PART 2 – SPREAD OF SARS-COV-2 AND A POTENTIAL ROLE OF UV-C FOR AIR AND SURFACE DISINFECTION

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S-Webinar-Part 2

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# SARS-CoV2: PRIMARY MEANS OF TRANSMISSION - as stated by Dr. Nardell

Airborne Transmission
 Respiratory Droplets (e.g., coughs)
 Aerosolized Droplet Nuclei



Contact Transmission (fomites)

### The Breathing Zone as Shown by a Schlieren Mirror $_{ m o}$



From: Tang JW, Nicolle ADG, Pantelic J, Jiang M, Sekhr C, et al. (2011) Qualitative Real-Time Schlieren and Shadowgraph Imaging of Human Exhaled Airflows: An Aid to Aerosol Infection Control. PLOS ONE 6(6): e21392.

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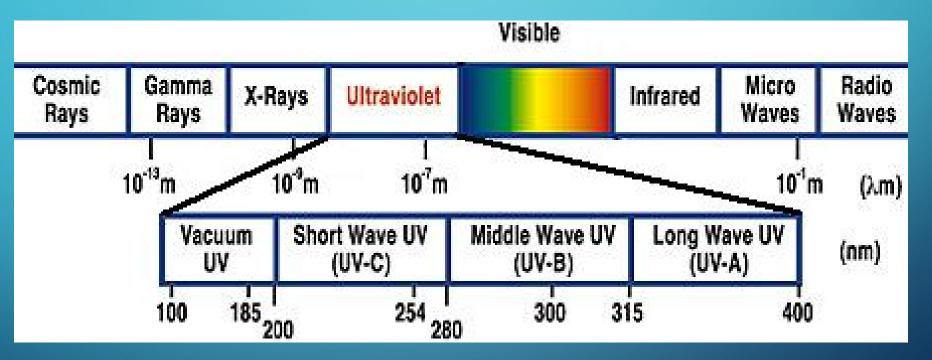
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# • WHAT IS "GERMICIDAL RADIATION" - OR "GERMICIDAL LIGHT?"

•UV-C, although longer-wavelengths of UV-B in sunlight are less effective, but have effectiveness, as summer sunlight is very intense.

UV-C is the only effective means for disinfecting air!
UV-A and violet light – only marginal effects in some microbes

### WHY IS ULTRAVIOLET RADIATION USEFUL? THE ULTRAVIOLET (AND VISIBLE) SPECTRUM ARE OF PRIMARY INTEREST IN PHOTOBIOLOGY...



... because the **photon energy** is sufficient to interact with biologically significant molecules.

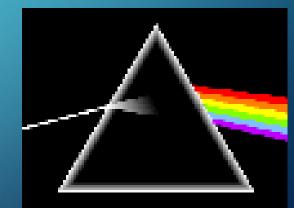
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# **PHOTOBIOLOGICAL SPECTRAL BANDS**

 In the early 1930's, the CIE Committee on Photobiology created the concept of the CIE photobiological spectral bands and named the bands. These remain as international standards for *short-hand notation*:

