2.0 Evidence That Exposure to EMF Radiation Can Cause Adverse Biological Effects to Eyes

Of the twenty one (21) positive studies listed below on the biological effects of EMF, nonthermal, non-ionizing radiation exposure on eyes, only one (1) study (marked with an *) has been included by AGNIR (2012 & 2003) or SCENIHR (2007, 2009) in their reviews of the evidence for biological effects of EMF radiation, even though many of these studies were published during the same time frame of their reviews. The conclusions of the AGNIR and SCENIHR reviews of evidence have been criticized by many other scientists for omitting relevant research. With the exception of Zareen et al, all studies on this list were compiled from peer-reviewed, published scientific reviews of evidence. Other groups of scientists have reviewed these studies and have concluded that there is evidence to support the conclusion that exposure to low level, nonthermal EMF/RF radiation causes adverse biological effects on eyes.

Effects On Eye Lens Transparency:

1. *Bormusov E, P Andley U, Sharon N, Schächter L, Lahav A, Dovrat A. ***Non-thermal electromagnetic radiation damage to lens epithelium.*** Open Ophthalmol J. 2008 May 21;2:102-6. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2694600/ **Abstract:** Exposure to 1.1 GHz , 2.22 mW microwaves caused a reversible decrease in lens optical quality accompanied by irreversible morphological and biochemical damage to the lens epithelial cell layer. The effect of the electromagnetic radiation on the lens epithelium was remarkably different from those of conductive heat. The results of this investigation showed that electromagnetic fields from microwave radiation have a negative impact on the eye lens. The lens damage by electromagnetic fields was distinctly different from that caused by conductive heat.

2. Carpenter RL.***Ocular effects of microwave radiation***. Bull N Y Acad Med. 1979 Dec;55(11):1048-57. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1807757/pdf/bullnyacadmed00125-0084.pdf Excerpt: Having determined the cataractogenic threshold for a single dose, it was found that a microwave dose incapable of producing apparent effects when applied only once might cause a lens opacity if applied repeatedly atregular intervals. The earliest identifiable effect of microwaves on the eye occurs within 18 hours, a decrease of more than 20% in the concentration of ascorbic acid in the lens. Radioautographic studies have demonstrated that a single cataractogenic exposure inhibits DNA synthesis and mitosis in lens epithelial cells; recovery does not begin until the fifth day postirradiation, and takes 10 days to two weeks. Histopathological studies of microwave cataract development in the rabbit eye reveal that the primary change occurs in the lens epithelium. *Irradiated epithelial cells at the lens equator migrate posteriorly under the capsule, meanwhile undergoing mitotic cell division, so that a posterior epithelial layer becomes aberrantly formed. Large spherical or ovoid "balloon cells" appear around the sixth day at the equator and in the posterior subcapsular cortex. In many cells small vesicles accumulate and coalesce to form cystic cells which may unite with others and form larger cystic spaces.* Measurement of the thickness of the posterior capsule reveals no significant differences between irradiated and nonirradiated lenses.

3. Dovrat A, Berenson R, Bormusov E, Lahav A, Lustman T, Sharon N, Schächter L**.** ***Localized effects of microwave radiation on the intact eye lens in culture conditions.*** Bioelectromagnetics. 2005 Jul;26(5):398-405 http://www.ncbi.nlm.nih.gov/pubmed/15887253 **Abstract:** A novel experimental system was used to investigate the localized effects of microwave radiation on bovine eye lenses in culture for over 2 weeks. Using this setup, we found clear evidence that this radiation has a significant impact on the eye lens. At the macroscopic level, it is demonstrated that exposure to a few mW at 1 GHz for over 36 h affects the optical function of the lens. Most importantly, self-recovery occurs if the exposure is interrupted. At the microscopic level, close examination of the lens indicates that the interaction mechanism is completely different from the mechanism-causing cataract via temperature increase. Contrary to the latter's effect, that is particularly pronounced in the vicinity of the sutures and it is assumed to be a result of local friction between the edges of the fibers consisting the lens. Even if macroscopically the lens has recovered from the irradiation, microscopically the indicators of radiation impact remain.

