INFRARED RADIATION & SKIN PROTECTION

We have been wrong before. We once believed that the sun circled the earth before Galileo Galilei argued for a new perspective. Sunscreen formulations that attempt to protect us from damaging effects on the skin do not currently protect us from infrared radiation (IR). Infrared rays and their effects are not addressed because they were not considered damaging. A new perspective on IR must be incorporated into sun care.

Whenever the subject of skin damage from the nonionizing infrared rays has come up in the past, it was summarily dismissed. IR rays were thought to be benign because of their relatively low energies and frequencies. Recent evidence, however, has shown that the IR rays, particularly the IR-A rays (see definitions that follow), induce significant free radicals in the dermis and diminish the skin's antioxidant capacity.[1] IR-A radiation has been reported to up-regulate an enzyme that destructs the collagen fibers (the matrix metalloproteinase-1 (MMP-1) expression).[2] Haywood recently reported that the ultraviolet filters used in today's sun care regimens prevent no more than 55% of the damaging free radicals from the sun's UV radiation but none of the IRA-induced free radicals.[3] It is estimated that 65% of the energy generated by the IRA radiation reaches the skin's dermal layers, the tissue responsible for the skin's structure with its fibers, elastin and collagen. IR-A biological effects cause the loss of elasticity and reduced firmness thus causing the formation of wrinkles and the aging of the skin.

Since the topic of infrared radiation has raised new concerns, the resulting damage to the skin and the protocols for protection are an important consideration in all future sun care products. The next two *The Sunscreen Filter* will be devoted to the subject. This month, I will detail the properties of infrared radiation. In May, I will conclude with all the studies examining the biological effects on the skin and the proposed regimens for protection from IR-A radiation. The vast majority of infrared radiation is emitted from the sun, but man-made devices also contribute to its proliferation. It is estimated that more than half (54%) of the sun's radiation is Infrared rays whereas the visible rays are 39% and the ultraviolet rays represent the remaining 7% *(Fig. 1)*.

The intensity of solar radiation varies significantly over the course of the year from minimum solar radiation during the polar winter to 350-400 watts per square meter (a significant amount) in the summer. Over the course of the day, the sun's angle above the horizon influences the intensity of solar radiation; the noon sun, for example, is more intense than the rising or setting sun. Clouds deflect some of the incoming radiation back to space, thereby reducing the amount of radiation that reaches the earth's surface.

First, let's review the electromagnetic spectrum.[4]

Radiation is energy that spreads around us in a wave-like motion. Human skin and hair are constantly subjected to solar radiation. Solar radiation that is visible to the eye is, however, only a very small segment of the total range of the electromagnetic waves *(see Fig. 2)*. We describe radiation via its electrical and magnetic properties. There are many types of radiation emitted around us that can be divided roughly into three regions:

- *Electrical rays* include wireless, Hertzian, radiowaves and microwaves. These rays are generally longer wavelengths (measured in meters) and are associated with lower energies and frequencies than the harmful UV rays.
- *Optical rays* are subdivided into infrared visible, and UV rays.
- *X-rays, gamma rays and cosmic rays* have short wavelengths measured in 10^{-9} to 10^{-15}m and are obviously high in energy and extremely damaging rays.

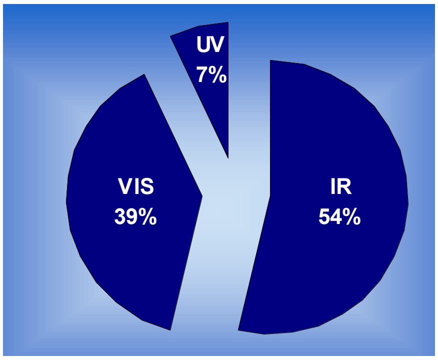

Fig. 1: Radiation emitted from the sun

In the optical region, the UV rays have the shortest wavelengths and the highest energies associated with them. These rays are sufficiently energetic to cause photochemical reactions—termed the photochemical effect—resulting in both immediate and delayed damage to the skin and hair. The visible region, or the light effect, is where the rainbow of the colors of the spectrum is exhibited (violet to red). The longest wavelength (hence,

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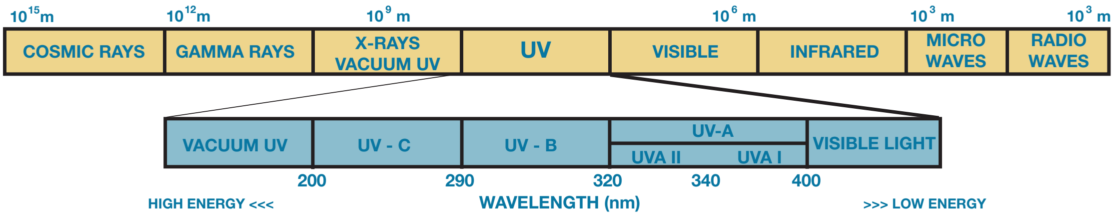


Fig. 2: The electromagnetic spectrum of radiant energy

lower energy) is the infrared region, which is responsible for the heat effect and the generation of most of the free radicals.

