Introduction to Photobiology

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KEYWORDS

• Ultraviolet radiation • Ultraviolet light • Phototherapy • Photobiology • Sunburn • Melanogenesis • Vitamin D production • Photoaging

KEY POINTS

- Solar radiation is made up of ultraviolet, visible, and infrared radiation.
- Ultraviolet radiation is made up of UV-C, UV-B, and UV-A.
- Most ultraviolet radiation that reaches the earth is UV-A.
- Sun exposure has a wide range of biological effects, including sunburn, tanning, vitamin D production, photoaging, and carcinogenesis.
- Phototherapy uses properties of ultraviolet light that are useful in the treatment of certain dermatologic conditions.

INTRODUCTION

Photobiology deals with the local and systemic effects of incident radiation on living organisms. This introductory article on cutaneous photobiology focuses on the effects of ultraviolet (UV) radiation (UVR), both from its natural source (ie, the sun) and artificial sources (ie, those used in phototherapy), on skin function and diseases. Although visible light and infrared radiation also have effects on skin cells, there is more information on UVR.

Phototherapy is the use of nonionizing radiation to treat cutaneous disease. For more than a century, phototherapy has played a pivotal role in the treatment of dermatologic diseases. In 1903, Niels Finsen received the Nobel Prize in Medicine for using light to treat a cutaneous mycobacterial disease. In the middle of the 20th century, advancements in UV-B light therapy expanded treatment options for patients with psoriasis. In the 1970s, photochemotherapy (ie, using psoralen as a photosensitizer in combination with UV-A radiation [PUVA]) made its debut. PUVA became an established player in the treatment of skin diseases in the last quarter of the 20th century. More recent advances in the last few decades (ie, narrowband UV-B therapy, laser therapy, targeted phototherapy, photodynamic therapy [PDT], UV-A1) have also revolutionized photodermatology.[1,2]

UVR

Solar Radiation

The rays of the sun hit the earth in the form of UVR, visible, and infrared radiation. These 3 entities are components of the electromagnetic spectrum, which also includes radiowaves, microwaves, radiographs, and γ radiation (**Fig. 1**). Solar radiation is made up of approximately 50% visible light, 40% infrared, and 9% UVR.[3] Visible radiation is that which is perceived by the human eye.[4] Each color of visible light represents a different wavelength range (see **Fig. 1**). UVR is the area of the electromagnetic spectrum that is considered most biologically active and therefore of greatest impact on health and disease.

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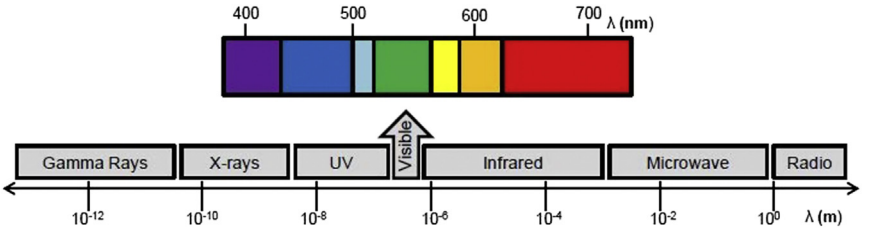

Fig. 1. Electromagnetic spectrum.

UVR

UVR spans the wavelengths 100 to 400 nm and is subdivided into UV-C, UV-B, and UV-A. There are subtle differences in the subdivisions described in the literature. In this article, the subdivision most commonly chosen in photobiology is used (ie, UV-C, 200–290 nm; UV-B, 290–320 nm; and UV-A, 320–400 nm).[4] Other ranges referenced in the literature include: UV-C at 200 to 280 nm, UV-B at 280 to 320 nm, UV-A at 320 to 400 nm, UV-C at 200 to 280 nm, UV-B at 280 to 315 nm, and UV-A at 315 to 400 nm.[5] The stratospheric ozone prevents wavelengths shorter than approximately 290 nm from hitting the earth. Most UV radiation that reaches the earth is UV-A. Only a small percentage (approximately 5%) of UV-B is present in terrestrial sunlight. UV-C is typically filtered by the ozone layer.[6] The amount of solar energy at a specific wavelength that can affect the earth varies with season, region, altitude, pollution, and the path that the solar radiation traverses through the ozone.[7] The amount of UV in sunlight also varies throughout the day. Being of a longer wavelength, UV-A is present consistently from sunrise to sunset, whereas UV-B peaks around noon. Approximately 50% of UV-A exposure occurs in the shade as a result of surface reflection and its penetration to cloud cover. Windows and automotive glass do not shield against UV-A but do shield against UV-B.[8]

For the purposes of phototherapy, UV-B has been further subdivided into broadband UV-B (290–320 nm) and narrrowband UV-B (311 nm–313 nm). UV-A radiation has been subdivided into UV-A1 (340–400 nm) and UV-A2 (320–340 nm), primarily because the biological effect of UV-A2 is closer to that of UV-B. The specific applications of these modalities are discussed in more detail in the article by Rkein and Ozog elsewhere in this issue.

Light-Skin Interactions

Light has both the properties of waves and particles known as photons. In cutaneous photobiology, it is important to understand what happens to photons when they encounter the skin surface. They can undergo reflection, scattering, or absorption. According to the Grothus-Draper law, light can have a biological effect only if it is absorbed. Once radiation is absorbed by molecules in the skin (termed chromophores), energy is transferred to produce heat or drive photochemical reactions. This process results in detectable responses at the cellular and molecular levels that could lead to a clinical outcome (**Fig. 2**).[9,10]

Reflection, scattering, and absorption

Reflection happens at the skin surface. Light reflected from the skin can be used for diagnostic

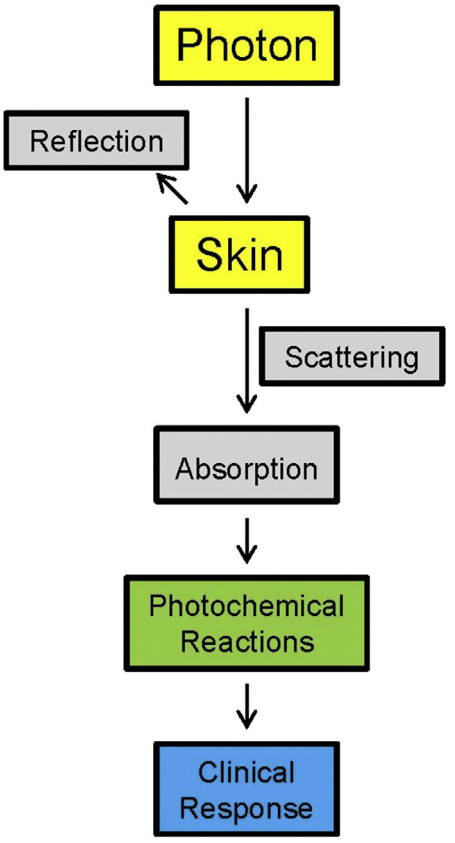

Fig. 2. Light-skin interaction pathway.