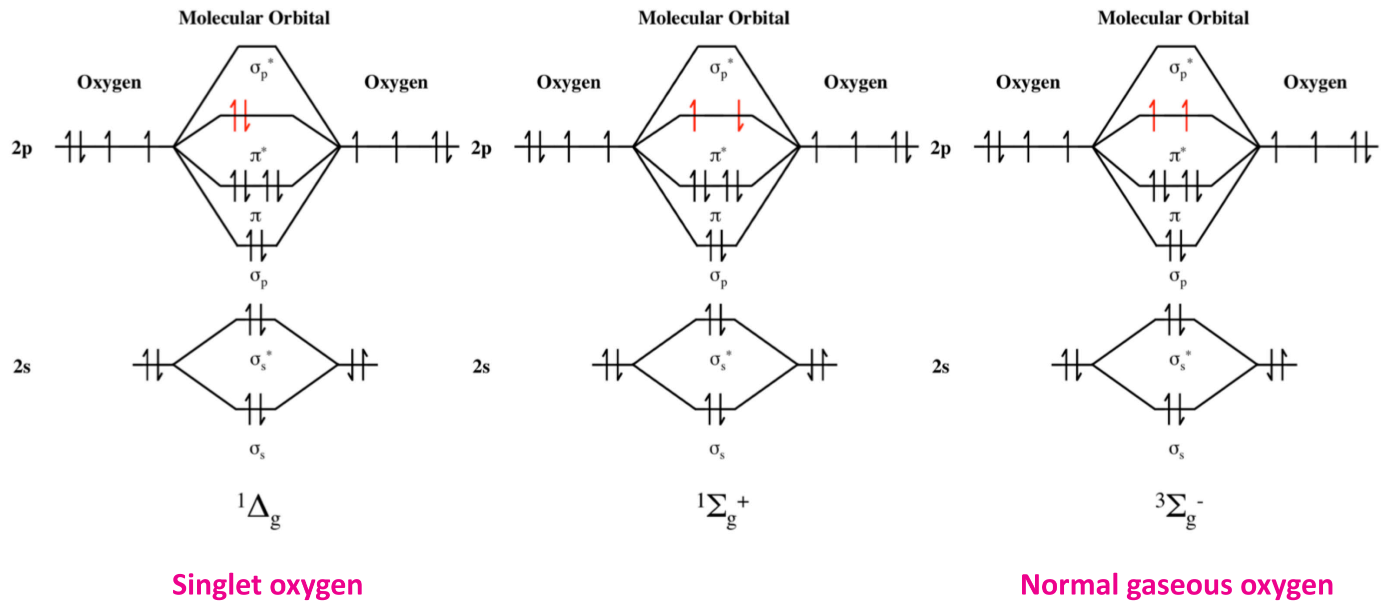


Figure 7: The diagram above shows three ways in which the electrons in two oxygen atoms are redistributed when the oxygen molecule (O_2) is formed.[2] Each electron is represented by a half-arrow pointing either up or down and the diagram is configured so that high energy is at the top and low energy is at the bottom. Since the three different configurations that the O_2 molecule can adopt all have the formula O_2 we see the need to resort to more complex symbols, with Greek letters used to define them more accurately and remove the need to draw each one.

The oxygen we breathe has the molecular structure shown on the right above and is given the symbol $^3\Sigma_g^-$. The important thing is that there are two electrons with the highest energy - shown in red, with both arrows pointing up (spins parallel). Of the two others shown, the most significant for this study is the one on the left, denoted by $^1\Delta_g$ and commonly referred to as 'singlet oxygen' (although the one in the middle is also a singlet state!) This singlet oxygen has its two most energetic electrons with spins paired (one pointing up, the other down.) The energy difference of 94.3 kJ/mol between ground state and singlet oxygen corresponds to a forbidden singlet-triplet transition in the near-infrared at ~1270 nm. We note that even though the process is formally 'forbidden', it can still occur. Singlet oxygen can exist for significant amounts of time - for example, in the gas phase it is extremely long lived (72 minutes).[3] In other environments such as are found in vivo its lifetime is far less, but cannot be ignored.

My own research[4] investigated the formation of singlet oxygen by means of a process called sensitization in which a chemical species that absorbs visible light (e.g. a dye) passes its acquired energy to the triplet oxygen molecule, allowing it then to participate in chemical reactions. The dye acts as a third-party or intermediary, promoting the creation of singlet oxygen by a mechanism that would not otherwise occur. In photochemistry, this is the way processes that are formally forbidden by the rules of quantum physics are overcome.

Why does all this matter? It is crucial to stress here that we do not require anything like 100% efficiency here; even if an otherwise forbidden process is given an efficiency of a fraction of one per cent, a dangerous chemical reaction that could lead to a DNA mutation can still occur.

