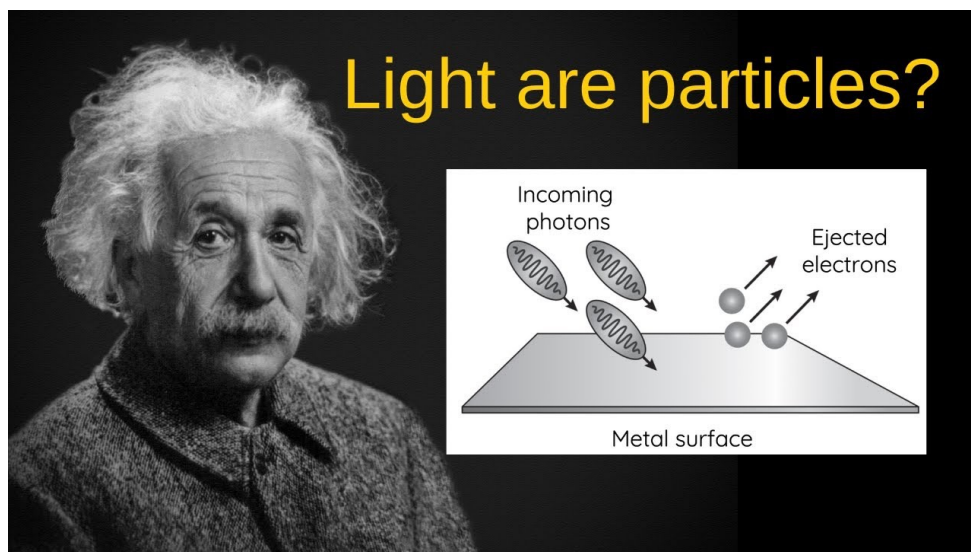


The Physics of Sunlight, Vitamin D and Circadian Rhythms

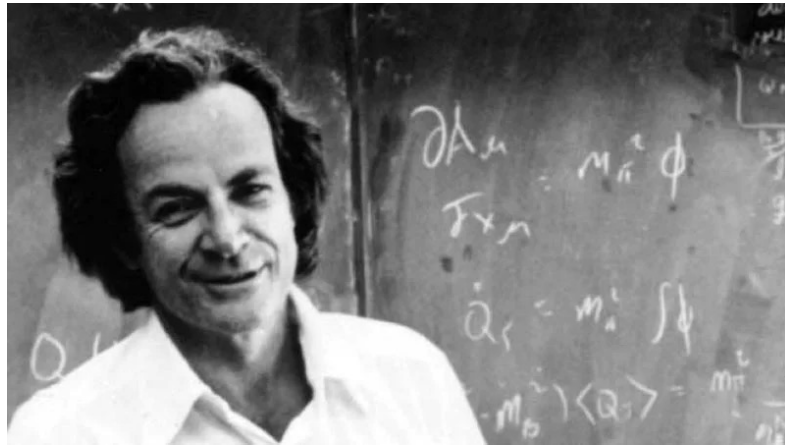
How one photon can unleash the activation of over 200 genes in our DNA!

1



Albert Einstein's Photoelectric Effect: Nobel Prize in 1927

2

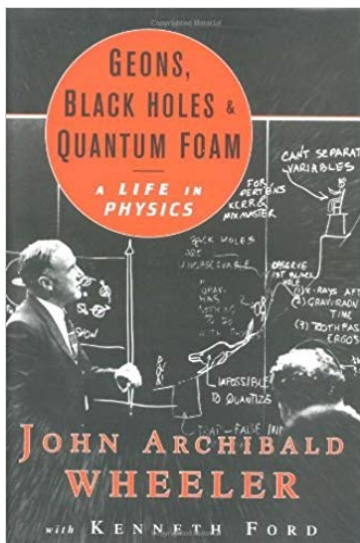


Richard Feynman

“Sunlight is captured in all matter.”

https://www.youtube.com/@The_Feynman_Way

3



“*It from bit* symbolizes the idea that every item of the physical world has at bottom...an immaterial source and explanation...that all things physical are information-theoretic in origin and that this is a participatory universe”