These electromagnetic rays are described by a few simple relationships. The first of these relationships is that the Energy (E) of these waves is directly proportional to their frequency (v) (Equation 1).

$$E = hv \quad \text{(Eq. 1)} \qquad v = c/\lambda \quad \text{(Eq. 2)} \qquad E = hc/\lambda \quad \text{(Eq. 3)}$$

Where c= speed of light = 3.0×10^{10} cm/s
h= Planck's constant = 6.62×10^{-27} erg/s

Since the frequency (v) and the wavelength (λ) are inversely proportional to each other (Equation 2), then it follows that the energy (E) and the wavelength (λ) are inversely proportional to each other (Equation 3). To describe the motion of the wave-like rays, imagine tying a rope to a wall and with an upward and downward motion you move the rope. If you do this gently, you will see the rope moving in a wave-like motion, and the waves will be well spaced and with large crests and troughs. If you now accelerate your motion of moving the rope, the intensity of the waves will increase, and the height of the crests and troughs will decrease significantly. As you increase the force you apply to the rope so, too, will its frequency. The wavelength is measured as the distance between two consecutive crests of the wave. See *Fig. 3* below.

The important take home relationship from this description is that as the frequency increases, energy also increases but the wavelength decreases. We measure frequency (V) in cycles per second (cps) or hertz (Hz). The wavelength is measured in meters (A nanometer is 10^{-9} meters) and we measure energy in electron volts *(see the units on Fig. 4.)*.

The ozone layer basically filters the vast majority of the rays emitted above the UVB radiation; i.e., UVC, X-ray, gamma and cosmic rays. The UV rays through the IR rays are emitted freely from the sun down to the earth *(see Fig. 1)*. We all know the damage that is caused by the energetic UVB (wavelengths of 290-320nm) and UVA rays (320-380nm). More importantly, the wavelengths of the UVA rays are longer than those of the UVB. Hence, they penetrate further into the skin *(see Fig. 5)*. That factor has been attributed to the long-term damage of the UVA rays since they will penetrate the skin deeper and, perhaps, reach the cellular and genetic material below the skin despite the fact that their energies and frequencies are weaker than those of the UVB rays.

If you peruse the electromagnetic spectrum further *(Fig. 2)*, you will note that the energy of the visible rays (wavelengths from 400-750nm) are weaker than the UV rays; the energy and frequencies of the infrared rays (750nm to 1mm) are even weaker than the visible (the rainbow). The microwave rays (ovens to heat food only or mobile signal transmissions) and the radio waves have energies and frequencies that are very weak with wavelengths described in meters. Thus, it was generally regarded that the radiation above the UV could not cause any serious damage to the skin; rather, they (IR, microwave, radio, etc.) are important in promulgating new modes of transmission and technological advances. In fact, we all know the beneficial effects of visible rays (and even some

Fig. 4: Wavelength, frequency and energy values of the electromagnetic radiation[5]

Name	Wavelength	Frequency (Hz)	Photon Energy (eV)
Gamma ray	less than 0.01 nm	more than 10 EHZ	100 keV - 300+ GeV
X-Ray	0.01 nm to 10 nm	30 PHz - 30 EHZ	120 eV to 120 keV
Ultraviolet	10 nm - 390 nm	30 EHZ - 790 THz	3 eV to 124 eV
Visible	390 - 750 nm	790 THz - 405 THz	1.7 eV - 3.3 eV
Infrared	750 nm - 1 mm	405 THz - 300 GHz	1.24 meV - 1.7 eV
Microwave	1 mm - 1 meter	300 GHz - 300 MHz	1.24 meV - 1.24 μeV
Radio	1 mm - 100,000 km	300 GHz - 3 Hz	1.24 meV - 12.4 feV