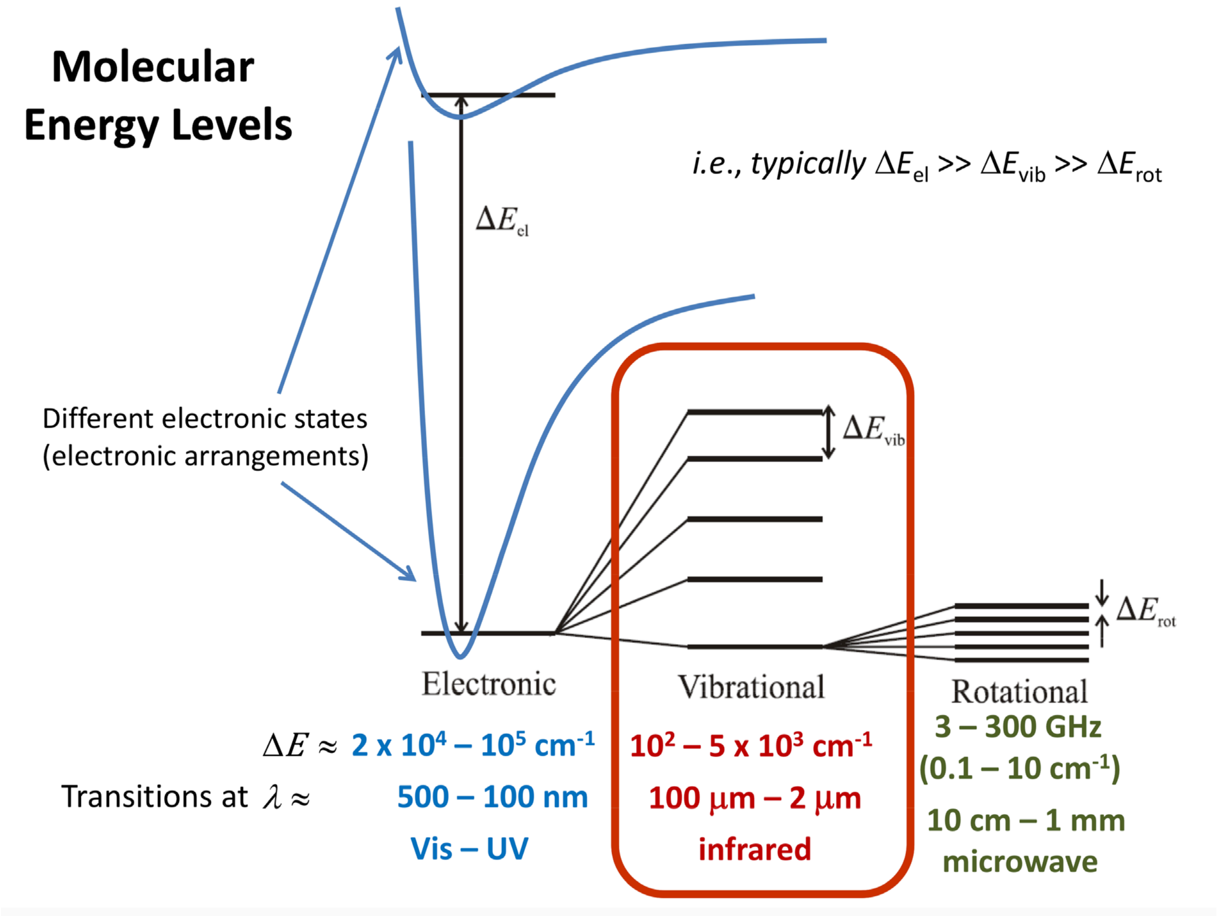


Figure 8: A schematic diagram used to indicate the relative energy differences between electronic, vibrational and rotational molecular energy levels.[5] Considerations of ionizing radiation only concern the loss of electrons by energy absorptions in the electronic levels on the left. The essence of this thesis is that excited state (more reactive) chemical species can arise from absorption of non-ionizing radiation in the vibration and even the rotational energy levels. These levels become much closer when there is extensive delocalization in the bonding of complex molecules such as chlorophyll and hemoglobin. We all know how microwave cookers cause heating of food. This is because of the absorption of microwave (non-ionizing_ radiation into the water molecules of the food, shown in Figure 14. It is highly likely that complex organometallic molecules can absorb non-ionizing radiation and lead to reactive intermediate species.

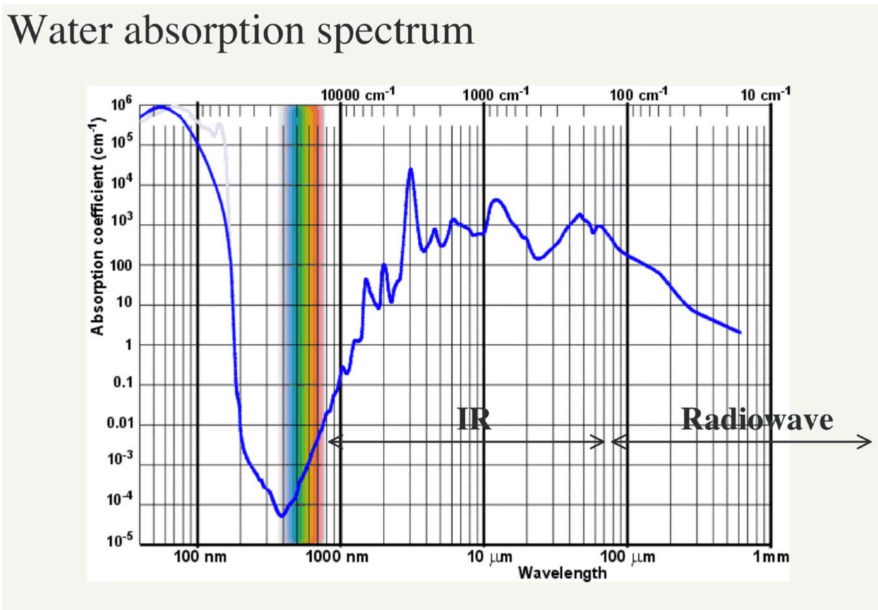


Figure 9: A Spectrum for the Absorption of Electromagnetic Radiation by Water.[6] We note that water absorbs radiation across most of the electromagnetic spectrum, but little in the visible range. Its great absorbancy in the region 100 cm^{-1} forms the basis for our 'microwave' ovens.