John Archibald Wheeler

...from particles to energy to information

4

PHOTON-MEMBRANE INTERACTION

The diagram illustrates the interaction of a photon with a skin cell membrane. On the left, a sun is labeled "GLOWING FLIGHT TRAIL". A "SINGLE PHOTON" is shown as a dot on a curved path moving towards the right. On the right, a "SKIN CELL MEMBRANE (PHOSPHOLIPID BILAYER)" is depicted as a double layer of phospholipids. A "CELL SURFACE RECEPTOR MOLECULE" is shown embedded in the membrane, with an arrow pointing to it from the photon's path. Below the membrane, the equation $E = hf$ is written, followed by the text "PHOTON ENERGY: E = Planck's constant x frequency".

https://www.youtube.com/@The_Feynman_Way

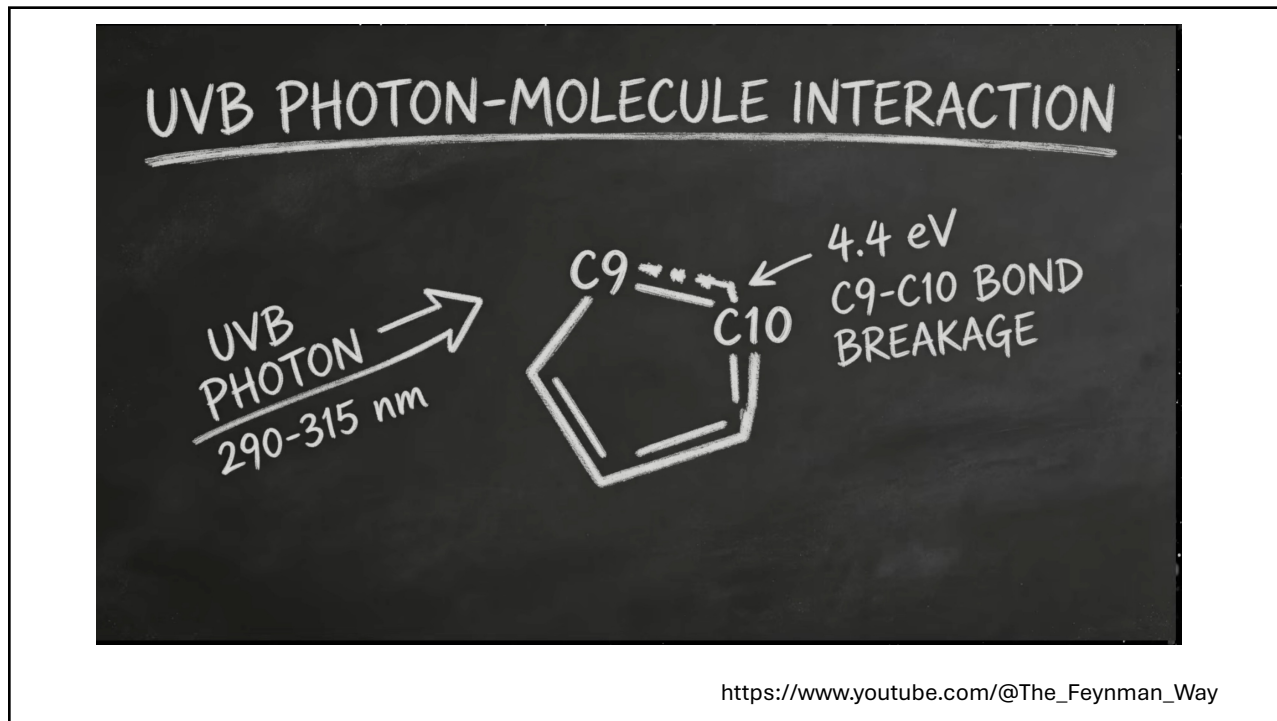
5

CHOLESTEROL → 7-DHC SKIN SYNTHESIS & TRANSPORT PATHWAY

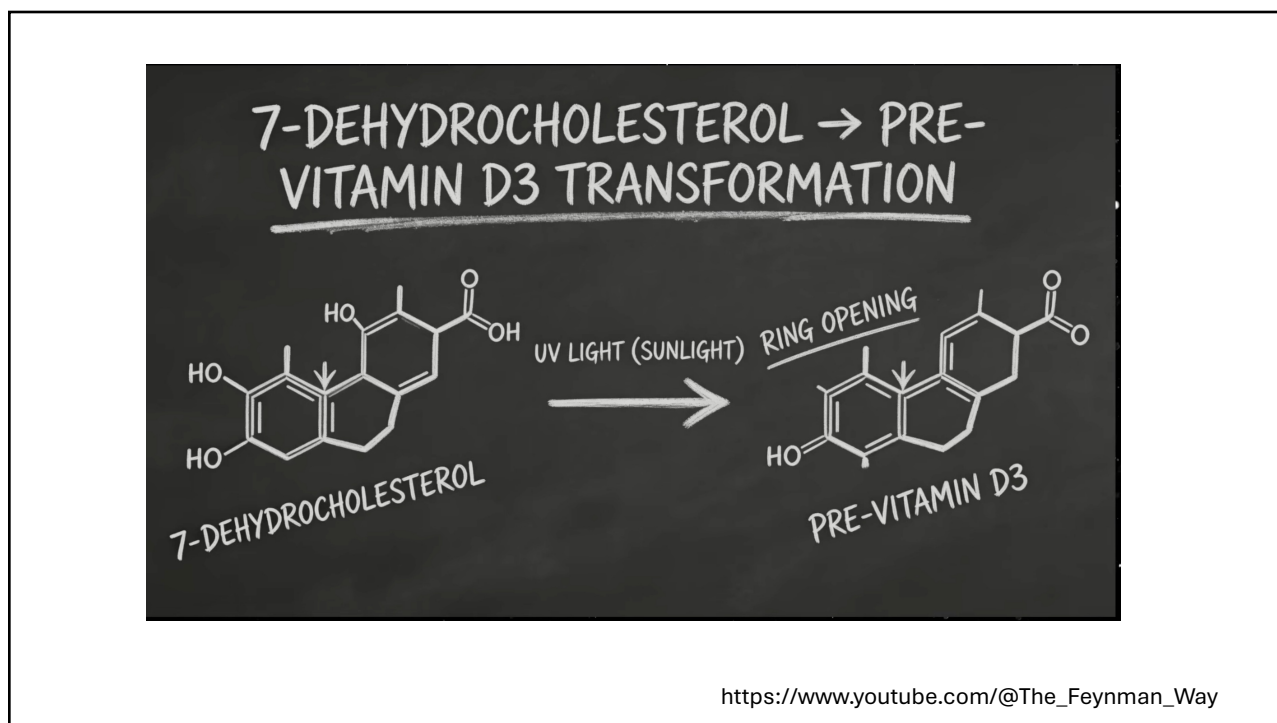
The diagram shows the synthesis and transport of 7-DHC from cholesterol. On the left, a box labeled "CHOLESTEROL" has an arrow pointing to a box labeled "7-DEHYDROCHOLESTEROL (7-DHC)" with the text "ENZYMATIC CONVERSION →" below it. An arrow labeled "7-DHC TRANSPORT TO SKIN LAYERS" points from the 7-DHC box to a cross-section of skin. The skin is divided into two layers: "STRATUM SPINOSUM" (the upper layer) and "STRATUM BASALE" (the lower layer). "UVB PHOTONS • PENETRATES THESE LAYERS" are shown as wavy arrows entering the skin. Below the skin cross-section, the text reads "UVB-INDUCED REACTION: 7-DHC → PREVITAMIN D3".

https://www.youtube.com/@The_Feynman_Way

6



7



8


★ UVB: THE BOND-BREAKER ★

$\phi = 295\text{nm}$

$$E = hc / \phi = (6.626 \cdot 10^{-34} \times 3 \cdot 10^8) / \sqrt{295 \cdot 10^{-9}}$$

$$= 6.74 \cdot 10^{-19} \text{ J} = 4.2 \text{ eV}$$

Pro-vitamin D₃ bond



UVB photon < Bond broken!

