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The Effect of Light on the Lens Related to Age

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The mechanism behind the ageing of the lens is complex and still not very well understood. The most obvious effect is the decrease of accommodation. An effect that is not so obvious is the change in colour so that certain colours do not reach the retina. The shorter part of the visual spectrum is cut off. It has been shown that artists may react to this change by increasing the amount of blue in objects they know to be blue, i.e. the sea. Another effect of ageing that is obvious to ophthalmologists is the increase in size of the lens, sometimes changing the anatomy of the anterior chamber to such an extent that angle closure may appear.

The lens ages measurably from birth. The factors not related to radiation have been discussed elsewhere, however I will mention briefly the protein changes that could be related to the absorption of radiation. The increase in water-insoluble proteins has been demonstrated. It is obvious that at the same time the character of the proteins will change in lenses with cataract, but not in the normally ageing lens. Even if the amount of high molecular weight proteins seems to increase with normal ageing and is a stage prior to the water-insoluble proteins, the molecules in the range of 10^6d would not result in a light scatter as can be seen in the cataractous lens. There seems to be enough evidence in the literature to state that the formation of cataract is not part of normal ageing and that the different processes we see in the ageing lens are not part of the development of a cataract.

Whenever discussing the interaction between biological tissue and radiation one must take the tissue's action spectrum into account. In most studies performed on the effect of different qualities of UV radiation on the lens, two things are often forgotten: The action spectrum and the fact that the lens in its normal environment will never be exposed to short wavelength radiation. One should also remember that even very small amounts of short wavelength radiation, if they reach the lens, will have a much stronger effect on the lens proteins than radiation of longer wavelengths, of which a greater amount is absorbed in the lens.

The reason for this is that the shorter wavelengths have a much higher energy in their photons, and can also be related to specific absorption. If one starts with the shorter part of the non-ionizing radiation spectrum, that is mainly UV-B, UV-A and near UV, it is obvious that the UV-B does not penetrate the cornea and the aqueous to any great extent. Also the amount of radiation of this quality in the environment is very low. In the UV-A, where part of the radiation can reach even the retina, at least in younger individuals, the absorption in the lens is high, and even if the energy per photon in this range of the spectrum is low, significant changes may take place. Also in the portion of the spectrum described as near UV some of the radiation is absorbed in the young lens. In the ageing lens all the UV and near UV is absorbed and cannot reach the retina.

In recent years the ageing lens has been considered a necessary filter to protect the ageing retina from the shorter wavelengths of light. The resemblance of the lens absorption properties and the absorption properties of the yellow pigment of the macular region, which also increases in density with age, correspond with the hazardous part of the

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blue light. It might be a rather theoretical explanation but it could be a proof of the wise arrangements of nature. However, the relationship between the blue light hazard in animal experiments and the senile macular degeneration that we see in elderly aphakic patients is far from clear. The problems of the ageing retina, and particularly the blue sensitive cones, may very will fit into this picture.

Why does the lens change colour with age? This has been a major question for researchers in the last decade. When radiation is absorbed in the protein molecules, the amount of energy in the photon must correspond with the energy gap between the ground state and the excited state of that molecule. If an excitation takes place, this can result in a number of different things. This absorption takes place mainly in the amino acid tryptophane. Apparently the tryptophane absorbs most of the radiation transmitted by the cornea. This amino acid, however, has a very complex photochemistry. Depending mainly upon the wavelength different events can take place. The presence of certain substances, i.e. indoles, can redirect the photodecomposition.

It is also possible that the presence of other qualities of radiation, such as IR, might influence the photodecomposition that takes place. Also other amino acids, as histidine, might be destroyed as a result of a change in the tryptophane molecule. The conversion to kynurenines as suggested by Pieri, Walrant and Santus creates efficiens singlet oxygen generators and can explain a number of the photosensitised reactions in the lens proteins. Thus any increase in oxygen will increase the photochemical processes. Recently Palmquist and co-workers have shown the deleterious effects on the lens in patients who inhaled very high oxygen levels in order to enhance wound healing.

The very complex role of a number of quenchers should also be taken into account. The role of ascorbic acid and certain carotenes as quenchers to block free radicals and superoxides and bringing excited molecules down to its ground stage, respectively, is of great importance in keeping the normal equilibrium and preventing cataract formation. However, the normal ageing process goes on at a well programmed pace.

At birth the human lens is pale or slightly yellow. With increasing age the lens turns more yellow. At the same time there is an increase in fluorescence that seems to have nothing to do with the changes in tryptophane. Here a change into new components attached to the cytosol proteins is suggested.

From what has been said the increase in the amount of water-soluble proteins, the increase of pigments and chromophores that give the lens a yellow appearance and serve as filters, and the increase of fluorescence are all part of normal ageing and can all be caused by photochemical reactions.

Animal experiments or the examination of human lenses *in vivo* are the basis for most of what we know. Unfortunately, good epidemiological studies on the ageing processes have not been undertaken.

As ophthalmologists we see patients every day and we have a long experience of what the ageing lens looks like in comparison to the cataract. However, we know that only through an optical definition can we separate the two, at least when it comes to the early nuclear cataracts. A few years ago a study on the frequency of cataract among glass-blowers was undertaken in our department. In this study the characteristic true capsule exfoliation could be seen as well as vacuoles in the lens. The result of this study was that glass-blowers' cataract existed, but one of the remarkable results was also that the change in colour of the lens was altered significantly. So also was the number of wedge-shaped opacities. The question arises whether the change in colour was the result of the exposure to infrared radiation or if the infrared could add to the normal ageing process, thus accelerating the ageing of the lens.

When discussing different types of cataract it is obvious that exposure to electromagnetic radiation is a causative factor. There seem however to be no characteristic findings which would separate one radiation cataract from another. The radiant energy seems to interfere with the biochemistry and the metabolism in a way that suggests a more general reaction that would cause pathological changes in the tissue.

When discussing normal ageing, however, one should take the natural radiation environment into account. We know that the exposure to UV radiation is different in different parts of the world. Some epidemiological studies suggest that in areas with many hours of sun the incidence of cataract is increased. However, no studies have been performed concerning the ageing of the lens or if the yellowing of the lens starts earlier in some areas. No studies have looked into the radiation geometry, which it is necessary to take into account as well as the population's natural or artificial ways of eye protection and living habits. In areas where the sun is intense and in zenith a very small part of the body is exposed, and certainly not the eyes. The albedo of the surroundings is of the greatest importance. We know that the sea as well as snow and sand have a great reflectivity, whereas grass does not reflect more than a few per cent. It is therefore an obvious necessity to describe the surroundings in which the individual lives.

The ageing process of the lens is far from understood, even if we know a great deal about the molecular events that take place and the tissue's interaction with radiation. In order to understand this process one has to start epidemiological studies in areas where the populations have differences in their exposure to radiation from the most common source we have—the sun. In such a study we should be aware of the geometry of the radiation and the characteristics of the surroundings. It is also of importance to repeat experimental studies where the action spectrum of the lens to different parts of the electromagnetic spectrum is taken into consideration, and also to consider the normal environment of the lens behind the tearfilm, the cornea and the aqueous humour.