Enlightened Growing:
Using Biomimicry to Understand and Emulate Sungrown Cannabinoid and Terpene Profiles

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"The day science begins to study non-physical phenomena, it will make more progress in one decade than in all the previous centuries of its existence." -Nikola Tesla.

BASIC TRUTH #1

Plants thrive in sunlight

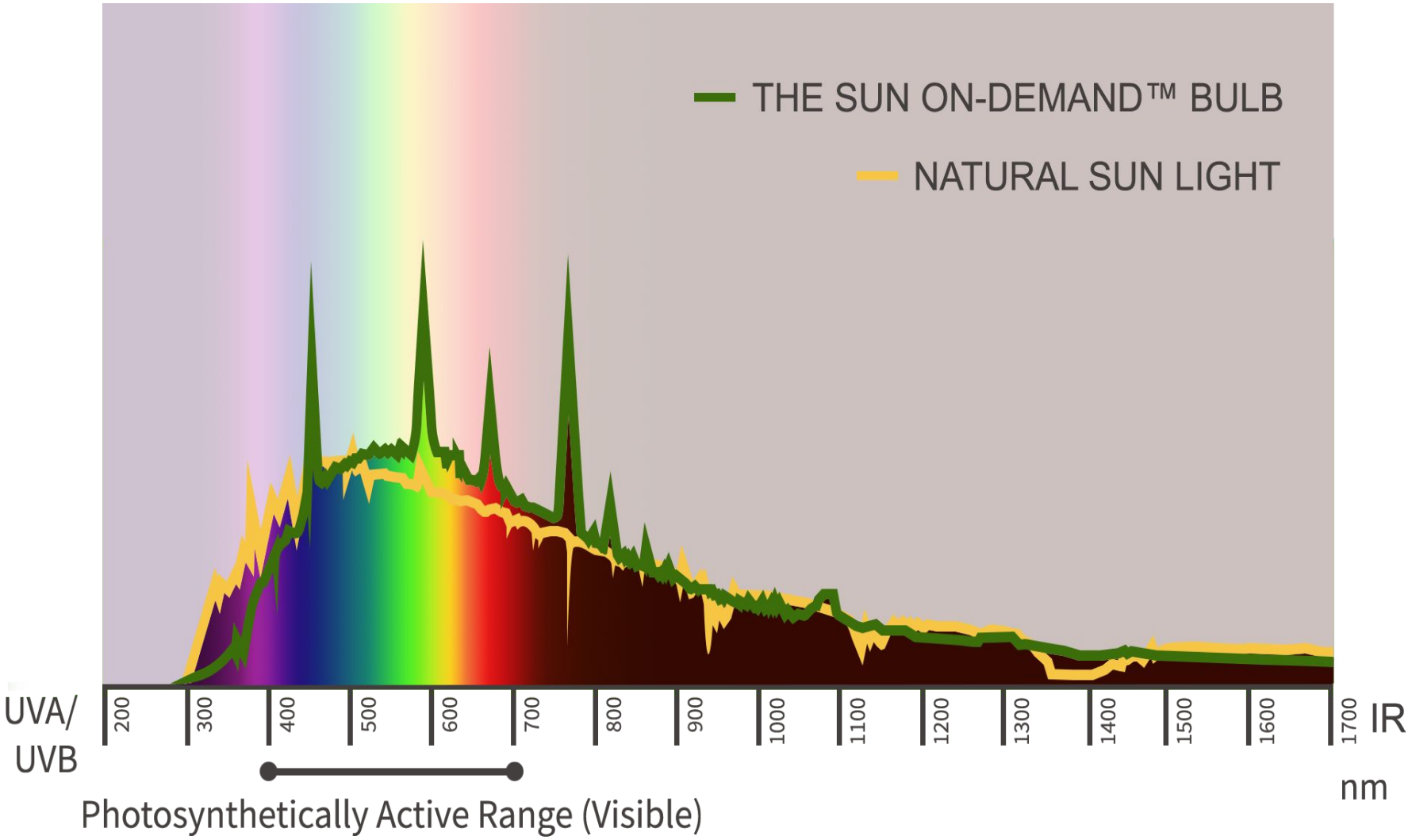
- The Sun is the lifeforce for all life on Earth
- Everything the plant needs is bioavailable from the sun's electromagnetic spectrum
- Photons contain particles of light and frequencies/wavelengths

Without sunlight, plants are weaker, more expensive, and dirtier to grow.