THE CASCADE

7-DHC absorbs

Pre-vitamin D₃
D₃ formed

Vitamin D₃
(cholecalciferol)

↓ ↓

200 GENES REGULATED

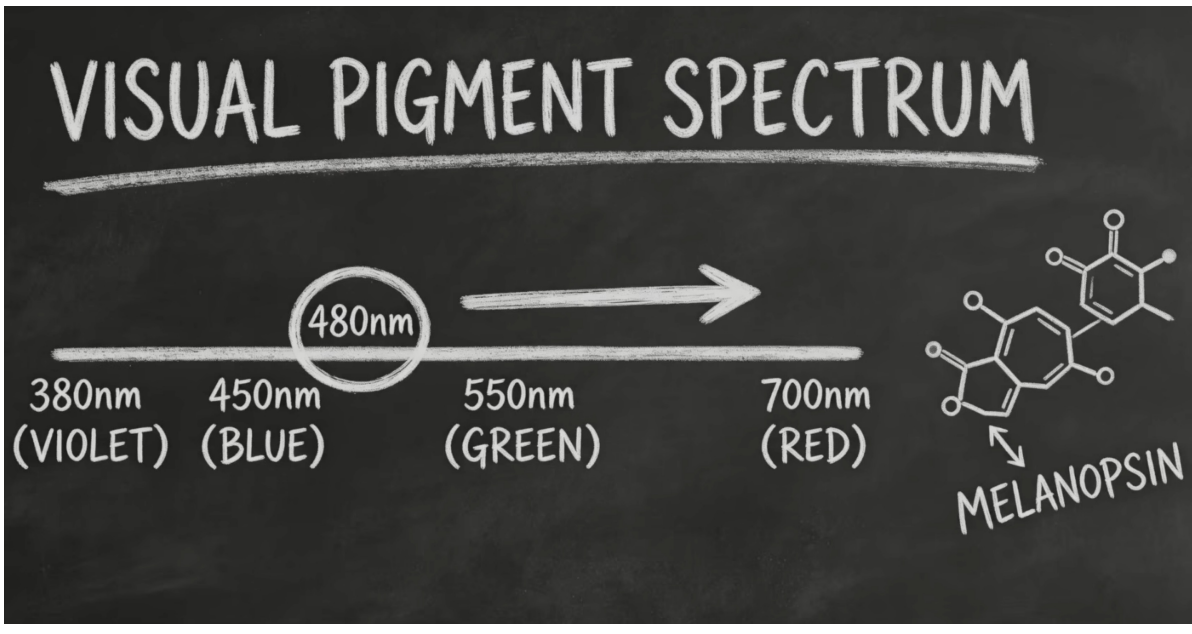
200⁰
transcription factor targets

ONE PHOTON = ONE BOND BREAK
200 GENE CASCADE

https://www.youtube.com/@The_Feynman_Way

9

VISUAL PIGMENT SPECTRUM



380nm (VIOLET) 450nm (BLUE) **480nm** 550nm (GREEN) 700nm (RED)

MELANOPSIN

https://www.youtube.com/@The_Feynman_Way

10

THE HIDDEN PHOTORECEPTORS OF THE RETINA

Most people have never heard of these cells – yet they govern your sleep-wake cycle

