Common Misconceptions about Light

K.C. Smith

Department of Radiology, Stanford University School of Medicine
Stanford, CA 94305, USA

All biological responses to light are the result of chemical and/or physical changes induced in biological systems when they absorb light energy. The absorption of light energy by biological molecules, and the subsequent dissipation of this energy (via heat, light emission or chemistry) are well understood, and obey the laws of physics and chemistry (1). Unfortunately, not all of those who use light experimentally in the laboratory or therapeutically in the clinic are trained in the physics and chemistry of light. Thus, even among scientists and physicians there exist numerous misconceptions about the properties of light (1). The following are some of the more common misconceptions that I have observed.

1. Wrong: Visible light is natural and therefore is safe. There are two misconceptions in this statement. First, because something is natural is no reason to consider it safe. After all, poisonous snakes and plants are natural, but they certainly aren't "safe".

Second, the safety of light is not an intrinsic property of the light. The first law of photochemistry states that light must be absorbed before photochemistry can occur. Therefore, if the light is not absorbed by a system it is "safe" for that system. Visible light can be safe for one system, and extremely harmful to another. For example, blue light is "safe" for pure deoxyribonucleic acid (DNA) since it isn't absorbed by DNA, but is not "safe" for bilirubin since it is absorbed by bilirubin.

2. Wrong: Visible light is not as photochemically active as ultraviolet (UV) radiation. This misconception has arisen from two other misconceptions. It is true that biological systems are generally more easily inactivated by UV radiation than by visible light, but this is not due to the properties of the light, but rather to the properties of the light-absorbing molecules whose photochemical alteration leads to the inactivation of the biological system. Thus, since DNA, the most important molecule in a cell, can be altered by the absorption of UV radiation, a cell is most easily killed with UV radiation. This fact has contributed to the misconception that visible light is less photochemically active than UV radiation.

The photons of UV radiation carry more energy than do the photons of visible light. Since UV radiation is more effective in killing cells than is visible light, some people have incorrectly assumed that it is the absolute energy of a photon that is important in determining its photochemical potential. As stated above, unless a photon is absorbed by a molecule it cannot cause photochemistry. Thus, the energy of a photon is important only in that it be of the correct energy to permit its absorption by the molecular

LASERS IN PHOTOMEDICINE AND PHOTOBIOLOGY
R. Pratesi and C. A. Sacchi (ed)
Springer-Verlag, Berlin (1980)

species of interest. The fact that photons of visible light carry less energy than do photons of UV radiation has also contributed to the misconception that visible light is less photochemically active than UV radiation.

It should be remembered that all wavelengths of light (UV through visible) are very active in initiating photochemical reactions, providing they are absorbed in appropriate molecules. No one wavelength is more photochemically reactive than another except as it relates to a specific target molecule. The absorption spectrum of a molecular species indicates what wavelengths of light are absorbed by that species.

3. Wrong: We need not be concerned with the biological effects of visible light because it does not penetrate human tissues. This misconception arises because of the further misconception that because we cannot see through a human hand, that light must not be transmitted through human tissues. When confronted with this incorrect statement, I ask if that person has played the childhood trick of putting the lighted end of a flashlight into his mouth or against his hand while in a dark room. Such a trick dramatically exemplifies that light does penetrate living tissue. It is mainly red light (670-760 nm) that is transmitted.

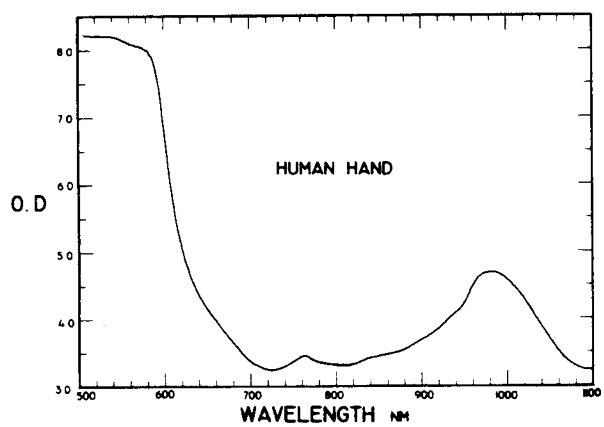

Fig.1 The absorption spectrum of a human hand. The spectrum was recorded by K.H. Norris with a very sensitive spectrophotometer with his hand close to the detector. The hand is rather transparent to light of wavelengths between 650 and 900 nm. An optical density (O.D.) of 3.5 corresponds to 0.05% transmission. (From reference 1.)

A dramatic example of the transmission of light by a human hand is on the cover of the March 1972 issue of Scientific American. The space between the fingers and the edges of the hand were carefully masked, and a flash lamp was fired on one side of the hand; a color photograph taken on the other side by the transmitted light yielded a picture of a red hand.

Using a very sensitive spectrophotometer, the absorption spectra of objects that seem opaque to human vision can be readily determined. The absorption spectrum of a human hand is shown in Fig. 1. A hand is rather transparent to wavelengths of light between 650 and 900 nm, however human visual acuity only extends between 380 to 700 nm, with a peak of efficiency around

550 nm. Thus, because humans can't see through the human body does not mean that the human body is opaque to all wavelengths of light.

Since light can penetrate deeply into human tissues (especially red light), and since absorbed light can cause photochemistry, it is appropriate to be concerned with the biological consequence of such absorbed light in the tissues of man.

4. Wrong: Light of different wavelengths always acts independently on biological systems. Actually when a biological system is exposed to two different wavelengths of radiation, the observed effect is frequently not the summation of the effects of the individual wavelengths (1,2). Most frequently one observes a synergistic effect, i.e., the effect of two wavelengths of radiation given together is greater than the sum of the two effects when given independently. Sometimes the effects are antagonistic (i.e., the opposite of synergistic), and often there is no interaction at all. Therefore, it is especially important to keep in mind the possibility of nonadditive effects of different wavelengths of light when one uses a polychromatic source of radiation, or two or more monochromatic sources.

5. Wrong: Laser radiation has magical properties. Lasers have long been the source of a great many misconceptions. Many people still feel that light from lasers has magical properties. Lasers can seem magical if their unique properties of micro-dot focusing, very high intensity, coherent radiation, possibility of ultrashort pulses, and monochromicity are made use of. If the first four properties are not useful in a particular application, then lasers are just expensive monochromatic light sources, whose emitted radiation follows (except for coherence) all the same laws of physics and chemistry that the same wavelengths of light from a conventional light source follow. Thus, in searching for new uses for lasers in the field of photobiology and photomedicine, one must make sure that the proposed application requires one or more of the unique properties of a laser. If this is not the case, then a conventional light source may be more cost effective.

One practice that has furthered the misconception of the magical properties of lasers is the use in publications of vague terms such as "laser radiation" or "sublethal ruby laser beams" instead of specifying the wavelength causing the effect. In many cases it may be irrelevant that a laser was used, but in all chemical and biological applications it is important to know the wavelength, the fluence rate, and the total fluence delivered to the target.

Also, before ascribing magical properties to laser radiation, the same studies should be performed with a conventional light source emitting the same wavelength(s) of light as the laser.

References

1. K.C. Smith (ed.), The Science of Photobiology, Plenum Press, N.Y. (1977)
2. R.M. Tyrrell, Radiation Synergism and Antagonism, in "Photochemical and Photobiological Reviews, Vol. 3" (K.C. Smith, ed.), pp. 35-113, Plenum Press, N.Y. (1978).