Photo source: https://blog.anton-paar.com/what-is-light-a-particle-or-a-wave/

THIS IS THE SUN INDOORS

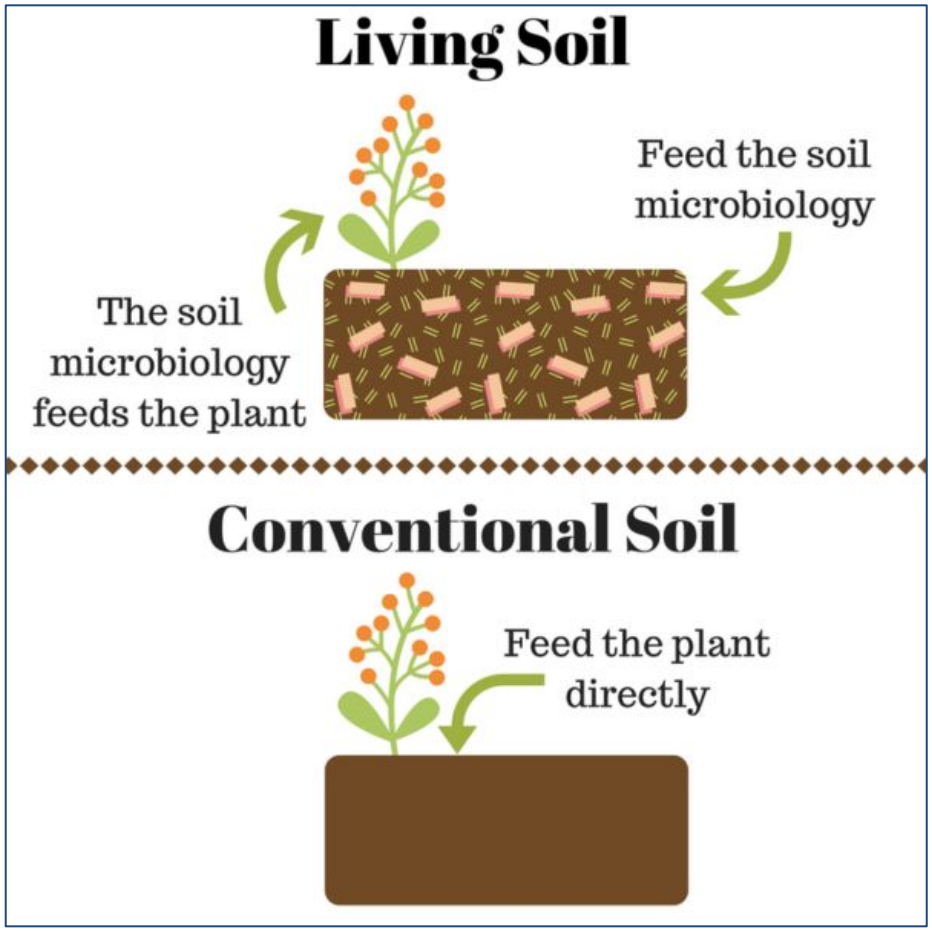
Full Electromagnetic Sun Spectrum Light



BASIC TRUTH #2

Plants thrive in living soil

- Living soil is key for craft & medicinal cannabis
- Creates a bio-dynamic exchange of energy and nutrients



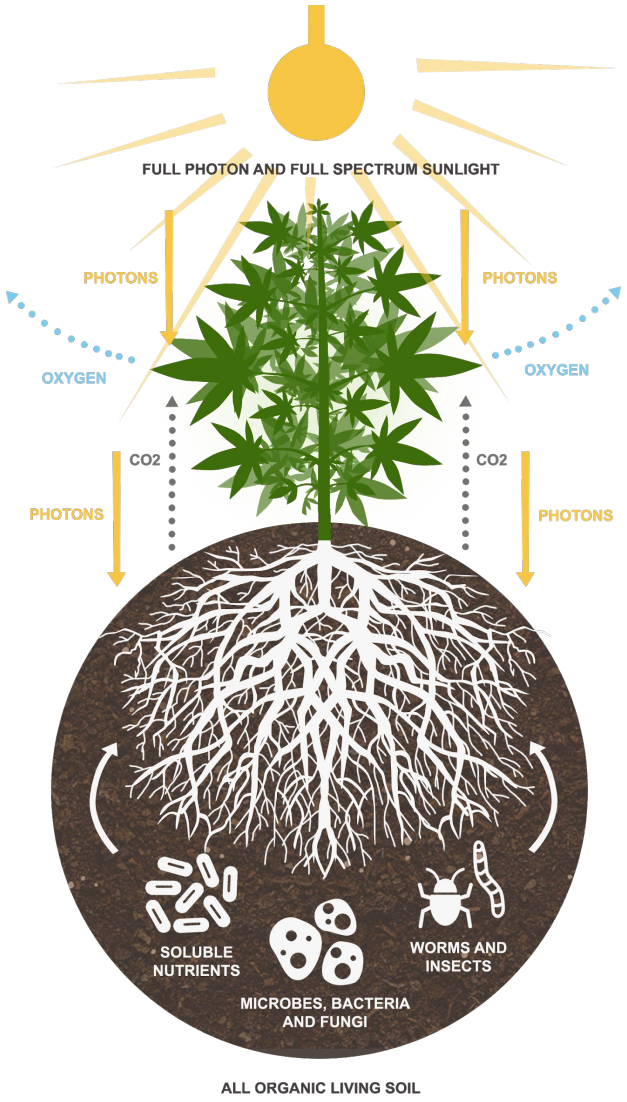
Source: Lowenfels, Jeff (2010). Teaming with Microbes, Second Edition. Portland, OR: Timber Press.

Photo source: http://www.agzaar.com/living-soil-beginner-guide/

CANNABINOID & TERPENE EXPRESSION

Cannabinoid and terpene expression controlled by complex interplay of:

- Strain genetics
- Electromagnetic spectrum & frequencies
- Soil food web + water
- Adaptive stress



HOW NATURE "DIALS IT IN"

1. Create maximum bioavailability with optimum **abiotic** conditions
   Such as: spectrum, Temp, humidity, CO_2, water, etc.
2. Enable adaptive stress reactions for maximum expression of genetic potential by cultivating **biotic** conditions
   Such as: plant genetics, beneficial microbial, bacterial, & fungal networks, plant communities, herbivorous insects, fungal pathogens, etc.
3. Achieve maximum desired plant responses