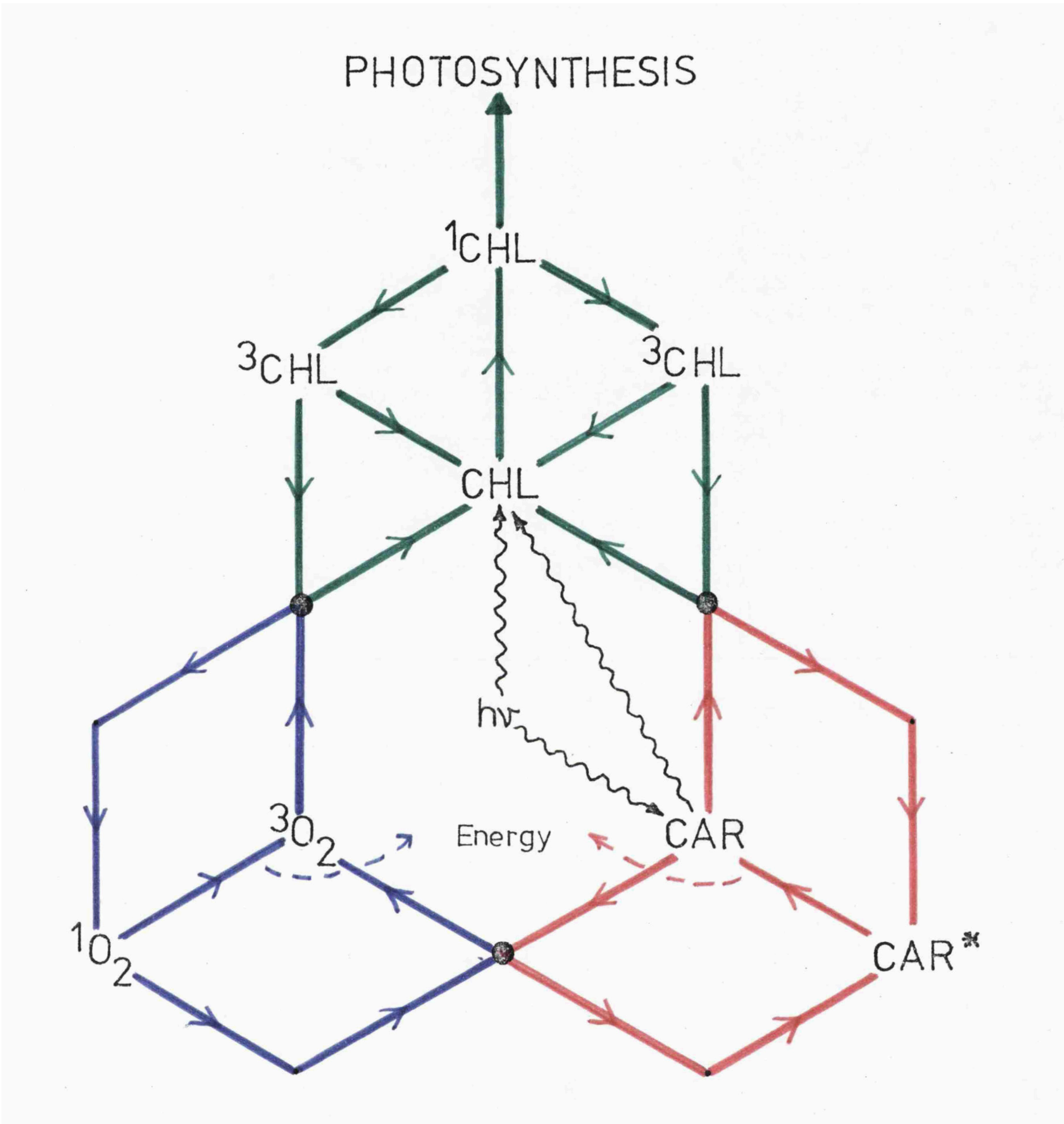
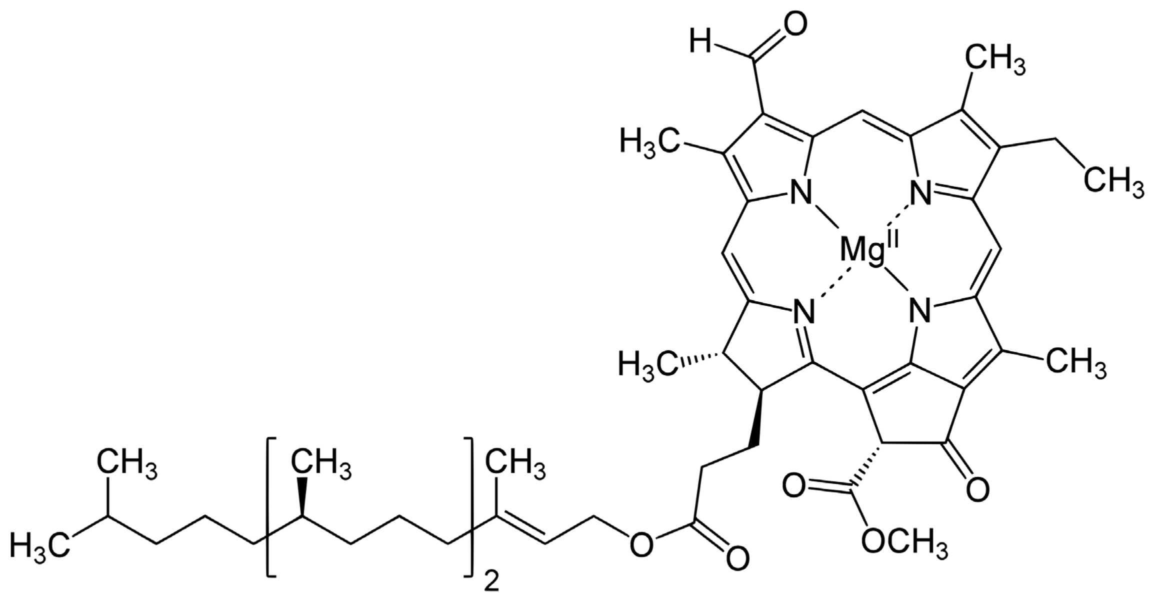


Figure 10: A schematic diagram invented by this author in 1976 [18] to illustrate the excited state interactions between chlorophyll (CHL), oxygen (O2) and β-carotene (CAR). Since then, other biomolecules have been suggested as playing similar roles in photosynthesis and the self-protection mechanisms of chlorophyll (below) from the ravaging effects of singlet oxygen.



Endnotes

1 Oxidative Stress is a term used to describe a deleterious process on tissue and cell structures caused by oxidation reactions that generally involve loss of electrons from one species to another. Electrons are not lost by outright removal, as they are under ionizing radiation, but by other means of electron transfer such as are described here.

2 Angelo Frei: Molecular orbital scheme for triplet oxygen and the two forms of singlet oxygen. (2013) Published under the Creative commons License.

3 Wikipedia: Singlet Oxygen; downloaded 31 Oct 2019.

4 Davidson R S, K R Trethewey, “The geometrical requirements for fluorescent intramolecular exciplex formation and fluorescent quenching.” J. Chem. Soc. (Chem. Comm.), 1976, 827.

4a Davidson R S, K R Trethewey, “The role of the excited singlet state of dyes in dye-sensitised photo- oxygenation reactions.” J Amer. Chem. Soc., 1976, Vol. 98, 4008.

4b Davidson R S, K R Trethewey, “Factors affecting dye-sensitised photo- oxygenation reactions.” J. Chem. Soc. Perkin II, 1977, 169.

4c Davidson R S, K R Trethewey, “Photo-sensitised oxidation of amines: mechanism of the oxidation of triethylamine.” J. Chem. Soc. Perkin II, 1977, 173.

4d Davidson R S, K R Trethewey, “Concerning the use of amines as probes for participation of singlet oxygen in dye-sensitised photo- oxygenation reactions.” J. Chem. Soc. Perkin II, 1977, 178.

4e Davidson R S, K R Trethewey, Beddard G S, “Quenching of chlorophyll fluorescence by beta-carotene.” Nature, 1977, Vol. 267, 373.

4f Davidson R S, K R Trethewey, Whelan T, “The quenching of excited singlet states of Rose Bengal by bi-functional compounds.” J. Chem. Soc. (Chem. Comm.), 1978, 913.

4g Davidson R S, K R Trethewey, Joussot-Dubien R, “Intramolecular quenching of the excited singlet state of a naphthyl group by halogeno substituents.” Chem. Phys. Letts., 1980, Vol 74, 318.