4. Van Ummersen CA, Cogan FC. ***Effects of microwave radiation on the lens epithelium in the rabbit eye***. Arch Ophthalmol. 1976 May;94(5):828-34. http://www.ncbi.nlm.nih.gov/pubmed/1267658 **Abstract:** These experiments were conducted to determine the effect of cataractogenic doses of microwave radiation at 2.45 gigahertz (GHz) on the lens epithelium of the rabbit. One hour before animals were killed, tritiated thymidine was injected into the anterior chamber of both eyes at postirradiation intervals varying from six hours to one month. Epithelial peels were made and autoradiographic techniques used to identify cells manufacturing DNA. Comparison of counts from both experimental and control epithelia revealed two patterns, depending on the presence or absence of vesicle strings. Those lenses without vesicle strings showed an initial pronounced suppression of mitotic activity followed by gradual return to normal levels. Those lenses with strings showed a precipitous rise in DNA synthesis on the fourth to fifth day after irradiation. This increased activity may be the result of lens hydration.

5. Wang KJ, Yao K, Lu DQ**.** ***[Effects of different dose microwave radiation on protein components of cultured rabbit lens].*** Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 2007 Apr;25(4):208-10. Chinese. http://www.ncbi.nlm.nih.gov/pubmed/17535651 [conducted at 2.45 GHz frequency] **Abstract:** Microwave radiation higher than 1.00 mW/cm(2) can affect the proportion of WSP and USP in cultured rabbit lens, and cause changes of lens transparency and refractive power, which leads to lens opacity

6. Wang KJ, Yao K, Tan J, Lu DQ, Jiang H. ***[Effects of microwave radiation on lens hydration and expression of PKC-alpha and transcription factors in lens epithelial cells].*** Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 2007 Aug;25(8):456-9. http://www.ncbi.nlm.nih.gov/pubmed/17945099 **Abstract:** Low power microwave radiation higher than 2.0 mW/cm(2) can activate PKC-alpha by increasing its expression in cell membrane, then induce high expression of c-fos and c-jun, which may relate to cellular signaling pathway of microwave radiation injury to lens and lens epithelial cells.

Effects On Eye Cell proliferation and Apoptosis:

7. Yao K, Wang KJ, Sun ZH, Tan J, Xu W, Zhu LJ, Lu DQ. ***Low power microwave radiation inhibits the proliferation of rabbit lens epithelial cells by upregulating P27Kip1 expression.*** Mol Vis. 2004 Feb 25;10:138-43. http://www.molvis.org/molvis/v10/a18/ http://www.molvis.org/molvis/v10/a18/v10a18-yao.pdf [conducted at 2.4 GHz] **Abstract:** Purpose: The goal of this study was to examine the effects of low power microwave radiation (<10 mW/cm2) on the proliferation of cultured rabbit lens epithelial cells (RLEC). Conclusions: This study suggests that low power microwave radiation higher than 0.50 mW/cm2 can inhibit lens epithelial cell proliferation, and increase the expression of P27Kip1. These effects may account for the decline of lens epithelial proliferation after exposure to microwave radiation.

8. Ye J, Yao K, Lu D, Wu R, Jiang H***. Low power density microwave radiation induced early changes in rabbit lens epithelial cells.*** Chin Med J (Engl). 2001 Dec;114(12):1290-4. http://www.cmj.org/Periodical/paperlist.asp?id=LW8344&linkintype=pubmed [conducted at 2.4 GHz frequency] **Abstract:** OBJECTIVE: To determine whether low power density microwave radiation can induce irreversible changes in rabbit lens epithelial cells (LECs) and the mechanisms of the changes. CONCLUSION: Low power densities of microwave radiation (5 mW/cm2 and 10 mW/cm2) can induce irreversible damage to rabbit LECs. This may be the non-thermal effect of microwave radiation.