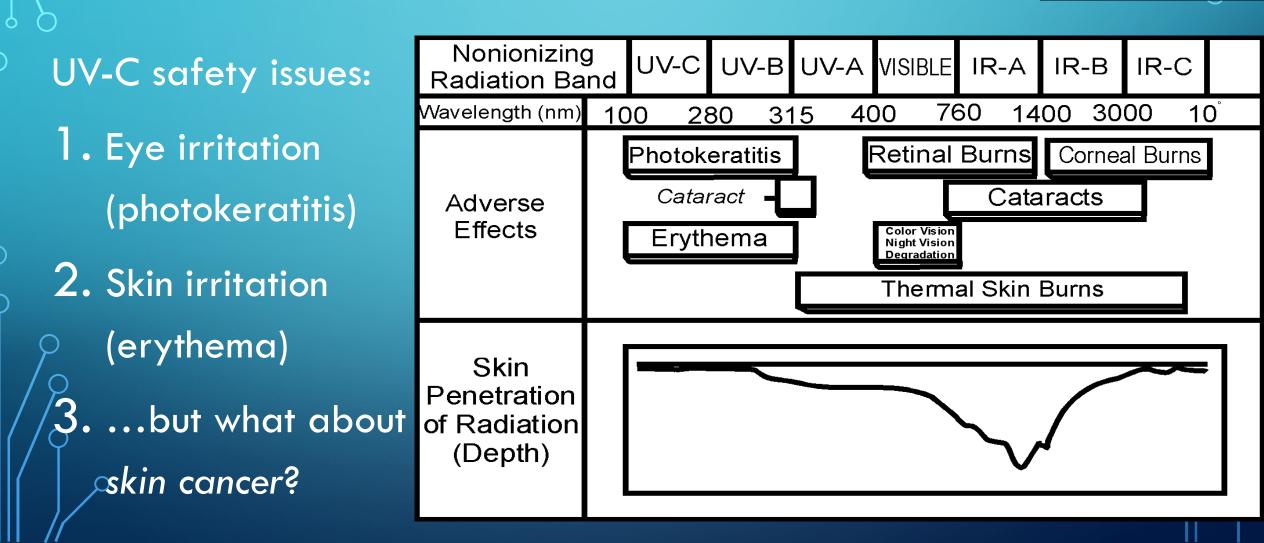
- UV-A 315 nm to 380-400 nm ("black light")
- UV-B280 nm to 315 nm ("actinic radiation")
- UV-C100 nm to 280 nm (Germicidal)
- Visible 360-380 nm to 780 nm (overlap intended)\*
- IR-A 760-780 nm to 1400 nm (0.78 μm to 3.0 μm)
- IR-B 1400 nm to 3000 nm (1.4 μm to 3.0 μm)
- IR-C 3000 nm to 10<sup>6</sup> nm (3.0 µm to 1 mm)

• Source: CIE Publication 134/1 – Standardization of the Terms UVA1, UVA2 & UVB



# UV PHOTOBIOLOGICAL EFFECTS ON HUMANS





# **REMEMBER: PHOTON ENERGY**

- All light is composed of photons of energy: "The Quantum Theory"
- The energy of a single photon varies with wavelength:  $Q = 7.8 \times 10^{-17} J @ 254 nm$
- Photon energy increases with decreasing wavelength
- In photochemistry: <u>One photon interacts with one</u> <u>absorbing molecule – the chromophore</u>
- Millions of photons inactivate a micro-organism

### DOSIMETRY - THE CONCEPT OF PHOTOBIOLOGICAL DOSE

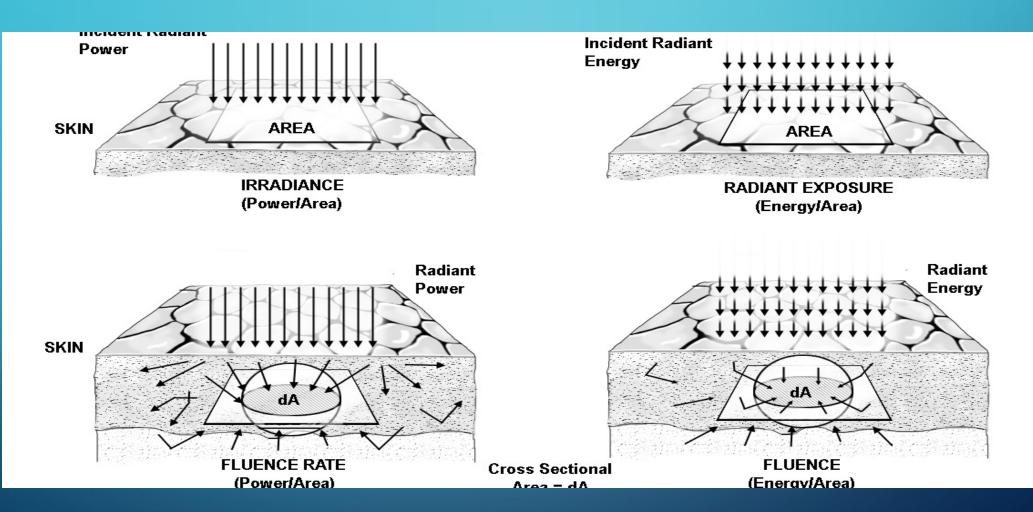
Fundamental to photobiology - Bunsen-Roscoe Law (photochemistry)
 reciprocity of dose-rate (irradiance) E and time t