BIOAVAILABILITY OF SUNLIGHT

Spectrum and Frequencies

- Photoreceptors absorb beyond PAR
- Stronger immune systems
  - Phenolics,
  - Terpenoids,
  - Antioxidants
- Faster growth and development

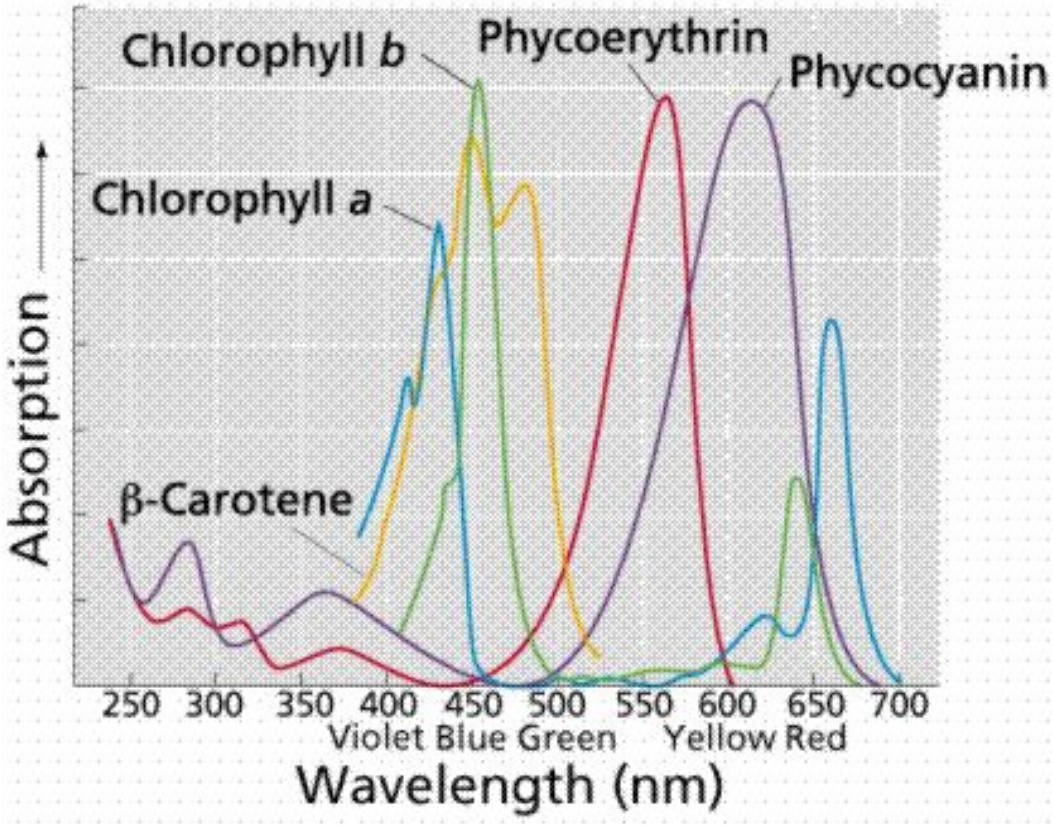


Photo credit:
https://13tellge.files.wordpress.com/2012/01/pigment.gif

BIOAVAILABILITY OF SUNLIGHT

Photoreactivation

- Combination of UVA + blue light allows plants to heal from and adapt to damage from UVB (Brit, 2004)
- Adaptations include increases in antioxidants, terpenoids, phenolics, and resistance to herbivorous insects (Goto, et. al., 2016).

UVB in isolation

UVB with UVA + Blue

Sources:
Britt, A. B. (2004). Repair of DNA damage induced by solar UV. Photosynth. Res. 81, 105–112
Goto, E., Hayashi, K., Furuyama, S., Hikosaka, S. and Ishigami, Y. (2016). Effect of UV light on phytochemical accumulation and expression of anthocyanin biosynthesis genes in red leaf lettuce, Acta Hortic, 1134, 179-186

BIOAVAILABILITY OF SUNLIGHT

Green Light

- Penetrates to deeper layers of chloroplasts to activate photosynthesis deeper in the leaves
- Improves absorption of photons
- Stimulates unique photoreceptors