5 http://mackenzie.chem.ox.ac.uk/teaching/Molecular%20Vibrational%20Spectroscopy.pdf

6 https://www.physics.uoguelph.ca/~garrettp/teaching/PHY-1070/lecture-23.pdf

Hemoglobin and Oxygen

In recent years there is increasing understanding of the mechanisms in which hemoglobin participates in transfer of electrons through biological systems without ever invoking ionizing radiation.[1]

The hemoglobin molecule is well known as a component of blood cells that provides the crucial chemical structural element to carry oxygen around our bodies (Figures 11 and 12). When oxygenated, it becomes red and when it does not carry oxygen, perhaps with the oxygen substituted by carbon dioxide on the way out of the human body, it makes blood appear blue. Hence, arteries with oxygenated blood cells are red, veins with de-oxygenated blood cells are blue. The very colour - red - tells us that radiation is being efficiently absorbed across the visible spectrum, much more so than were the molecule to be colourless. A similar example is offered by the photosynthetic material - chlorophyll, well known to be at the heart of the fundamental life-giving process of photosynthesis whereby a molecule, rather like the one shown above, but with magnesium at its centre actually absorbs visible radiation from sunlight - leaving it green, and invoking strong chemical reactions that convert carbon dioxide (CO2) into oxygen (O2). Here we see how the absorption of visible light is essential for the chemistry and changes to molecules that keep us alive. In hemoglobin, the oxygen-carrying capacity is provided by the iron (Fe) atom at the centre of the molecule to which an oxygen molecule makes a bond directly onto the iron. Clearly, any process that interferes with the iron content or its ability to bond to oxygen is seriously detrimental to our breathing. Carbon monoxide (CO) is very toxic because it bonds with the iron to form a strong bond that is difficult to break. Once the Fe atom is bound to CO, the site is not available for bonding to O2 and breathing is impaired. Once our blood cells have a high concentration of CO-bonded hemoglobin, they can no longer give us the oxygen that we need to stay alive and we suffocate. This carbon monoxide 'poisoning' is hard to reverse. To some extent this is a distraction, but I hope it helps with the general understanding of the importance of these large chemical molecules.

A second property of hemoglobin is caused by the iron atom at the heart of the molecule (no pun intended!) We all know about the magnetic properties of iron and these are caused by the distribution of the electrons in the atom - a distribution that is not available to magnesium. Without wishing to dive to an even greater depth into chemical and quantum theory, it transpires that iron has four (!) unpaired electrons that give it a great facility to react to magnetic fields. (There are six electrons occupying five d orbitals. Since two of them must be paired in one of the d orbitals, then four must be unpaired in the remaining four d orbitals.) This chemical property tells us immediately that we should expect a strong interaction between iron atoms at the centre of a hemoglobin molecule and an immersive magnetic field. We might predict that the electrons could be affected in ways that affect the electronic distribution across the entire molecule and that new chemistry could be initiated. This is where we realize that we need to consider the role of oxygen.

The Effects of Electronic Structure in Molecules

A person with a basic understanding of the way in which electrons form bonds in a large molecule such as hemoglobin will realise that there is much delocalization of the electrons over a large part of the molecule. Electrons in single covalent bonds are strongly localized between the atoms concerned. However, in cases such as hemoglobin, not just having 'double' bonds, but also 'ring' structures, electrons become much freer to move about within a molecule, and in some cases, such as perhaps the oxygenated hemoglobin molecule, from one molecule to another. This was very much the essence of my PhD thesis, already mentioned.

The typical characteristic of these types of molecules in which electrons are freed up to occupy large spaces across multiple atoms is that it requires less energy to excite them into higher energy levels. The reader should note that this is not an ionization process, but simply a process by which a molecule or, more importantly, a system of interacting molecules can absorb energy and become 'excited' - that is, it carries more energy than it would normally carry. Once a molecule is excited, it may undergo chemical reactions with other systems in the immediate vicinity where, if the new additional energy can be transported, there are new, radiationless pathways such as vibrations, rotations and translations to revert back to the ground state. If an electron is transmitted from molecule (or molecular system) A to molecule (or molecular system) B, then molecule A gains a hole left behind by that lost electron, whilst molecule B gains an additional electron. These intermediate species might be described as ionic because an electron has been lost in one place and gained somewhere else, but in large molecules such as these it is too simplistic to think in this way. The resulting chemistry is governed by what mechanisms are available to that particular group of atoms and the same or similar chemical processes could be possible with these exposures to non-ionizing radiation as to ionizing radiation; **the effect is equivalent to ionizing radiation without actually having absorbed any ionizing radiation**. The excited state species very rapidly interact with other species in the immediate vicinity to find renewed stability by whatever means is possible. The end result is that the system before the absorption of radiation into the hemoglobin molecule is different from the one that pertains after the energy has been lost once more to the surroundings.

This is the explanation as to why blood is especially susceptible to exposure to non-ionizing radiation. It tells us that one of the worst things we can do to our bodies is to fall asleep (or even lie for anything other than the shortest periods) on an electric blanket that is switched on. Many body functions are controlled by minute nervous impulses, usually taken to be tiny electrical currents passing along nerves to the brain. Any interference or alteration of these process caused by flow of stray electrons as a result of the delocalized electrons in excited state hemoglobin molecules or molecular systems has the potential for damage, especially to the brain where there is a high density of electron movement throughout the nerves, memory cells and micro-capillaries. Is it surprising that there have been many questions about possible links between brain tumours and exposure to non-ionizing electromagnetic fields, particularly in children where brains are still developing and much less protected by skull bone thickness?[2]

It is not hard to extrapolate this reasoning to those - especially children - who sleep under exposure to the high electromagnetic fields emitted by overhead power lines, a subject that remains a matter of great dispute, merely because of the very poor amount of serious scientific study. The mechanisms that could lie behind this terrible statistic amongst children (and adults too) are overwhelmingly obvious to those of us who understand the science.

Chemical Conformation

One of the factors that has received little attention is the importance of the conformation (shape) of the molecules involved. Most biomolecules are large. They have large numbers of atoms and consequently take up considerable space. Proteins are examples of large molecules, often termed macromolecules. However, we should be aware that the space occupied by macromolecules is crucial to their functionality. It is the proximity of atom groups of one domain to atom groups in another domain that produces the crucial biological function. Any change to the shape of the macromolecule will interfere with this function. The kinds of effects being discussed here will result in changes to the shape of the molecules. Thus, a macromolecule such as the protein containing hemoglobin is almost certain to undergo changes of shape when there are changes to the disposition of electrons within it. These changes will not only affect the functionality of the molecule, but may then lead to deleterious impacts on genes. In simple substances like water the uneven distribution of electron charge on the molecule leads to the very significant changes of properties between ice and liquid water, even over very small temperature change. The effects of charge transfer interactions on long chain molecules were the subject of research by this author.[1] It is hardly surprising therefore that exposure of hemoglobin to electromagnetic fields that causes change to the electron distribution in this macromolecule lead to new interactions between domains (and may or may not result in charge transfer) and thus cause malfunction in the biomolecules.

Relevant Chemical Equations

Let us represent the reactive component of hemoglobin by the shorthand symbol Hb. We also represent the usual form of oxygen in the air we breathe as $^3O_2$. To distinguish excited states of molecules from their normal states we attach an asterisk (*).