https://www.youtube.com/@The_Feynman_Way

11

UVA – NITRIC OXIDE – BLOOD PRESSURE

Photon energy = 315-400

https://www.youtube.com/@The_Feynman_Way

12

PHOTOCHEMISTRY OF SUNLIGHT IN HUMAN TISSUE

<p style="text-align: center;">SKIN</p> <p>7-dehydrocholesterol + $h\nu$ (UVB) → previtamin D₃</p> <p>$\phi = 290-315$ nm required quantum yield $\epsilon < 0.002-0.05$</p>	<p style="text-align: center;">RETINA</p> <p>ipRGC melanopsin: ϕ_e peak = 480 nm signal path: retina – SCN – pineal gland melatonin suppression: $\Delta M < \log(E_e \text{ illuminance})$</p>
<p style="text-align: center;">BONE</p> <p>D₃ + 25(OH)D₃ → 1,25(OH)₂D₃ (calcitriol) Ca²⁺ absorption: $dCa/dt = k < [\text{calcitriol}]$ bone mineral density equation: BMD(t) = BMD₀ + f[D₃]</p>	<p style="text-align: center;">BLOOD PRESSURE</p> <p>UVA + skin – NO (nitric oxide) NO → vascular smooth muscle relaxation $\Delta BP < -f(\text{NO concentration})$</p>

All four pathways initiated by:
 $E = h\phi = hc/\sigma$

https://www.youtube.com/@The_Feynman_Way

13

RED LIGHT THERAPY: THE THIRD BAND

Band 1: UVB

- ✓ skin rejuvenation
- ✓ wound healing
- ✓ pain reduction
- ✓ mood improvement

Band 2: Near-infrared

Band 3: Red / near-red
600-1000 nm

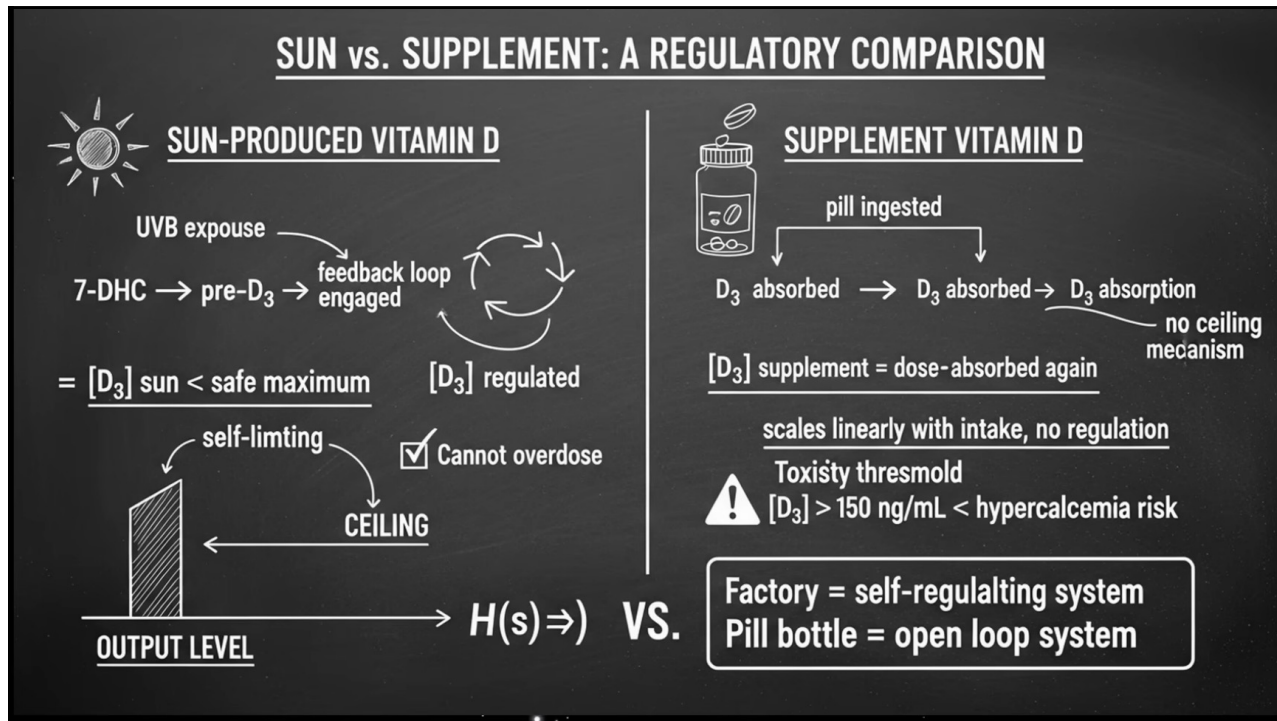
Photon ($\lambda = 630-850$ nm) + cytochrome c oxidase
→ ATP production restored

Mechanism: real. Physics: described in prior section.