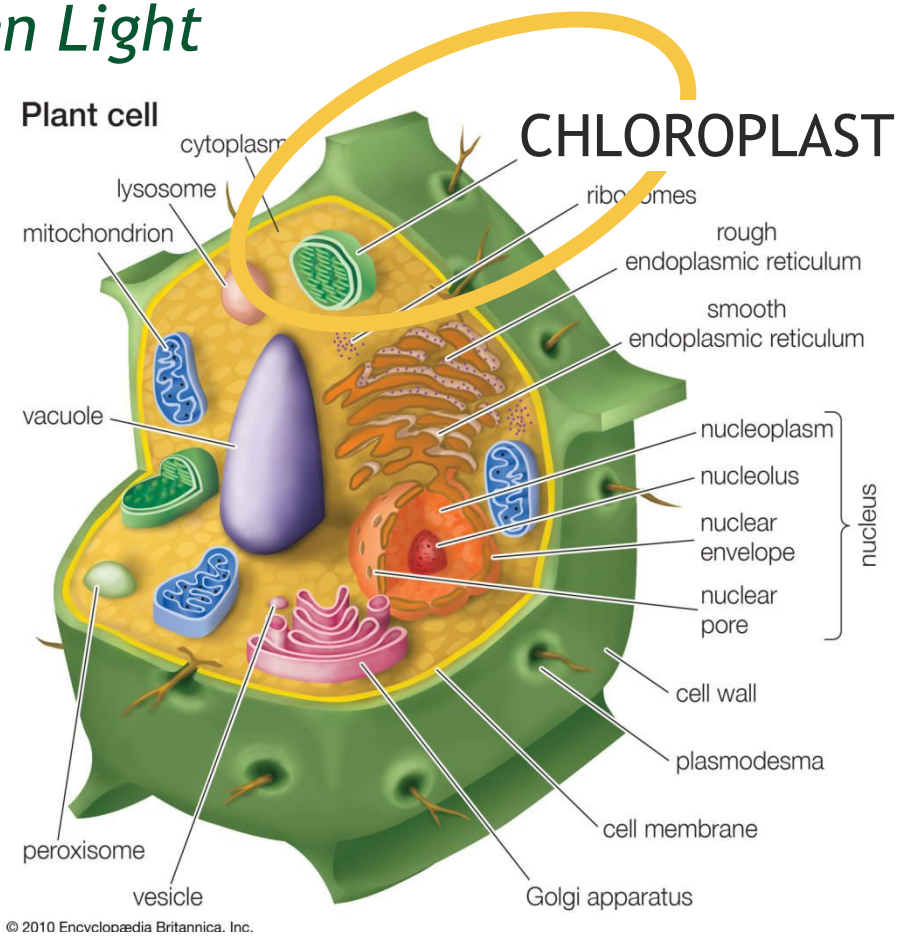


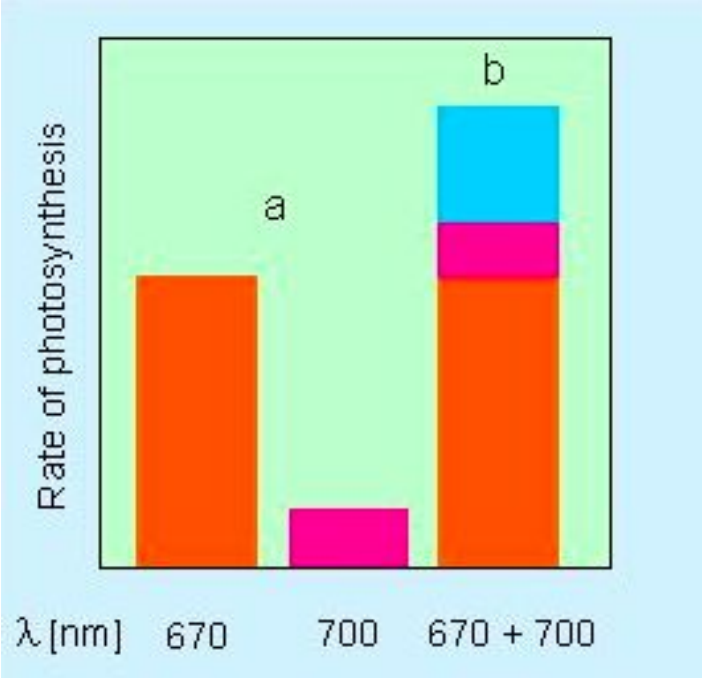
Photo Source: Copyright 2010 Encyclopedia Britannica, Inc.

Source:
Ichiro Terashima, Takashi Fujita, Takeshi Inoue, Wah Soon Chow, Riichi Oguchi. (2009). Green Light Drives Leaf Photosynthesis More Efficiently than Red Light in Strong White Light: Revisiting the Enigmatic Question of Why Leaves are Green, *Plant and Cell Physiology*, Volume 50, Issue 4, Pages 684–697

BIOAVAILABILITY & SUNLIGHT:

The Emerson Effect

- Two complementary photosystems for optimized photosynthetic efficiency in Red (670 nm) and Far red (700 nm) wavelengths
- Helps plants maximize photosynthetic efficiency in variable light conditions



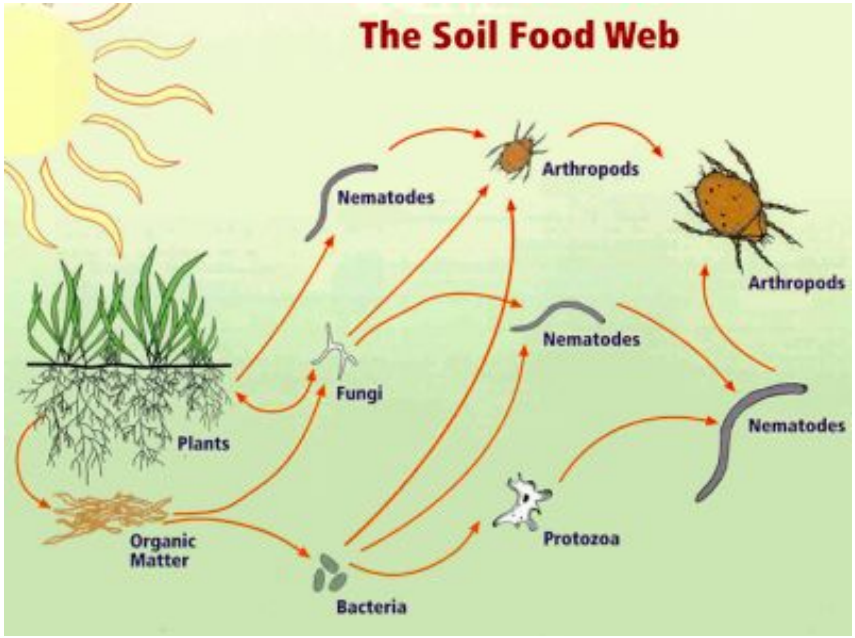
Plant photosynthesis rate when exposed to:
Red (670 nm), Far red (700 nm), and both frequencies
Graph source: © Peter v. Sengbusch - b-online@botanik.uni-hamburg.de

Source: Emerson, Robert. (1957). Dependence of yield of photosynthesis in long wave red on wavelength and intensity of supplementary light. *Science*.