Let us describe the process taking place in the lungs in which an unoxygenated site in the heme molecule absorbs oxygen as:

$$Hb + {}^3O_2 \rightarrow Hb\text{-}{}^3O_2 \qquad (1).$$

We know that this oxygenated hemoglobin (oxyhemoglobin) is carried around the body in the bloodstream to cells where the oxygen is required to fuel a given cell function. In so doing, the hemoglobin

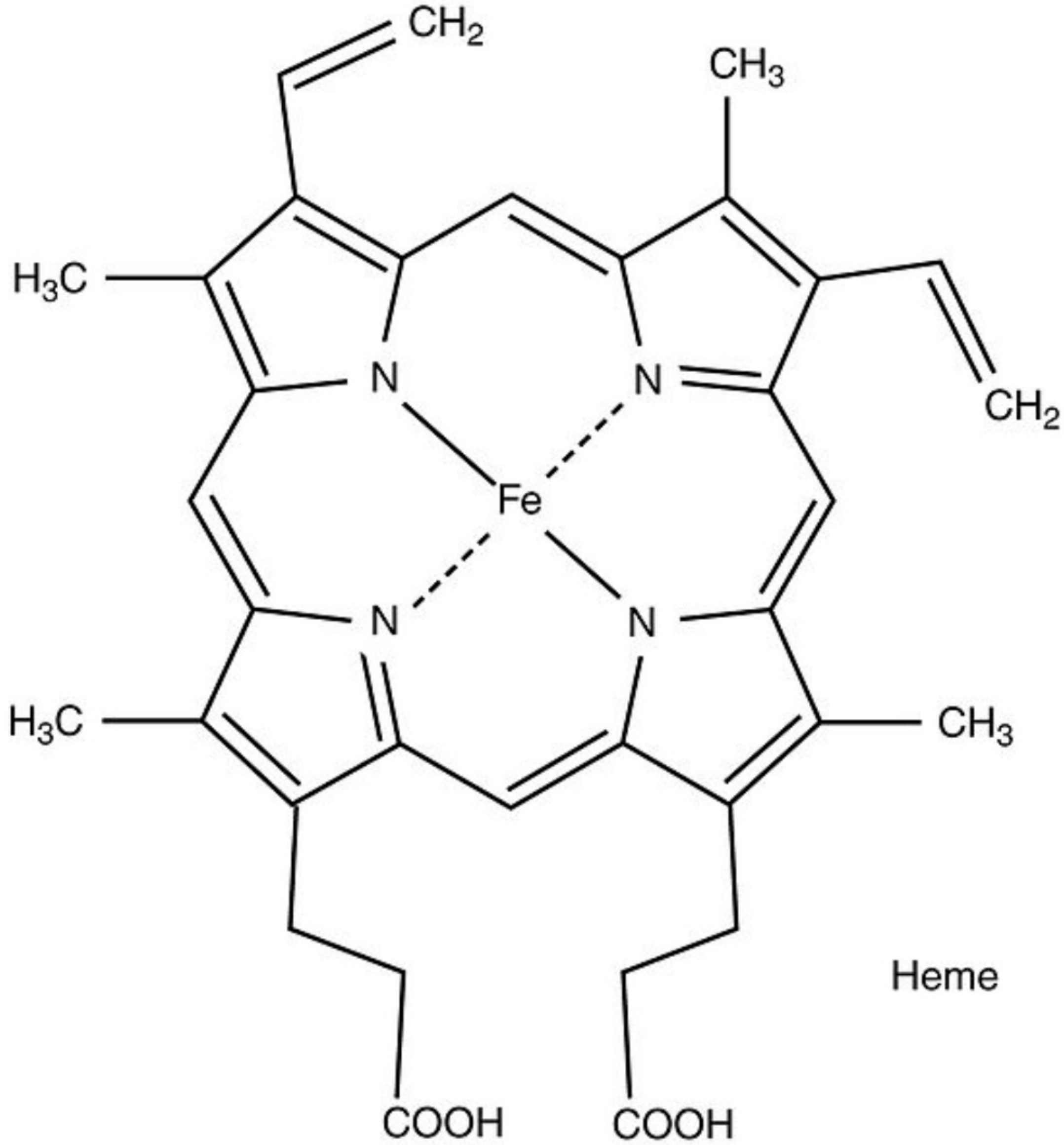


Figure 11: The chemical structure of part of the hemoglobin molecule (a domain) in which the iron (Fe) atom is at the centre with links to the 4 nitrogen (N) atoms. The double lines around the core of the molecule are symbolic of an extensive array of energy bands, as shown in Figure 6. Electrons are free to occupy space around all of these atoms with energies in the range E_3 to E_4. The energy to promote an electron into an excited state is much smaller than in biomolecules not having this kind of structure. This means that non-ionizing radiation is quite enough to cause excited state electron configurations in hemoglobin. The molecular structure shown above is essential to the absorption and desorption of oxygen in respiration and to the delivery of oxygen around the body. However, an excited state of hemoglobin is likely to have different absorption and desorption parameters and this can interfere with the usual oxygenating processes. We note that chlorophyll has a similar structure and it is the absorption of non-ionizing radiation that is essential to all plant life and the inter-conversions between oxygen and carbon dioxide.