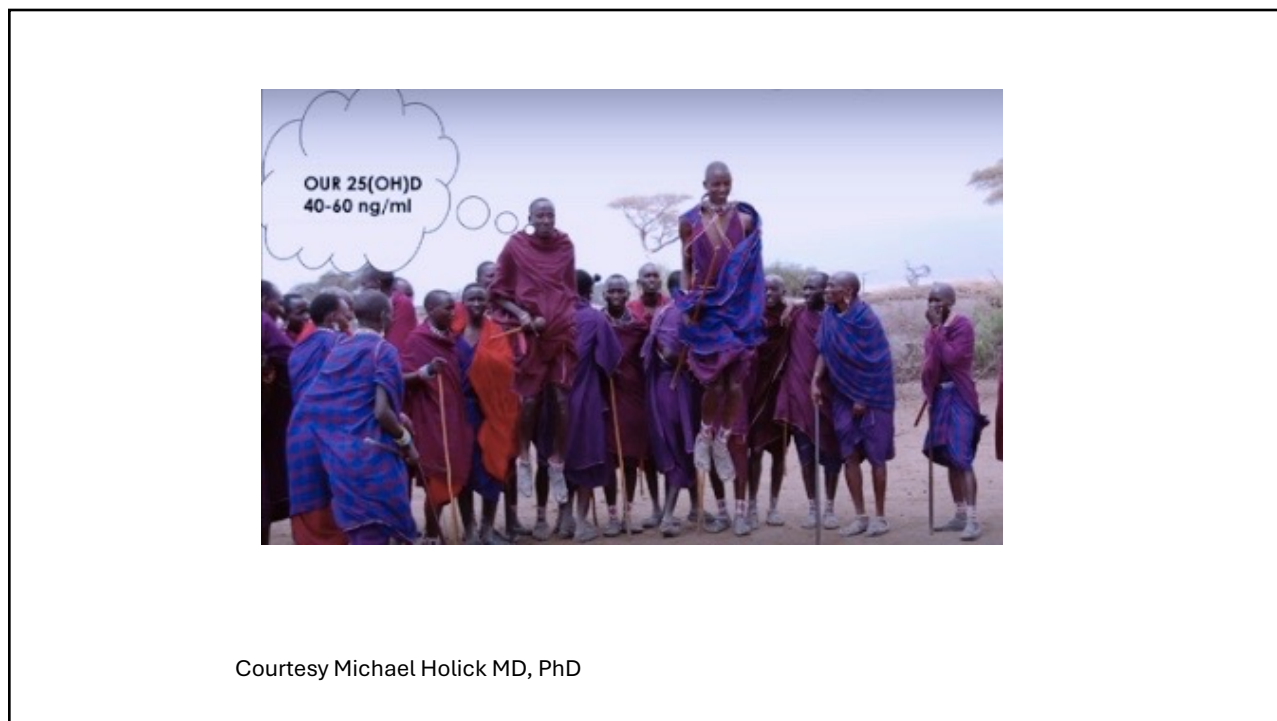
Band 3 delivered in isolation. Bands 1 and 2 absent.

https://www.youtube.com/@The_Feynman_Way

14



15



16

MELANIN AS UVB OPTICAL FILTER

UVB photon $h\nu$
 $\lambda = 290-315 \text{ nm}$

absorbed by melanin = heat (no vitamin D synthesis)
photon reaches 7-DHC = vitamin D synthesis

Labels: Stratum corneum, Stratum basale / spinosum, 7-dehydrocholesterol (7-DHC) (resolHC) resides here, Dermis