SUNLIGHT AND THE SOIL FOOD WEB

Sunlight strengthens plant and soil food web connections

- Improved nutrient fixation
- Improved immune systems
- Optimized use of CO_2
- Faster growth
- Improved cannabinoid and terpene profiles



Microbial and fungal networks in living soil form the "stomach" of plants

Source: https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/biology/?cid=nrcs142p2_053868

Source: Lowenfels, Jeff (2010). Teaming with Microbes, Second Edition. Portland, OR: Timber Press.

NEED TO UNDERSTAND MORE

- Plant growth & intelligence
- "Brain-gut-heart" connection
- Role of "light" beyond PAR: electromagnetic energy

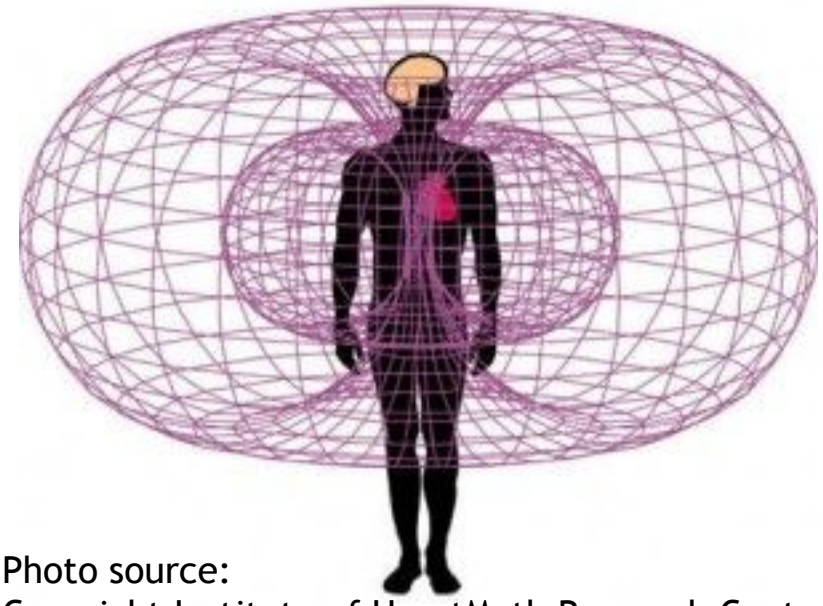


Photo source:
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Hypotheses about the gut-brain axis