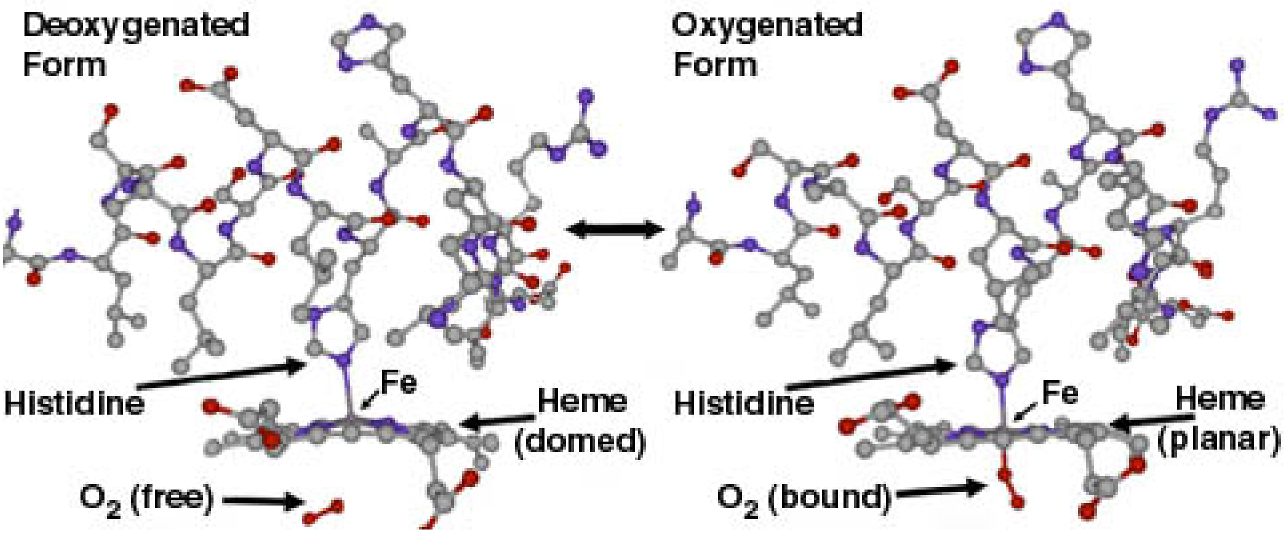


Figure 12: Part of the molecular structure of hemoglobin showing how oxygen is bonded to the iron atom. On the left, the oxygen is unattached and the heme adopts the so-called "domed" conformation (shape). On the right, the oxygen is attached to the iron and the heme becomes planar. With regard to the spelling of the molecule, haemoglobin in English is hemoglobin in US English. Similarly, haeme becomes heme. Although the author prefers to use English, in this report the US spelling is used throughout.

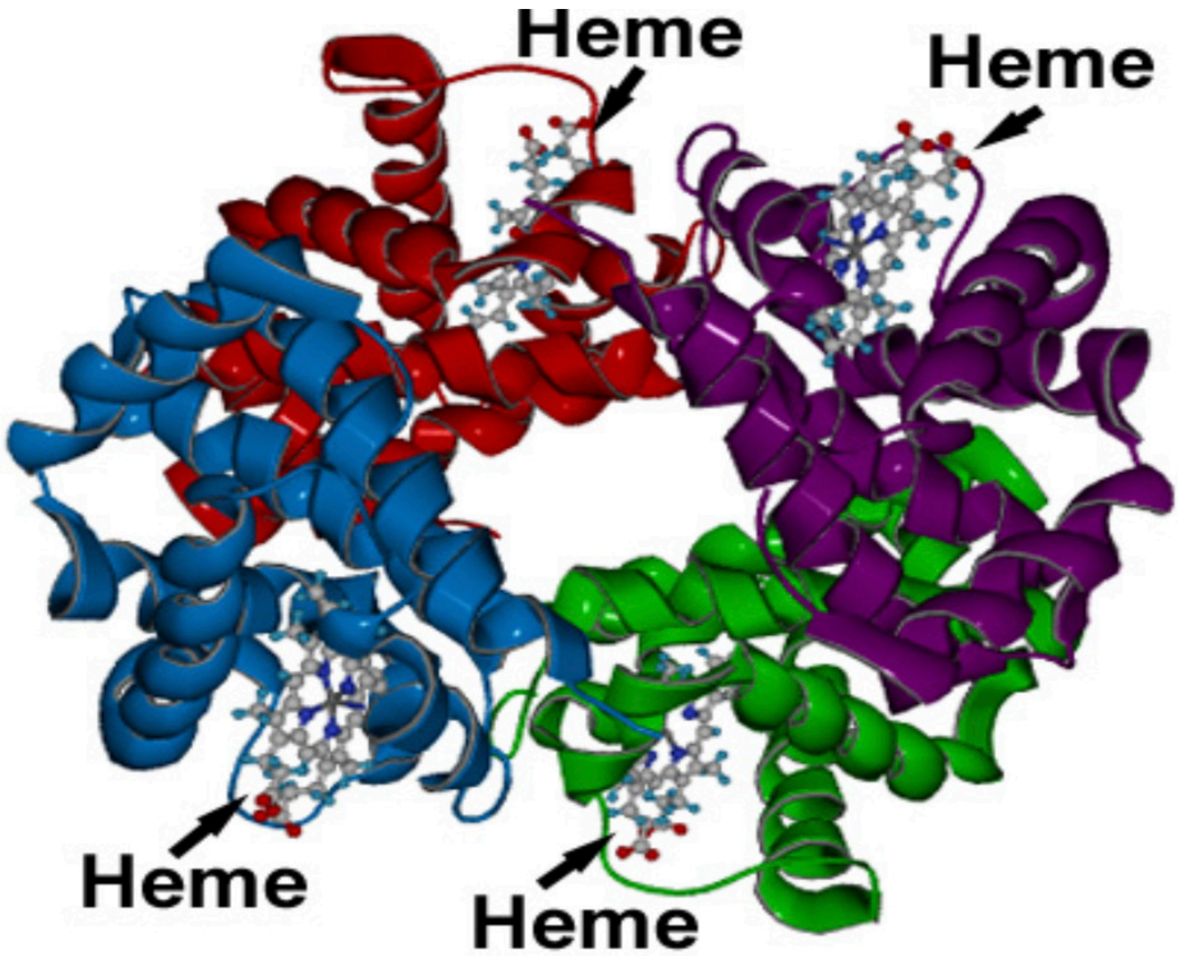


Figure 13: The hemoglobin molecule has four domains, each containing a heme component. Thus each molecule is able to absorb four oxygen molecules. [14]

loses its oxygen molecule thus:

$$Hb - {}^3O_2 \rightarrow Hb + {}^3O_2 \qquad (2).$$

The naked hemoglobin is then circulated back through the veins to the lungs where the oxygenation cycle is repeated.

Let us now consider the situation where the oxyhemoglobin arrives at the site where the oxygen is required for correct cell function. However, this time, the molecule is exposed to energy from non-ionizing radiation that is absorbed and creates an excited state (a packet of energy is usually abbreviated as hv in chemistry. Remember the Planck equation above that stated E = hv):

$$Hb - {}^3O_2 + hv \rightarrow Hb - {}^3O_2^* \qquad (3).$$

I should emphasize at this point that we have created a chemical species that is more likely to undergo an abnormal reaction with nearby molecules because it has been given extra energy than it might otherwise have because of the absorption of non-ionizing radiation, hv. This is my explanation for the mutation to DNA that results in a cancer trigger.

The key question to be asked by scientists at this point is: How long does this excited species exist before it degrades to the safe low energy state once more? The short answer is that we don’t know because to the best of my knowledge the measurements have not been made. However, we do know the lifetime of singlet oxygen (the high energy - excited - state of normal oxygen). We can be confident that when bound to the hemoglobin molecule, the lifetime of the excited state will be significantly longer. We also know that it is the proximity of the reactive species to the site of the unwanted DNA mutation that is crucial, and the closer the two species are, the more likely the mutation is to occur.