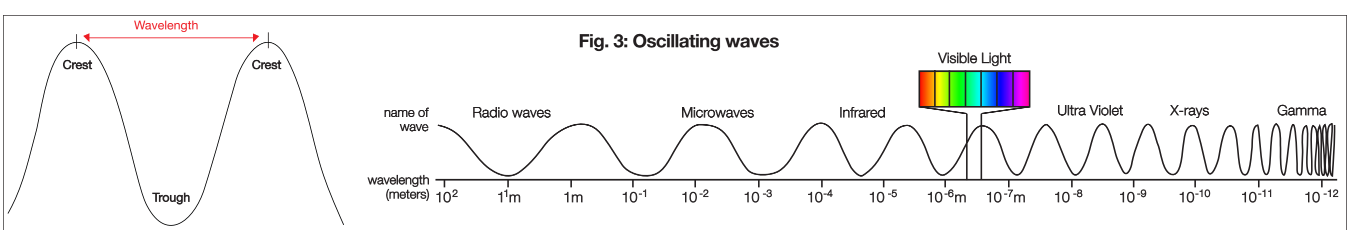


Fig. 3: Oscillating waves

Fig. 5. Relationship between skin penetration and energy of the wavelength of radiation.[4]

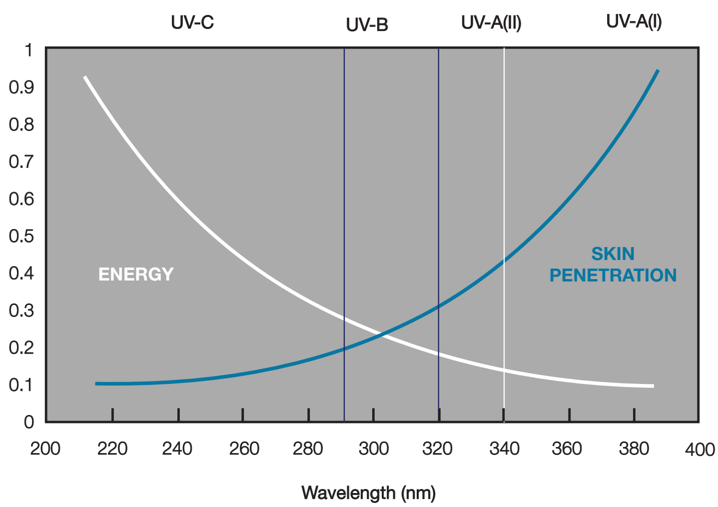
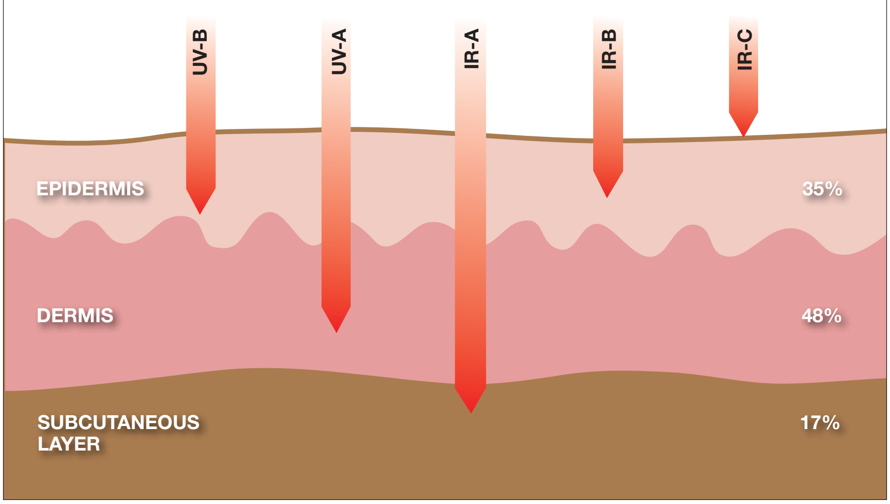


Fig. 6: Penetration of UV and IR rays into the skin



UV rays) in promoting health and in generating vitamin D in particular. Well, the recent evidence is pointing to the fact that the over exposure to IR rays, despite their weak energies and frequencies, may damage the skin.

Sources of IR-A

As noted, roughly half (54%) of the electromagnetic rays emitted from the sun are infrared radiation. Infrared waves are thermal. In other words, we experience this type of infrared radiation every day in the form of heat! The heat that we feel from sunlight, a fire, our bodies, stars and galaxies, a radiator, or even a warm sidewalk all have infrared radiation. Infrared radiation has been used successfully in cosmetic dermatology due to its ability to stimulate collagen and elastin for many years. Equipment such as Fraxel, Smoothbeam and the FotoFacial machines produce a synergy opulsed optical light and radio frequency energy. Other examples of man-made IR radiation include hair dryers, tanning booths, night vision (infrared cameras), LEDs, heat packs (for skiing or camping), infrared sauna, and de-icing equipment for airplanes. Infrared heating is also becoming more popular in industrial manufacturing processes such as curing of coatings, forming of plastics and print drying. It's all around us!