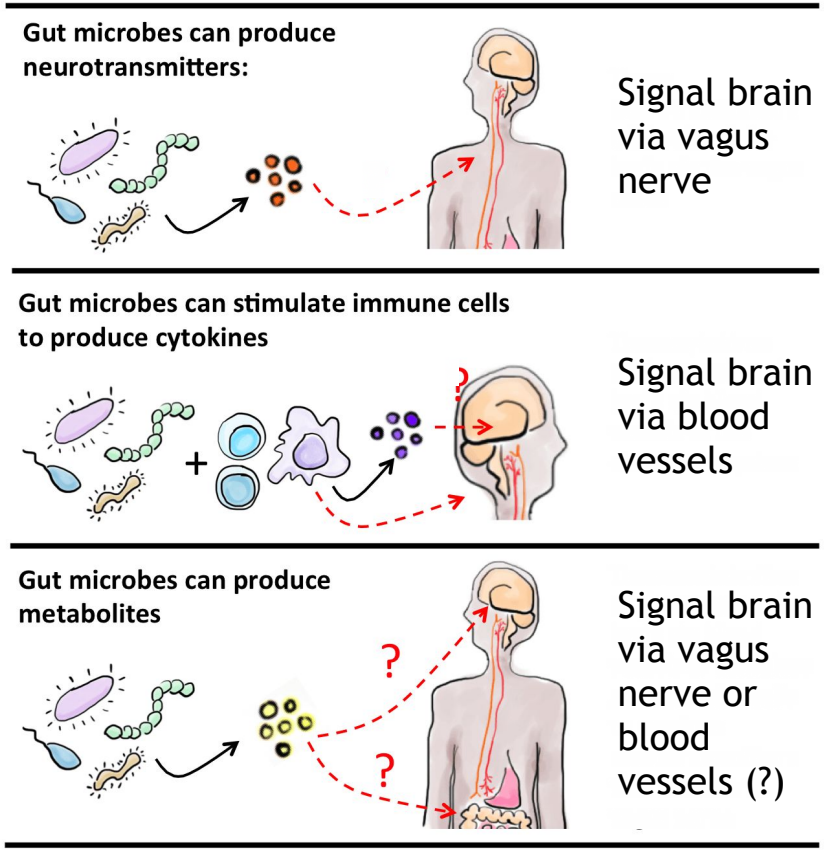
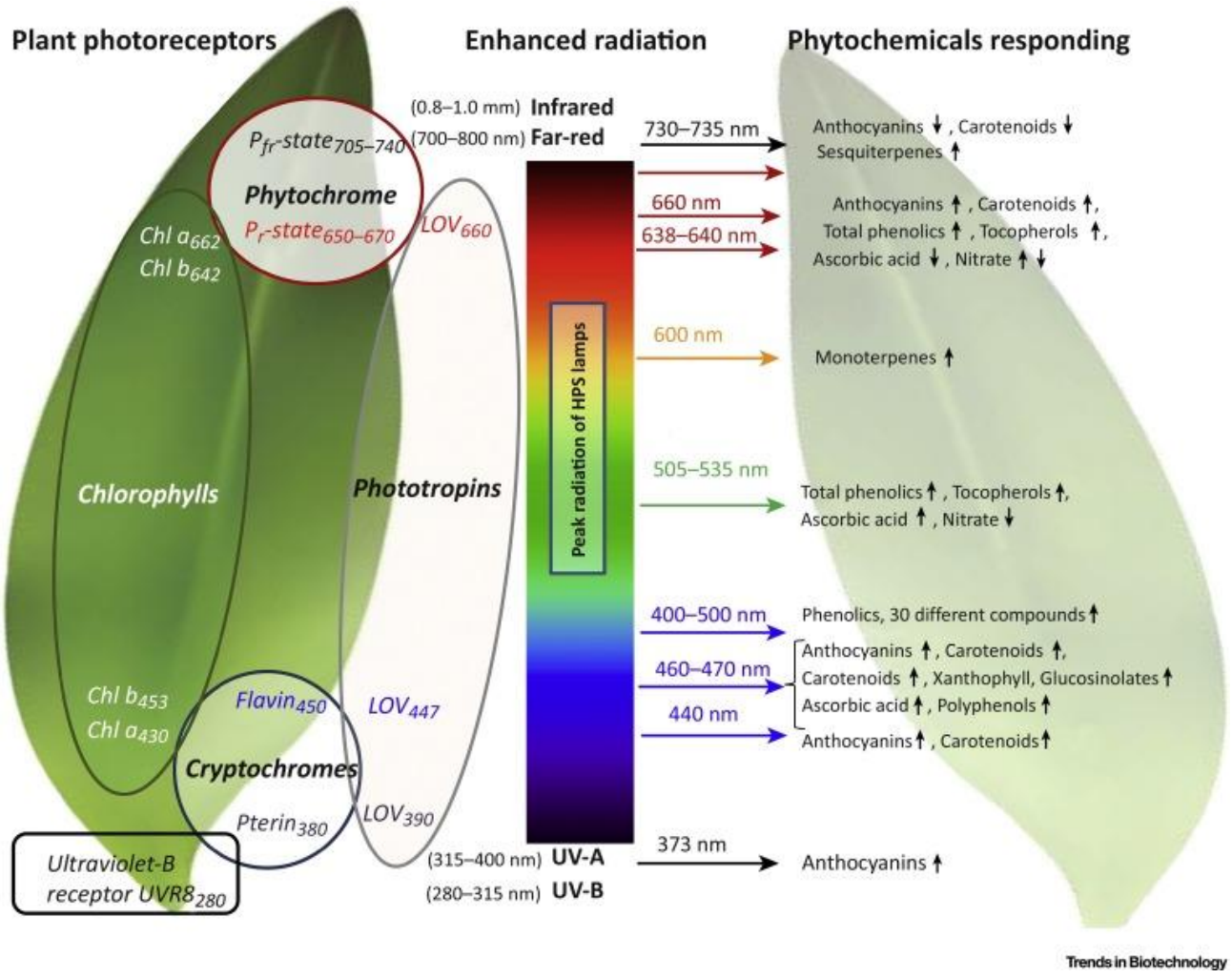


Photo source:
http://www.wildculture.com/article/gut-feelings-parkinson%E2%80%99s-and-depression/1651

NEED TO UNDERSTAND MORE



Copyright Fondriest Environmental, Inc. (2014) "Solar Radiation and Photosynthetically Active Radiation." Fundamentals of Environmental Measurements.

THANK YOU

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TRICHOMES: ABIOTIC & BIOTIC INFLUENCES

- Abiotic Influences
  - Full sun radiant flux and frequencies
  - Air temp, humidity, gas mix
  - Water
- Biotic Influences
  - Genetics
  - Beneficial microbial and fungal network (soil food web)
  - Plant community
  - Herbivorous insects, fungal pathogens

BIOAVAILABILITY & SUNLIGHT: THREE EXAMPLES

- Photoreactivation
  - Presence of UVA + blue light allows plants to heal from and adapt to damage from UVB (Brit, 2004)
  - Adaptive adaptations include increases in antioxidants, terpenoids, phenolics, and resistance to herbivorous insects (Goto, et. al., 2016).

UVB damages the DNA of plants (and people). Production of phenolics including terpenoids:

- Nutrient and antioxidant compounds (anthocyanins and beta-carotene); and
- Glycosides which ward off insect herbivores (Goto, et. al., 2016).

GOING GREEN

Green light penetrates below upper layer of chloroplasts, and increases efficiency of photosynthesis in high-light conditions.