A second question concerns the efficiency for which non-ionizing radiation is absorbed by oxyhemoglobin. The epidermis is typically 0.1 mm in thickness, therefore blood vessels contain hemoglobin are very close to the external surfaces of the human body. Any radiation impacting upon the human body is likely to interact with hemoglobin. There are some reports that say that hemoglobin is more absorbent than oxyhemoglobin. Oxyhemoglobin is bright red, whilst the hemoglobin is generally blue. Reflected blue colours indicate absorption in the red end of the spectrum which is close to infrared. Red-reflecting species are absorbing in the blue region which is of shorter wavelength.

Everyone knows that red is associated with the colour of blood and this alone tells us that blood absorbs visible (non-ionizing) light. The absorption characteristics of hemoglobin and oxyhemoglobin are well known and it is surprising that complete studies of absorption of non-ionizing radiation have not already flagged up the possibility that the molecules can absorb non-ionizing radiation at lower energy levels such that new chemistries involving reactive species are highlighted. We also know that when an oxygen molecule is bonded to hemoglobin, its electrons will be strongly delocalized over the entire molecule, enhancing its absorption characteristics and thus stabilising any higher energy species that might be formed - the mutation-enhancing reactive species are given greater stability and longer time to act as cancer triggers.

We can reasonably assume that if this process was extremely common, scientists would have discovered this mechanism much earlier. Therefore we conclude that the process is uncommon, **but not negligible.** Although (1) the lifetime of the excited oxyhemoglobin may be short (2) it may not be in very close contact with the genetic site where mutation occurs, and (3) the reaction efficiency is small, its finite probability is still enough to trigger cancer.

Notes

1 Marian Breuera, Kevin M. Rossob and Jochen Blumbergera: Electron flow in multiheme bacterial cytochromes is a balancing act between heme electronic interaction and redox potentials. PNAS, January 14, 2014, vol. 111, no. 2, pp611–616. www.pnas.org/cgi/doi/10.1073/pnas.1316156111.

J. Peisach, W. E. Blumberg, Beatrice A. Wittenberg, And Jonathan B. Wittenberg :The Electronic Structure of Protoheme Proteins III. Configuration of the heme and its ligands. The Journal of Biological Chemistry, Vol. 243, No. 8, Issue of April 25, PP. 1671-1380, 1963.

Paper on the Electronic structure of iron in hemoglobin

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Myoglobin (symbol Mb or MB) is an iron- and oxygen-binding protein found in the muscle tissue of vertebrates in general and in almost all mammals. It is distantly related to hemoglobin which is the iron- and oxygen-binding protein in blood, specifically in the red blood cells.

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Kara L. Bren : Going with the Electron Flow: Heme Electronic Structure and Electron Transfer in Cytochrome c. Israel Journal of Chemistry: First published: 08 August 2016 https://doi.org/10.1002/ijch.201600021; Volume56, Issue9-10; Special Issue: New Frontiers in Bioinorganic Chemistry, October 2016; Pages 693-704.

Heme is an essential and functionally versatile cofactor. Our understanding of how the environment of a heme in a protein tunes its function has benefited from spectroscopic and functional investigations of heme proteins and their variants with altered heme environments. Two properties of current interest are the conformation of the heme and hydrogen bonding to heme propionates. By combining nuclear magnetic resonance experiments and density functional theory calculations, both of these characteristics have been shown to influence the distribution of the singly occupied molecular orbital on the heme of ferricytochrome c, which affects coupling to redox partners and electron-transfer rates. In addition, heme conformation has been shown to tune reduction potential.

These results reveal that subtle variations in heme conformation and in interactions with its propionates can have significant impacts on electron-transfer activity.

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Dayle M. A. SmithMichel DupuisErich R. VorpagelT. P. Straatsma : Characterization of Electronic Structure and Properties of a Bis(histidine) Heme Model Complex. J. Am. Chem. Soc.2003 125 9 pp2711-2717. https://doi.org/10.1021/ja0280473

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Shin-ichi J. Takayama, Georgia Ukpabi, Michael E. P. Murphy, and A. Grant Mauk: Electronic properties of the highly ruffled heme bound to the heme degrading enzyme IsdI. PNAS August 9, 2011 108 (32) 13071-13076; first published July 25, 2011

https://www.pnas.org/content/108/32/13071

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Eduardo Torres, Marcela Ayala : Biocatalysis Based on Heme Peroxidases: Peroxidases as Potential Industrial Biocatalysts. Springer Science & Business Media, 20 Aug 2010 - Science - 358 pages. Chapter 11 - see screenshot 5.35p 7Jun. Discusses the bonding - strengthening and weakening of the iron 5 and 6 ligands; Vis spectra given

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Good basic description of hemoglobin:

http://mriquestions.com/types-of-hemoglobin.html

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Wiki: Hemoglobin is a metalloprotein. A healthy individual has 12 to 20 grams of hemoglobin in every 100 ml of blood. Hemoglobin is found in many other parts of the body, not just red blood cells.

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https://www.cliffsnotes.com/study-guides/biology/biochemistry-i/oxygen-binding-by-myoglobin-and-hemoglobin/hemoglobin-and-myoglobin

A good article about O_2 binding to hemoglobin:

"When molecular oxygen encounters an isolated heme molecule, it rapidly converts the Fe(II) to Fe(III). The oxidized heme binds oxygen very poorly. Obviously, if this happened to the Fe(II) groups of hemoglobin and myoglobin, the proteins would be less useful as oxygen carriers. Oxidation of the heme iron is prevented by the presence of the distal histidine side chain, which prevents the O 2 from forming a linear Fe–O–O bond. The bond between Fe and O 2 is bent, meaning that this bond is not as strong as it might be. Weaker oxygen binding means easier oxygen release. This is an important principle in understanding not only heme chemistry but also the regulation of hemoglobin's affinity for oxygen.

"The differences between hemoglobin and myoglobin are most important at the level of quaternary structure. Hemoglobin is a tetramer composed of two each of two types of closely related subunits, alpha and beta. Myoglobin is a monomer (so it doesn't have a quaternary structure at all). Myoglobin binds oxygen more tightly than does hemoglobin. This difference in binding energy reflects the movement of oxygen from the bloodstream to the cells, from hemoglobin to myoglobin."

Clearly, the energy state of the hemoglobin will affect the bonding of the oxygen molecule. Whether weakening (more likely) or strengthening (less likely) there is an effect upon the oxygen function. Perhaps oxygen is pleased quickly as singlet oxygen causing damage?