E x t = H = "the exposure dose"
Loss of reciprocity over several hours typical

Normally all optical radiation, including UV is absorbed on a surface

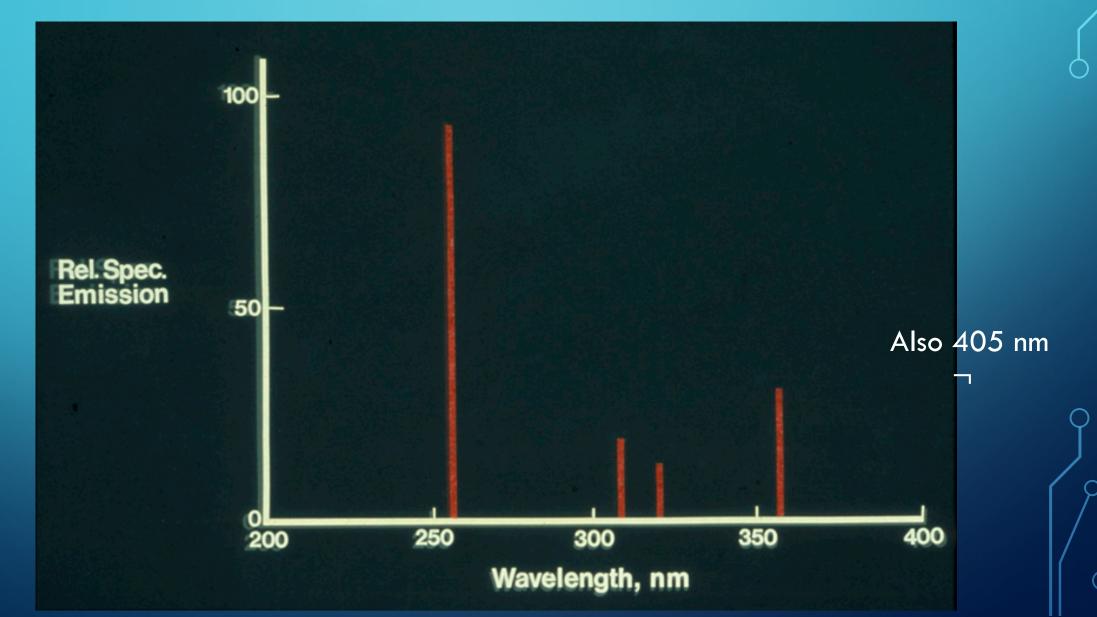
- Power divided by exposed surface area is the irradiance, E, or "the dose-rate" –however:
- In tissue or in air, photobiological exposure rate is fluence rate in power-per-unit-area

# **DESCRIBING EXPOSURES (CIE)**



Current guidance – Fluence rate of  $\sim$ 5-15  $\mu$ W/cm<sup>2</sup> in room air

#### LOW-PRESSURE MERCURY (GERMICIDAL) LAMP EMISSION - C SEVERAL MONOCHROMATIC LINES - BUT 90% AT 254 NM



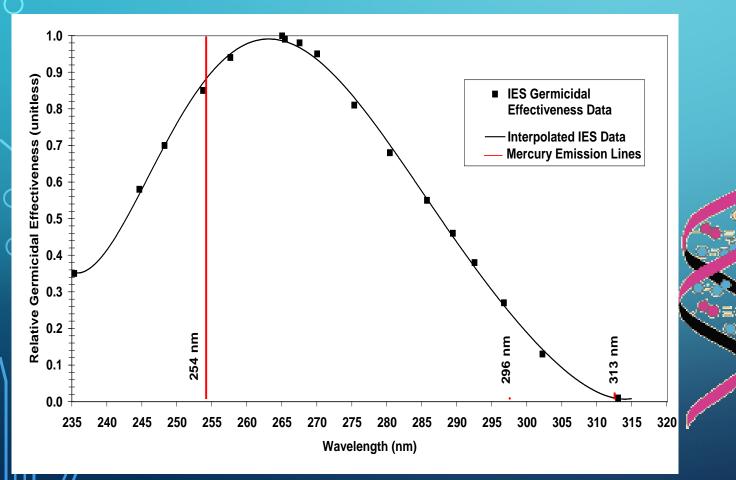
# ACTION SPECTRUM--THE IMPORTANCE OF WAVELENGTH

In photochemistry and Photobiology, the action spectrum is critical. It describes the relative effectiveness of different wavelengths to produce defined response or end-point
 Generally the full width at half maximum is less than 100 nm
 Sharp cut-off due to low photon energy

What is the target molecule for Germicidal UV (GUV)?