- "...red light is more effective than green light in white light at low PPFDs, but as PPFD increases, light energy absorbed by the uppermost chloroplasts tends to be dissipated as heat, while ***penetrating green light increases photosynthesis by exciting chloroplasts located deep in the mesophyll***." (Terashima et al, 2009, emphasis added)*

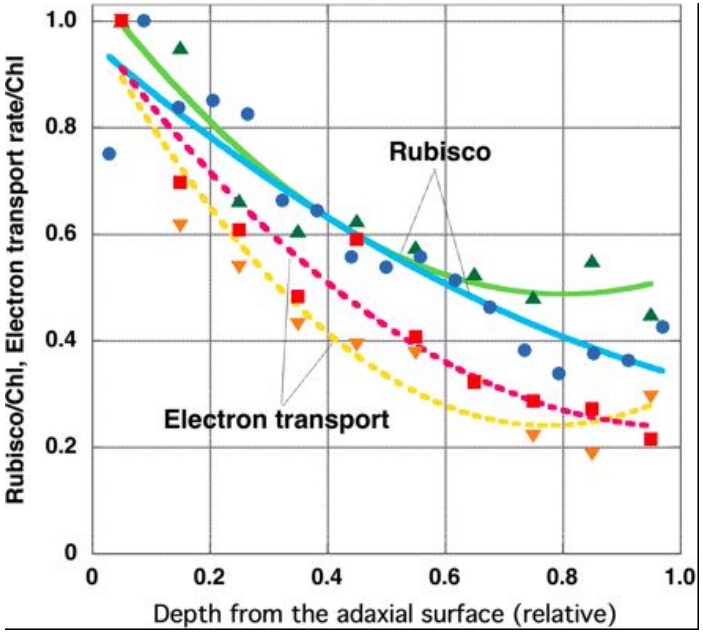

Figure 5: photosynthetic capacity under blue and green light as measured by RuBisCo content and DCPIP reduction (Terashima et al, 2009)

*Photosynthetic Photon Flux Density (PPFD) is a measure of the density of light within the visible range (400 to 700 nm) across 1 m^2. As it is limited to the visual range of frequencies, it represents an incomplete measure of the electromagnetic energy useful for plants.

THE EMERSON EFFECT

Established in 1957: two complementary photosystems for optimized photosynthetic efficiency in red and far-red frequencies.

- When plants are exposed to red (670 nm) and far-red (700+ nm) wavelengths simultaneously, the rate of photosynthesis increases significantly (Emerson, 1957).
- Multiple photosystems (PS1 and PS2) combine to maximize efficiency in variable lighting conditions.

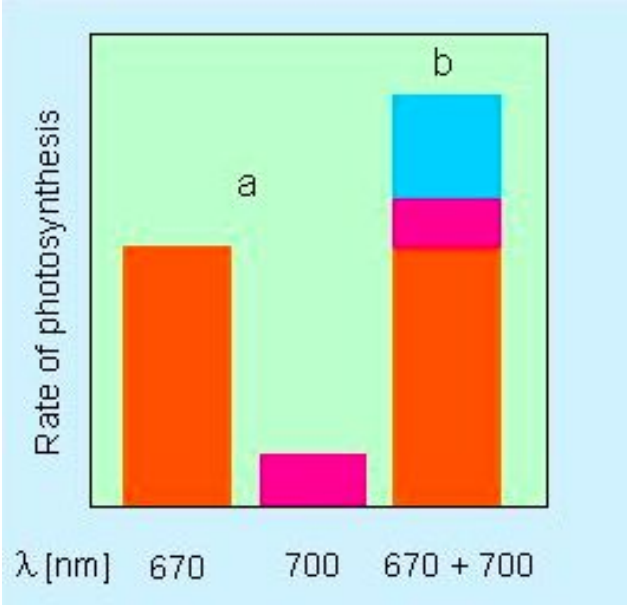

Figure 6: the rate of photosynthesis of plants exposed to red (670 nm) and far red (700 nm) frequencies in isolation, compared with the rate of photosynthesis when both frequencies are bioavailable (© Peter v. Sengbusch - b-online@botanik.uni-hamburg.de)

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Britt, A. B. 2004. Repair of DNA damage induced by solar UV. Photosynth. Res. 81, 105–112

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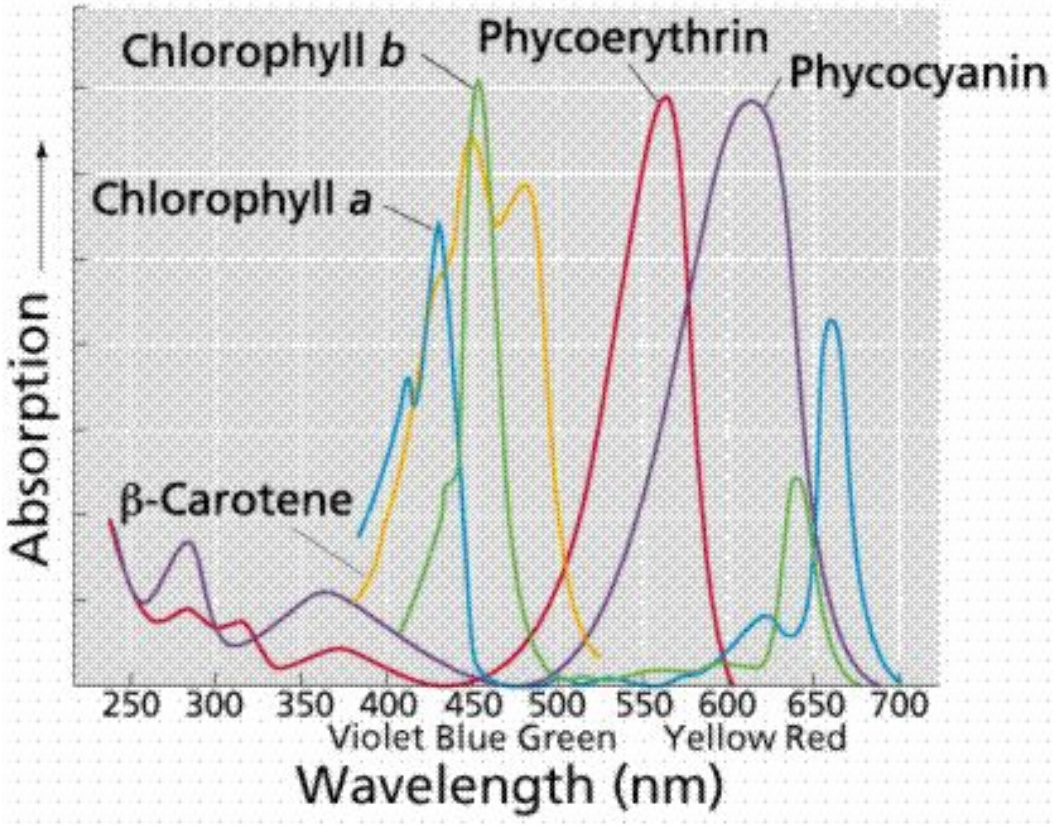
BIOAVAILABILITY OF SUNLIGHT SPECTRUM AND FREQUENCIES