2 Skull thicknesses: average men: 6.5 mm; women 7.1 mm. Skull thicknesses in children ranging from 0 to 3 years old are quoted as in the range 1 mm to 6 mm

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PMCID: PMC4436309

PMID: 25992998

Zhigang Li, Byoung-Keon Park, Weiguo Liu, Jinhuan Zhang, Matthew P. Reed , Jonathan D. Rupp, Carrie N. Hoff, and Jingwen Hu. : A Statistical Skull Geometry Model for Children 0-3 Years Old

Conclusions

Why is there no general agreement about the dangers of non-ionizing radiation? The elucidation of cancer mechanisms has pre-occupied scientific and medical minds throughout the 20th century, but it is really only since more has been revealed about the structure and mechanisms of cells and DNA that real progress has been made. However, the more complete understanding has involved large elements of statistical mathematics and the recording and analysis of millions of medical histories over many decades. Only now is this more complete understanding beginning to emerge. It has been very easy to jump to conclusions in the past, and conclusions drawn this way have generally been shown to be wrong. However, in the 21st century, real progress has been made in the understanding of cancer, its initiation and progression, and its methods of treatment. At last we seem to be approaching the attainment of the dream of a 'cure' for cancer.

Nuclear and other forms of ionizing radiation and their links to cancer have also been studied in great depth, but the answers have been far from simple. Whilst we are certain that ionizing radiation may cause cancer in many forms, it is by no means predictable that some humans, given the same levels of exposure, will definitely contract cancer whilst others will not. Only statistics can be used on large populations to make predictions about overall probabilities. In some cases, notably breast cancer, it is already possible to identify certain individuals from their DNA profiles that have a greater disposition to cancer than others. [1]The current best practice is to define a measure called a 'dose' whereby an individual carries on his or her person a special device called a dosimeter that collects all of the radiation to which that individual is exposed over a fixed time period - typically 1 year. By defining maximum dose levels, it is possible to tell an individual, after inspection of his or her dosimeter, that his annual safe dose has been exceeded and he needs to be protected from further exposure. The nuclear industry defines a safe limit for an industrial worker to be 20 mSv/y. For an ordinary citizen it is 1 mSv/y. Workers in the nuclear industry are not exposed to greater danger by having a much higher safe limit, but it is deemed acceptable because they are given regular health checks that are not necessarily available to ordinary citizens.

Much is known and internationally accepted about the dangers from ionizing radiation. Legislation is in place and enforced in most countries of the developed world and there is no reason to believe (despite what the ill-informed nuclear protest lobby may say) that any individual in these countries is at an unnecessary risk to his or her health.

Unfortunately, the same is not true with non-ionizing radiation. Only a tiny fraction of the necessary scientific studies have been made compared to the much studied effects of ionizing radiation. To make matters worse, the Internet is now causing the proliferation of rumour, speculation and plain bad science that either exaggerates or plays down the risks according to the writer's own biases. We have a great distance to travel, but the two situations of exposure to ionizing and non-ionizing radiation are not at all comparable.

Whilst governments have been content to accept the science behind the health effects of ionizing radiation, there has been a general assumption that non-ionizing radiation cannot be dangerous because it is only of low energy and does not involve actual damage to molecules in human tissue. As I have attempted to show in this paper, this assumption is dangerously incorrect.

Virtually all of us live in environments that are unpolluted by ionizing radiation, and we rightly expect it to be so. However, everyone of us is content to accept environments in our own homes that could well be seriously damaging to our health - over both short term and long term. Not only that, but we are seeing a great increase in our exposures today than we were even ten years ago as the overwhelming increase of wi-fi devices is seen a great benefit to modern living. There are many reports by highly reputable scientists that provide sufficient evidence for us to embark upon an immediate and deep investigation into non-ionizing radiation safety, but governments have been unwilling to take the lead on this issue, especially in view of the fact that, if proven, the remedial action to provide us with safe living environments will be extremely disruptive and expensive. Overall, the likelihood of any substantive change on this issue in the foreseeable future is likely to cause as much argument and inertia as the fight to tackle climate change.

In Summary

1. There is a considerable ground swell of opinion that electromagnetic radiation causes health problems.

2. There is significant pressure amongst the scientific community to treat these concerns with contempt.

3. The presentation of cancer statistics frequently attempts to disguise increases indicated by raw data as being caused by changes in collection techniques.

4. Acceptance of the concerns of the public is too uncomfortable for politicians and industry to take seriously.

5. There are plausible, reasons based in everyday science why living systems should suffer harmful effects when exposed to electric (and magnetic) fields.

6. The current lack of unequivocal evidence for these harmful effects is more due to the complexity of the exposures, combined with a commercial desire to ignore the published evidence, than an indication of harmlessness.

7. Far from getting the health situation under control, society is making things worse by relentlessly increasing exposure of humans to electromagnetic fields.

8. Unless action is taken, we can expect the incidence of diseases of the nervous system, brain tumours and cancers of all types to increase exponentially over the coming years.

Notes

1 The rise in incidences of breast cancer could be described as alarming. The NHS suggests:

"Possible explanations for the increases are speculated to be due to known hormonal risk factors for cancer – such as having children later in life. Increased alcohol intake, another risk factor for breast cancer, could also be involved."

https://www.nhs.uk/news/cancer/breast-cancer-rates-in-under-50s-at-record-high/

Appendix

Throughout this paper I have tried to show that whether or not a person experiences unexpected health problems is a balance of risk, susceptibility and exposure. We are all unique, whether in terms of our biological structure or the environment in which we live and work. This is why it has proved to be so difficult to be precise about the risks to our health from exposure to to non-ionizing radiation.

Some of us will live into old age with no unexplained health impacts. Others amongst us will suffer from problems that appear to defy explanation. In these circumstances I propose here that we should consider the following:

Do you suffer from...

Regular unusual headaches?
Migraines?
Fibromyalgia?
Extreme fatigue?
Unusual nerve symptoms?

Do you...

Sleep with your mobile phone close to your head or body?
Charge your phone close to your head or body at night?
Have other electric devices close to your head at night?
Have bed headboards with inbuilt light switches or power sockets close to your head?
Live close to high voltage electrical transformers or overhead power lines?
Have a microwave cooker close to your head in your kitchen?
Use a microwave cooker many times a day in such a way that you are close to it?
Use a hairdryer frequently or for more than a couple of minutes each day?
Use electrically heated hair dressing devices on a regular basis?
Spend a lot of time with your head inside a hair dryer?
Use wireless or in-ear headphones on a regular basis?
Use any other Bluetooth devices to send signals around your body?
Participate in frequent stage performances or live music or work in media studios?
Have Bluetooth speakers and mobile devices close to your head or body?
Use Virtual reality headsets?
Wear Bluetooth headsets for frequent use in a call centre?
Work amongst dense arrays of electrical equipment?
Work with radio transmission equipment?
Live or work close to or in direct line of sight to a phone mast?
Live or work close to electric powered street furniture outside?
Spend long periods with a mobile phone next to your ear?

Any unexplained health effect should be analysed with careful consideration of the above, especially if the conditions apply in children or in adults over a long period of time.