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Solar Ultraviolet Radiation: Definitions and Terminology

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Is "UV" (ultraviolet) a ray, or is it light, a wave, energy, or radiation? Does the "A" in UVA really stand for "aging" and the "B" in UVB for "burning?" Should one use a minimum or standard erythema dose? The definition of and terminology associated with UV and its effects on human biology have been, and continue to be, an area where there is abundant potential for confusion and inaccuracy. In recent years, matters have been made worse as the highly exacting field of photobiology has been popularized due to dramatic rises in the incidence of skin cancer in developed geographies and the ensuing need for national education programs. This article includes a brief review of modern definitions, nomenclature, and terminology associated with this topic.

Definition of ultraviolet radiation

"UV" is only a relatively small component of a broad *electromagnetic spectrum* that is defined by *wavelength* and *frequency*. As shown in Table 1, the entire electromagnetic spectrum spans a huge waveband of radiation with wavelengths ranging from 10^{-14} m (γ radiation) to 10^4 m (radio waves). "UV" refers to a narrow waveband of radiation with wavelengths in the 10^{-7}-m (hundreds of nm) range, specifically 100 nm to 400 nm. Radiation in the 400- to 700-nm wavelength region constitutes "light," principally because the photoreactive cells of the human retina are sensitive only to this waveband, driving the phenomenon of human vision. Importantly, therefore, it is inappropriate to refer to "UV" as "light," rather as *ultraviolet radiation* or *UVR*. According to quantum theory, light and other forms of electromagnetic radiation may at times exhibit properties like those of particles in their interaction with matter. The individual quantum of excitation of electromagnetic radiation is known as the *photon* (from the Greek word φοτος, meaning light) and is symbolized by the Greek letter gamma (γ). As electromagnetic radiation, thus, UVR is no exception and is quantized in photons.

UVR is, therefore, a specific, narrow waveband of electromagnetic radiation that travels, quantized as photons, in waves. Waves are measured not only by their wavelength, however, but also by *frequency*. Whereas, wavelength is measured in meters, frequency is measured by the number of waves or cycles that pass a given point in 1 s (one cycle per second termed a Hertz [Hz]). Because electromagnetic radiation travels at a constant speed (approximately 300,000,000 m/s), wavelength and frequency are related on a fundamental one-to-one basis by Eq. 1:

$$c = f \cdot \lambda \text{ or } f = c/\lambda \text{ or } \lambda = c/f \qquad (1)$$

where c is the speed of light (~300,000,000 m/s), f is the frequency in Hertz (cycles/s), and λ is wavelength in meters.

Shorter wavelength electromagnetic radiation, therefore, has a higher frequency. Frequency and energy are also related at a fundamental level through

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Table 1
Approximate wavebands of the electromagnetic spectrum

Electromagnetic radiation	Waveband (m)
Gamma radiation	10^{-14} to 19^{-10}
X rays	10^{-10} to 10^{-8}
UV radiation	10^{-7} to 4×10^{-7}
Visible light	4×10^{-7} to 7×10^{-7}
Infrared radiation	7×10^{-7} to 10^{-3}
Microwaves	10^{-3} to 10^{-2}
Radio waves	10^{-2} to 10^{4}

the Planck constant (the constant of proportionality relating the energy of a photon to frequency; Eq. 2):

$$Q_p = h{\cdot}f \tag{2}$$

where $Q_{\rm p}$ is photon energy (electron volts or eV), h is the *Planck constant* (6.626×10^{-34} J s), and f is the frequency in Hertz.

Quite simply, the shorter the wavelength of electromagnetic radiation, the higher its respective frequency and energy. As regards expanding the definition of UVR, this is a very important relationship as the higher the energy of a UVR photon, the more reactive it is with human biology. This has led to a subdivision of the UVR waveband (100 nm to 400 nm) into three further spectral regions: UVC, UVB, and UVA, based principally on differing biologic effect. The bounds of these spectral regions were determined initially in the 1930s by W.W. Coblentz, of the U.S. National Bureau of Standards, and colleagues [1] by using the transmission properties of three common filters. A pyrex filter determined the UVC waveband (100 nm to 280 nm, "germicidal" UVR, absorbed almost entirely by stratospheric ozone), a barium-flint-pyrex filter, the UVB waveband (280 nm to 315 nm, so-called "erythemal" UVR, the lower end of this waveband also marking the upper cut-off for the absorption spectra of protein and DNA), and a barium-flint filter defined the UVA (315 nm to 400 nm; "black light"). These wavebands became endorsed at the 2nd International Congress on Light in Copenhagen in 1932 and again by the La Commission Internationale de l'Eclairage (CIE) in 1970 [2]. These spectral divisions are, therefore, somewhat arbitrary. Most modern dermatologists and photobiologists have redefined and cite these three wavebands thus:

UVC: 200 nm to 290 nm
UVB: 290 nm to 320 nm
UVA: 320 nm to 400 nm

Clearly, therefore, the origin of the "A" and "B" nomenclature of these wavebands has nothing to do with "aging" or "burning." Most recently, the subdivision of the 290- to 400-nm waveband into UVB and UVA has been reviewed, and there is now growing support for recognition of a further subdivision of the UVA waveband into:

UVAI: 340 nm to 400 nm
UVAII: 320 nm to 340 nm

The UVAII subdivision now recognizes the relatively high erythemal potential (and, hence, biologic interaction) that the 320- to 340-nm waveband possesses when compared with the remainder of the UV spectral region (ie, UVAI, 340 nm to 400 nm). Although at first appearing confusing and even retrograde, this is actually a perfectly logical outcome of fitting rigid broad spectral regions to a continuous electromagnetic spectrum; after all, it would be nonsense to maintain that a UV photon of 319 nm is meaningfully different in biologic effect to one of 321 nm, even though they would be classed as UVB and UVA photons, respectively. As we shall see, creation of further subdivisions, such as those above, within these relatively large wavebands is acknowledgment of the broad gradation and range of biologic effect across the portion of electromagnetic spectrum occupied by UVR.

Ultraviolet radiation radiometric symbols, units, and nomenclature

Before defining solar UVR, we must first introduce the language and terminology of *radiometry*, the science of measurement of electromagnetic radiation spanning wavelengths from 10^{-8} m to 10^{-3} m (including, of course, UVR). This should be differentiated from *photometry*, which relates to electromagnetic radiation detectable by the human eye (all terms, thus, weighted correspondingly by the eye's spectral response).

To simplify the text of this short summary, the most commonly used radiometric terms and their respective meanings and recommended symbols are listed in Table 2. In general, radiometric units can be divided into two conceptual areas—those relating to (1) either *energy* or *flux* (ie, specific to a wave of electromagnetic radiation passing through space) and (2) those related to the geometric quantities of area and solid angle (ie, specific to the relationship of this radiation to either the source [*radiant intensity* and *radiance*] or the object that is struck by it [*irradiance*]).