- Photoreceptors absorb beyond PAR
- Stronger immune systems
  - Phenolics,
  - Terpenoids,
  - Antioxidants
- Faster growth and development



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SUNLIGHT ELECTROMAGNETIC SPECTRUM

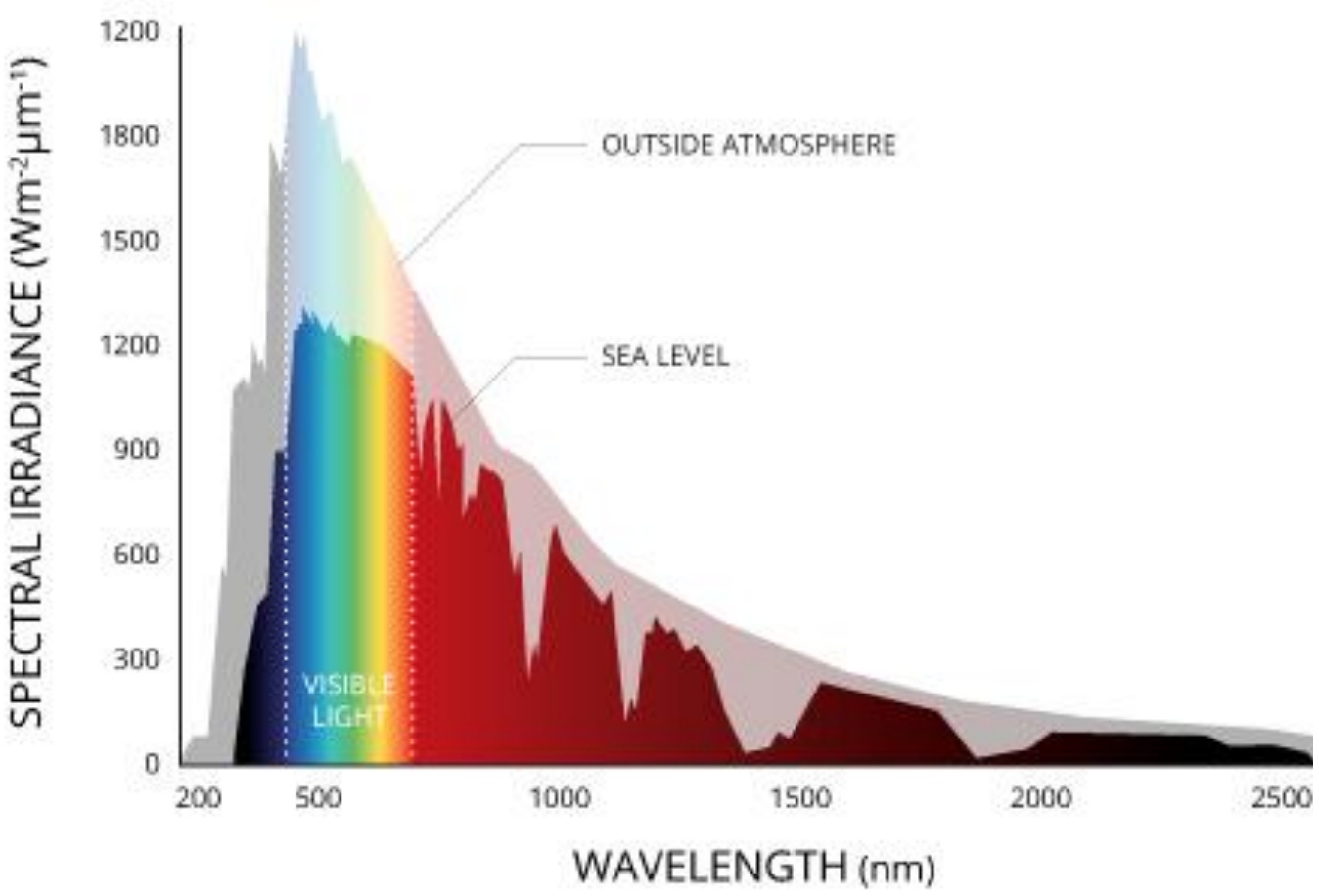

Figure 1: full electromagnetic sunlight spectrum outside Earth's atmosphere and at sea level (Fondriest Environmental, Inc)