9. Wang KJ, Yao K, Lu DQ, Jiang H, Tan J, Xu W. ***[Effect of low-intensity microwave radiation on proliferation of cultured epithelial cells of rabbit lens].*** Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 2003 Oct;21(5):346-9. http://www.ncbi.nlm.nih.gov/pubmed/14761396 **Abstract:** OBJECTIVE: To compare the effects of different doses of microwave on the proliferative activity and cell cycle of cultured epithelial cells of rabbit lens, and to investigate the limit tolerant of microwave exposure. METHODS: Cultured epithelial cells of rabbit lens were exposed to microwave radiation with frequency of 2,450 MHz and power density of 0.10, 0.25, 0.50, 1.00, 2.00 mW/cm(2) for 8 h in vitro. HE staining was used to observe the morphological changes of lens epithelial cells, the proliferative activity and cell cycle were measured by MTT assay and PI fluorescent staining. RESULTS: 8 h after radiation, 0.50, 1.00 and 2.00 mW/cm(2) microwave could decrease the proliferation of lens epithelial cells, make the cells disordered arrangement, shrinkage, detachment, and inhibit the synthesis of cell DNA. CONCLUSION: Microwave exceeding 0.50 mW/cm(2) may make injury to lens epithelial cells after 8 hour radiation, which may be related to the effect of microwave radiation on cell cycle.

Effects On Eye Cell Gap Junctional Intercellular Communication:

10. Ye J, Yao K, Zeng Q, Lu D. ***Changes in gap junctional intercellular communication in rabbits lens epithelial cells induced by low power density microwave radiation.*** Chin Med J (Engl). 2002 Dec;115(12):1873-6. http://www.cmj.org/Periodical/paperlist.asp?id=LW7290&linkintype=pubmed
Abstract: OBJECTIVE: To demonstrate the changes in gap junctional intercellular communication (GJIC) mediated by low power density microwave radiation in rabbits lens epithelial cells (LECs) and its mechanisms. CONCLUSIONS: Low power densities microwave radiation (5 mW/cm(2) and 10 mW/cm(2)) induces damage to connexin 43 and inhibits the GJIC of rabbits LECs. These changes result in an osmotic imbalance within the lens and induce early cataract. 5 mW/cm(2) or 10 mW/cm(2) microwave radiation is cataractogenic.

Effects On Eye Cell Genetic Toxicology:

11. * Yao K, Wu W, Wang K, Ni S, Ye P, Yu Y, Ye J, Sun L***. Electromagnetic noise inhibits radiofrequency radiation-induced DNA damage and reactive oxygen species increase in human lens epithelial cells.*** Mol Vis. 2008 May 19;14:964-9
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2391079/ **Abstract:** PURPOSE: The goal of this study was to investigate whether superposing of electromagnetic noise could block or attenuate DNA damage and intracellular reactive oxygen species (ROS) increase of cultured human lens epithelial cells (HLECs) induced by acute exposure to 1.8 GHz radiofrequency field (RF) of the Global System for Mobile Communications (GSM). **CONCLUSIONS:** DNA damage induced by 1.8 GHz radiofrequency field for 2 h, which was mainly SSBs, may be associated with the increased ROS production. Electromagnetic noise could block RF-induced ROS formation and DNA damage.

Effects On Eye Cellular Stress Responses:

12. Balci M, Devrim E, Durak I***. Effects of mobile phones on oxidant/antioxidant balance in cornea and lens of rats.*** Curr Eye Res. 2007 Jan;32(1):21-5. http://www.ncbi.nlm.nih.gov/pubmed/17364731
Abstract: PURPOSE: To investigate the effects of mobile-phone-emitted radiation on the oxidant/antioxidant balance in corneal and lens tissues and to observe any protective effects of vitamin C in this setting. CONCLUSIONS: The results of this study suggest that mobile telephone radiation leads to oxidative stress in corneal and lens tissues and that antioxidants such as vitamin C can help to prevent these effects.

13. Bernat R. ***Glutathione concentration and peptidase activity in the lens after exposure to microwaves.*** Acta Physiol Pol. 1985 Sep-Dec;36(5-6):360-5. http://www.ncbi.nlm.nih.gov/pubmed/3837605
Abstract: Differences were found between the control group and the groups of animals exposed to microwaves in which the glutathione concentration in the cortex and core of the lens was decreasing with time in proportion to the number of exposures. Parallel to the number of days of exposure to microwaves the enzymatic activity of carboxypeptidase A and aminopeptidase increased in the cortex of the lens. The observed changes demonstrate cumulation of the absorbed microwave energy leading to changes in the permeability of the capsule and membranes of lenticular fibres which lead to secondary metabolic disturbances in the lens of the eye.