# **ONA - A KEY TARGET MOLECULE FOR UV-C**

dES Germicidal Action Spectrum (after Gates and others)



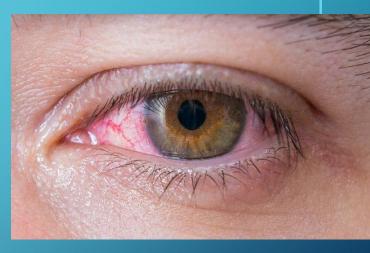
...for bacteria and some viruses, but also the susceptible molecule in eye or skin!



# But SARS-CoV-2 is a RNA virus!

# **OCCUPATIONAL SAFETY ISSUES**

- Ultraviolet Safety is a very important issue!
- Accidental exposure of skin & eyes:
  - Photokeratitis ("welder's flash," or "snowblindness" with symptom of "sand in the eyes" - Cornea is most sensitive tissue
  - Erythema reddening of the skin
    - Can be severe if penetrating UV-B rays ("sunburn")
    - Mild if UV-C very superficial absorption
- Delayed Effects
  - Skin Cancer?
    - UV-B in sunlight penetrates to basal (germinative) layer of epidermis and is the recognized cause of most skin cancers
    - UV-C heavily absorbed in superficial epidermis & stratum corneum



#### Photokeratoconjunctivitis



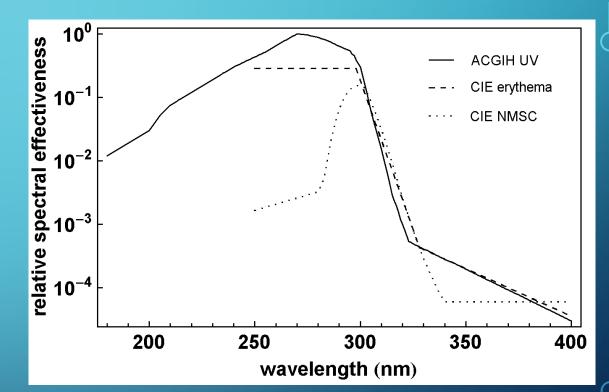
Erythema (skin reddening)

### WHAT ARE THE SAFETY GUIDELINES FOR HUMAN EXPOSURE IN THE GUV UV – C BAND?

 Action spectrum for safety is the ACGIH/ ICNIRP/CIE/ISO/IEC action spectrum S(λ)

$$E_{eff} = \sum_{180}^{400} E_{\lambda} \bullet S(\lambda) \bullet \Delta \lambda$$

- S(λ)-spectral weighting leads to an effective radiant exposure of 3.0 mJ/cm<sup>2</sup> (30 J/m<sup>2</sup>)
- Limit is **daily** including multiple exposures
- Time-weighted average (TWA) over a day
- At 254 nm this is 6 mJ/cm<sup>2</sup> (60 J/m<sup>2</sup>)
  - Or, time-averaged irradiance of 0.2  $\mu$ W/cm<sup>2</sup>
- Large safety margin for human skin in UV-C Should
   there be two limits? For the Eye, For the Skin?