Before concluding this description of electromagnetic radiation, it is important to define two more terms: ionizing and non-ionizing radiation. Rays that are of high frequency and energy—UVC, X-ray, gamma and cosmic—are sufficiently energetic to cause the ionization of the molecules leading to possible chemical reactions. These rays would be called ionizing radiation. On the other hand, non-ionizing radiation is generated by weaker, low-frequency radiation starting from the visible, infrared, microwave or radiowave radiations that are not sufficiently energetic to ionize the molecules that lead to chemical reactions. For the most part, they tend to cause minor bending, twisting, rotating or vibrating motions of the molecules. These are very important for diagnostic purposes as utilized in IR and ultraviolet spectroscopy or in the transmission of signals as in microwave and radio/TV waves.

IR Radiation and Skin

The IR rays have a frequency of 750nm, just above that of the color red in the visible spectrum, and extend all the way to 1mm. In fact, conventions subdivide the IR rays into three categories:

IR-A (Near IR):	750nm-1400nm
IR-B: (Mid-IR):	1400nm-3000nm
IR-C (Far IR):	3000nm-1mm

Since half of the solar radiation is IR rays (30% is exclusively IR-A), it may have a significant biological effect on the human skin. For example the skin disease called erythema ab igne is due to chronic heat exposure.[6] Most (65%) of the IR-A rays penetrate epidermal and dermal layers and reach subcutaneous tissues without increasing the skin temperature significantly. The IR-B rays penetrate much less into the epidermis and the IR-C rays are mostly absorbed by the epidermal layers and tend to increase the temperature significantly[7] *(See Fig. 6)*.

In my May column, I will elaborate on the science that discusses the biological damage to the skin caused by IR radiation.

Whether it's UVA, UVB, IR-A, IR-B or IR-C, the sun's rays damage skin.

The current research, published by several scientists and dermatologists, clearly reveals that IR radiation significantly damages the skin. In addition to the obvious heat effect of IR radiation, recent research has documented the formation of free radicals on the skin when exposed to IR rays.

Maxim Darvin and his associates in Germany have used Electron Paramagnetic Resonance (EPR) Spectroscopy to determine that IR irradiation gives rise to the production of free radicals in the skin. They also report that IR will reduce the antioxidative potential of the skin. It is likely that enzymatic processes in the skin are induced by increased temperature of the skin.[8] Lademann and his associates utilized Raman Spectroscopy to detect free radicals on the skin that were induced by IR radiation.[9]

Free radicals are the main cause of premature skin aging. They also contribute to immunosuppression, skin disease and, ultimately, skin cancer. The human organism has developed a protection system against the destructive action of free radicals by means of the antioxidant network. Craig Elmets and his associates at the University of Alabama report "recent studies suggest an important role for IR-A radiation in dermal inflammation, photoaging and photocarcinogens."[1] Christian Calles from the IUF Institute in Düsseldorf in Germany has identified and analyzed the IRA-induced transcriptome in human fibroblasts.[2] Korean scientists[7] have also reported that IR and heat exposure can induce cutaneous angiogenesis (forms new blood vessels), cause inflammatory cellular infiltration, disrupt dermal extracellular matrix (induces matrix metalloproteases) and alter dermal structural proteins which causes premature aging of the skin.

The current prevailing evidence paves the way for new research possibilities in IR-A photobiology and raises important questions regarding appropriate protection from the sun. Since ultraviolet protection with UV-absorbing molecules and light scattering particles has been a mainstay of protecting individuals from the ravaging rays of the sun, it seems that including filters and antioxidants to combat the IR-induced free radical generation on the skin is highly recommended. Formulation design will need to incorporate the new findings. A call to innovation has been issued. Stay tuned for the May issue!

The Latest Word from FDA

Finally, I asked Dr. Reynold Tan if the rumors that the FDA maybe planning to delay the deadline that they gave manufacturers for implementation of its 2011 Final Rule for Labeling and Testing of Sunscreens? I received the following answer," I can only say that we have received a request to delay the effective date of the 2011 Sunscreen Final Rule. The request was submitted to the public docket jointly by the Personal Care Products Council & the Consumer Healthcare Products Association. We are considering their arguments for delaying the effective date."

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