14. Jelodar G, Akbari A, Nazifi S.***The prophylactic Effect of Vitamin C on Oxidative Stress Indexes in Rat Eyes Following Exposure to Radiofrequency Wave Generated by a BTS Antenna Model.*** Int J Radiat Biol. 2012 Aug 15. http://www.ncbi.nlm.nih.gov/pubmed/22892052 **Abstract:** Results: The results indicate that exposure to RFW in the test group decreased antioxidant enzymes activity and increased MDA compared with the control groups ($P < 0.05$). In the treated group vitamin C improved antioxidant enzymes activity and reduced MDA compared to the test group ($P < 0.05$). Conclusions: It can be concluded that RFW causes oxidative stress in the eyes and vitamin C improves the antioxidant enzymes activity and decreases MDA

15. Li HW, Yao K, Jin HY, Sun LX, Lu DQ, Yu YB. ***Proteomic analysis of human lens epithelial cells exposed to microwaves.*** Jpn J Ophthalmol. 2007 Nov-Dec;51(6):412-6. Epub 2007 Dec 21. http://www.ncbi.nlm.nih.gov/pubmed/18158590 **Abstract:** PURPOSE: To study proteomic changes in human lens epithelial cells (HLECs) exposed to 1800-MHz Global System for Mobile Communication (GSM)-like microwaves. METHODS: In three separate experiments, HLECs were exposed and sham-exposed (six dishes each) to 1800-MHz GSM-like radiation for 2 h. The specific absorption rates were 1.0, 2.0, or 3.5 W/kg RESULTS: When the protein profiles of exposed cells were compared with those of sham-exposed cells, four proteins were detected as upregulated. After analysis by ESI-MS-MS and through a database search, heat-shock protein (HSP) 70 and heterogeneous nuclear ribonucleoprotein K (hnRNP K) were determined to be upregulated in the exposed cells. CONCLUSIONS: Two-dimensional polyacrylamide gel electrophoresis combined with mass spectrometry may be a powerful tool for screening potential electromagnetic-reaction protein markers. HSP70 and hnRNP K are involved in the stress reaction of HLECs exposed to microwaves. These cell responses are nonthermal effects of the electromagnetic field.

16. Ozguner F, Bardak Y, Comlekci S. ***Protective effects of melatonin and caffeic acid phenethyl ester against retinal oxidative stress in long-term use of mobile phone: a comparative study***. Mol Cell Biochem. 2006 Jan;282(1-2):83-8. **Abstract:** There are numerous reports on the effects of electromagnetic radiation (EMR) in various cellular systems. Melatonin and caffeic acid phenethyl ester (CAPE), a component of honeybee propolis, were recently found to be potent free radical scavengers and antioxidants. Mechanisms of adverse effects of EMR indicate that reactive oxygen species may play a role in the biological effects of this radiation. The present study was carried out to compare the efficacy of the protective effects of melatonin and CAPE against retinal oxidative stress due to long-term exposure to 900 MHz EMR emitting mobile phones…Retinal levels of NO and MDA increased in EMR exposed rats while both melatonin and CAPE caused a significant reduction in the levels of NO and MDA. Likewise, retinal SOD, GSH-Px and CAT activities decreased in EMR exposed animals while melatonin and CAPE caused a significant increase in the activities of these antioxidant enzymes. Treatment of EMR exposed rats with melatonin or CAPE increased the activities of SOD, GSH-Px and CAT to higher levels than those of control rats. In conclusion, melatonin and CAPE reduce retinal oxidative stress after long-term exposure to 900 MHz emitting mobile phone…