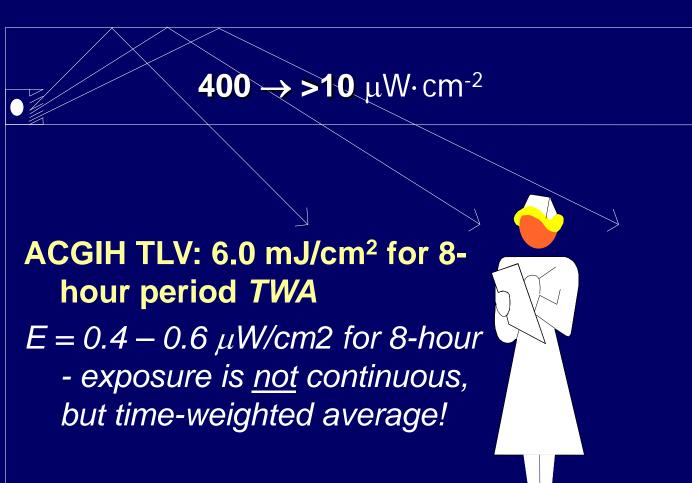


ACGIH UV S( $\lambda$ ) spectral weighting function (action spectrum) is the solid line.

$$S(\lambda) = 1.0$$
 at 270 nm  
 $S(\lambda) = 0.5$  at 254 nm

### From Dr. Nardell: "Upper Room 254 nm GUV is Safe for Room Occupants"

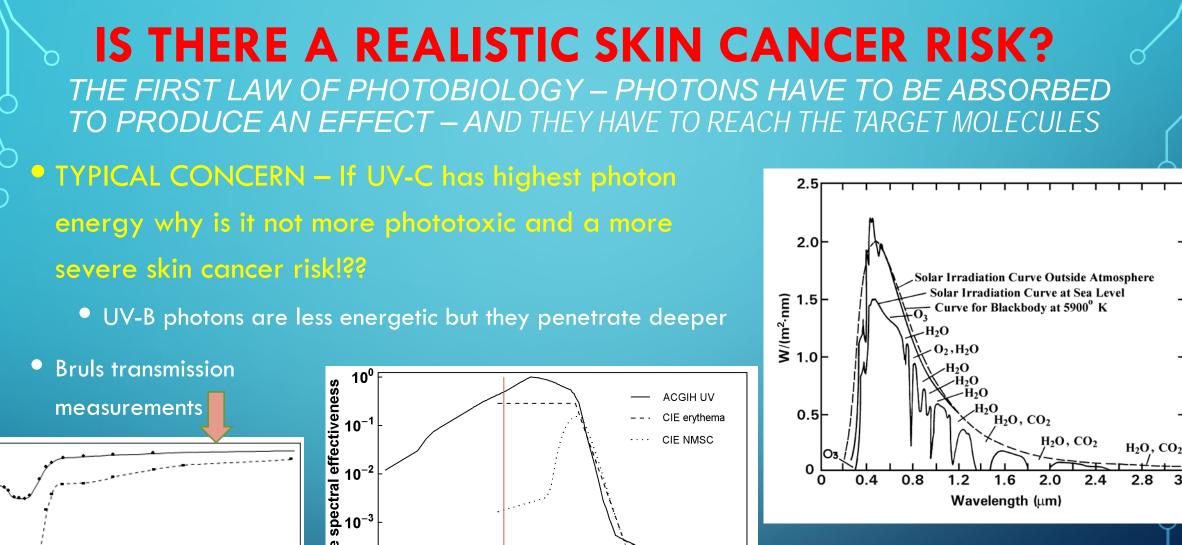
The TLV is measured only within an 80-degree cone angle!



TLV is a limiting value for the eyes

Skin limit may be raised in the future

Tuberculosis UV Shelter Study (TIUSS) showed no eye or skin complaints compared to placebo lamps Ref: Public Health Rep. 2008 Jan-Feb;123(1):52-60



300

wavelength (nm)

350

400

Wavelength (µm)

3.2

Sunlight spectrum – only trace amounts of UV-B reach ground level and no UV-C at all (Sliney & Wolbarsht, 1980); Sliney DH, Balancing the Risk of Eye Irritation from UV-C with Infection from Bioaerosols<sub>†2013</sub>

See: CIE 187:2010 – UV-C Photocarcinogenic Risks from Germicidal Lamps

200

250

relative

550

 $100_{1}$ 

ion (%)

n.