17. Yu Y, Yao K, Wu W, Wang K, Chen G, Lu D. ***Effects of exposure to 1.8 GHz radiofrequency field on the expression of Hsps and phosphorylation of MAPKs in human lens epithelial cells.*** Cell Res. 2008 Dec;18(12):1233-5 http://www.nature.com/cr/journal/v18/n12/full/cr2008306a.html **Excerpt (last**

pargrah): These results indicate that mobile phone radiation can induce an immediate effect in the cytoplasm that activates ERK signaling so as to further induce transcription of a variety of genes , and that long exposure can activate JNK. However, we did not find the activation of p38 after RF exposure. The appearance of p-ERK1/2 and p-JNK1/2, together with Hsp up-regulation, suggests that non-thermal RF exposure can induce the stress response in human LECs. Our results suggest that exposure to RF of wireless communications can induce expression of Hsp27 and Hsp70 and the activation of ERK1/2 and JNK1/2 in human LECs. The induction of Hsp27 and Hsp70, by a non-thermal stress, together with the activation of signal transduction pathways, provides reliable and sensitive biomarkers that could serve as the basis for improved mobile phone safety guidelines.

Comprehensive Scientific *Reviews* of Evidence for EMF Effects On Eyes:

18. Yu Y, Yao K, ***Non-Thermal Cellular Effects of Low-power Microwave Radiation on the Lens and Lens Epithelial Cells***. Journal of International Medical Research, 2010; 38: 729-736. *Review* [Full Copy filed in Docket] **Abstract:** Because of the increased use of modern radiofrequency devices, public concern about the possible health effects of exposure to microwave radiation has arisen in many countries. It is well established that high-power microwave radiation can induce cataracts via its thermal effects. It remains unclear whether low-power microwave radiation, especially at levels below the current exposure limits, is cataractogenic. This review summarizes studies on the biological effects of low-power microwave radiation on lens and lens epithelial cells (LECs). It has been reported that exposure affects lens transparency, alters cell proliferation and apoptosis, inhibits gap junctional intercellular communication, and induces genetic instability and stress responses in LECs. These results raise the question of whether the ambient microwave environment can induce non-thermal effects in the lens and whether such effects have potential health consequences. Further in vivo studies on the effects on the lens of exposure to low-power microwave radiation are needed.

19. Zareen N, Khan MY, Ali Minhas L. ***Derangement of chick embryo retinal differentiation caused by radiofrequency electromagnetic fields***. Congenit Anom (Kyoto). 2009 Mar;49(1):15-9. http://www.ncbi.nlm.nih.gov/pubmed/19243412 **Abstract:** The possible adverse effects of radiofrequency electromagnetic fields (EMF) emitted from mobile phones present a major public concern. Biological electrical activities of the human body are vulnerable to interference from oscillatory aspects of EMF, which affect fundamental cellular activities, in particular, the highly active development process of embryos. Some studies highlight the possible health hazards of EMF, while others contest the hypothesis of biological impact of EMF. The present study was designed to observe the histomorphological effects of EMF emitted by a mobile phone on the retinae of developing chicken embryos. Fertilized chicken eggs were exposed to a ringing mobile set on silent tone placed in the incubator at different ages of development. After exposure for the scheduled duration the retinae of the embryos were dissected out and processed for histological examination. The control and experimental embryos were statistically compared for retinal thickness and epithelial pigmentation grades. Contrasting effects of EMF on the retinal histomorphology were noticed, depending on the duration of exposure. The embryos exposed for 10 post-incubation days exhibited decreased retinal growth and mild pigmentation of the epithelium. Growth retardation reallocated to growth enhancement on increasing EMF exposure for 15 post-incubation days, with a shift of pigmentation grade from mild to intense. *We*

conclude that EMF emitted by a mobile phone cause derangement of chicken embryo retinal differentiation.

20. Frey AH. ***Data Analysis Reveals Significant Microwave-Induced Eye Damage in Humans.*** J Microw Power Electromagn Energy. 1985;20(1):53-5. http://www.ncbi.nlm.nih.gov/pubmed/3847507 [Copy filed in Docket] **Abstract:** Appleton and McCrossan undertook a study for the U.S. Army at Ft. Monmouth to determine if microwave exposure would cause cataracts. They concluded: "The comparison showed the groups (microwave exposed vs. not exposed) to be essentially the same and did not support the hypothesis that human cataracts are being caused by chronic exposure to microwaves in the military environment in this country." There are three major flaws in Appleton and McCrossan's work. First, the exposed group likely included people with little or no exposure. This would tend to minimize the possibility of finding microwave effects. Secondly, their control group consisted of people working with equipment known to cause eye damage. This also would tend to minimize the possibility of finding microwave effects. Thirdly, and most important, they did not do a statistical analysis on their data. When the writer did one, it was found that Appleton and McCrossan have a statistically significant difference between groups, with the microwave exposed showing more lens opacities than would be expected by chance. Thus, their conclusion should have been the opposite of what they stated. It is the uncritical acceptance of negative biological studies of non-ionizing radiation, such as this, that has contributed to the distortion of science in this area of research and has stimulated public opposition to the installation of such energy sources. **Excerpt (pg 55):** The statistical test showed that there are significantly more lens opacities in the microwave exposed group (Chi square 4.2, $p < .05$). This contradicts Appleton and McCrossan's published conclusion. Moreover, if one considers that their experimental design works against finding statistically signifiicant differences, the fact that effects were found suggests that the affect of the microwaves is substantial…It should be noted that three years later Appleton et al reported another similar study (1975) It was also flawed. The fact that the flaws in Appleton and McCrossan's study were not previously reported and discussed raises legitimate questions about what is happening to the scientific process in the area of microwaves bioeffects research. Appleton and McCrossan's study has been quoted over and over again as supposedly scientific evidence supporting radiation is not dangerous. It is the uncritical acceptance of "negative" biological studies of non-ionizing radiation, such as this, as well as misquotation and misrepresentation in the scientific literature, that have contributed to the distortion of science in this area of research (Frey, 1982; 1983; Steneck, 1984). This has led a historian on science, who has made a study of microwave bioeffects research, to conclude: "One major obstacle that has consistently been used to exclude information from U.S. standard-setting efforts is the selected use of scientific rigor." (Steneck, 1984). But more than science is at stake. The conclusions offered in such flawed studies are being used to make decisions that affect the public. The public is being told not to worry, and is then handed such supposedly objective studies, as well as other misinformation, as proof….Is it not time for those concerned with the application of microwave technology to think deeply about the consequences.

21. Cleary S, ed. ***Proceedings of the Symposium on the Biological Effects and Health Implications of Microwave Radiation*** U.S. Department of Health, Education, and Welfare Public Health Service Bureau of Radiological Health, 1970 Review [Copy Filed in Docket] **Excerpt: (pg 80): SUMMARY** 1. The lens is highly susceptible to damage by microwave radiation at several different frequencies, as it is also to damage by ionizing radiation. 2. Lens opacities have been induced by irradiation of the eye at frequencies from 2450 MHz to 10,000 MHz, continuous or pulsed wave.3. Microwave cataracts may

result from a singleincident of exposure or they may develop as the cumulative effect of repeated exposures at power levels low enough so that no single exposure is itself harmful. 4. The radiation dose required for opacity induction, expressed as power density times duration of exposure, is not a constant. *5.* Irradiation causes a rise in intraocular temperature which is related to the power density. However, the induction of lens opacities is not dependent upon a critical temperature. 6. Following irradiation and before opacities appear in the lens, there is a latent period which varies from one to six days. In the case of ionizing radiation the latent period is 25 days or more. The susceptibility of the lens to damage by microwave radiation is unrelated to the age of the animal, as is also the length of the latent period. With ionizing radiation, the younger the animal, the shorter is the latent period. 7. In their development, morphology and histopathology, microwave cataracts are similar to those induced by ionizing radiations. They represent a permanent alteration of lens transparency. 8. Inasmuch as opacities will develop in lenses removed immediately after irradiation and cultured in vitro, it appears that microwave cataracts develop as a direct effect of the radiation on the lens rather than as a result of a change in its intraocular environment. 9. During the latent period preceding onset of an opacity, two specific biological effects which can be identified in the lens are an early marked reduction in ascorbic acid level and an inhibition of DNA synthesis and cell division in the lens epithelium. 10. At the time when opacities first become apparent, there occurs an increase in lens electrolytesand water, suggesting that one result of microwave radiation is an increase in membrane permeability in the lens. 11. There is evidence to suggest that the double or triple "cortical banding" seen by slit-lamp examination as the first visible change in the lens following irradiation may be related to a change in ascorbic acid distribution in the lens cortex