250

300

350

400

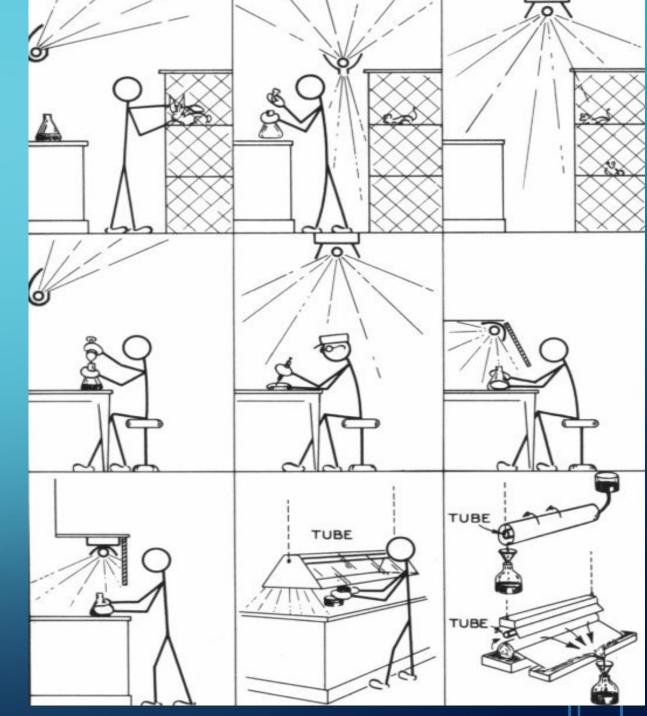
wavelength (nm)

450

500

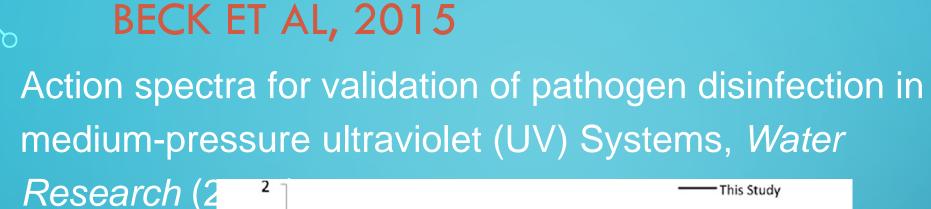
# **Experience of the 1950's**

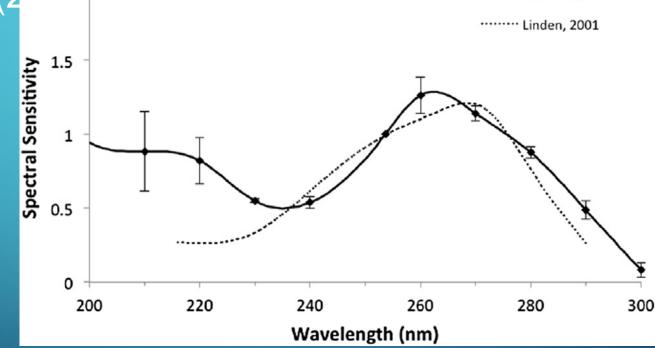
- Applications of UV-C germicidal radiation
  - Localized irradiation can be used with proper design of louvers and irradiators
  - Use diminished with development of anti-biotics and germicidal disinfectants.
  - Revised interest with multidrug-resistant strains



# **UVGI SAFETY REVIEWS**

• UV Germicidal irradiation can be safely and effectively used for upper air disinfection with out a significant risk for long term delayed effects such as skin cancer. (CIE 187:2010) Photochemistry and Photobiology, **Invited Review** Balancing the Risk of Eye Irritation from UV-C with Infection from **Bioaerosols**<sup>+</sup> David Sliney\*<sub>1,2</sub> Consulting Medical Physicist, Fallston, Maryland <sup>2</sup>Department of Environmental Health Sciences, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD Received 13 November 2012, accepted 3 May 2013, DOI: 10.1111/php.12093 ABSTRACT The very aspect (phototoxicity) that makes shortwavelength ultraviolet (UV) radiation an effective germicidal agent also is responsible for the unwanted side effects of erythema (reddening of





This research from the University of Colorado led to the hope for applying 222/207-nm KrCl lamp for GUV! The NEXT Presentation!
 Efficacy? Safety? Lamp technology?