$I(z) = I_0 \sim e^{-\sigma_a z}$
Beer-Lambert attenuation
 σ_a = melanin absorption coefficient
 z = depth into skin
 $\sigma_a(\text{darker skin}) \gg \sigma_a(\text{lighter skin})$
fewer photons reach 7-DHC layer

LOW melanin concentration:

https://www.youtube.com/@The_Feynman_Way

17

THE ONLY INPUT THE CLOCK ACCEPTS

Inputs (marked with X):

- Sleeping pills: sedation < sedation reset
- Melatonin supplement: weak phase shift only, no amplitude restoration
- Exercise: minor modulator only
- Caffeine: masks sleepiness, minor modulator only
- Exercise: weak zeitgeber

Primary Zeitgeber: 480nm photons (ipRGC > retinohypothalamic tract) → SCN

Equation: $\frac{d\phi}{dt} = K \alpha L(t) \frac{1}{\sin(\phi - \phi_{light})}$ response

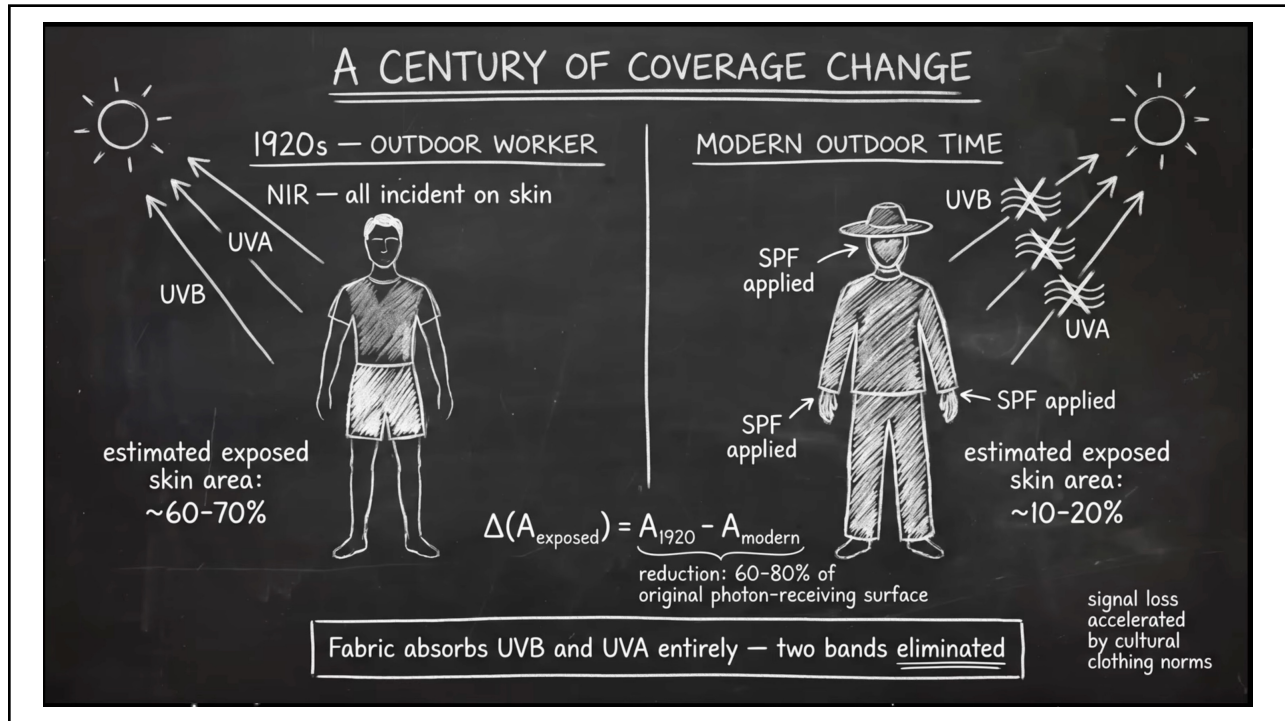
SCN Circadian Clock
 $\rho = 24.0h$ (entrainment)

480nm melanopsin absorption peak

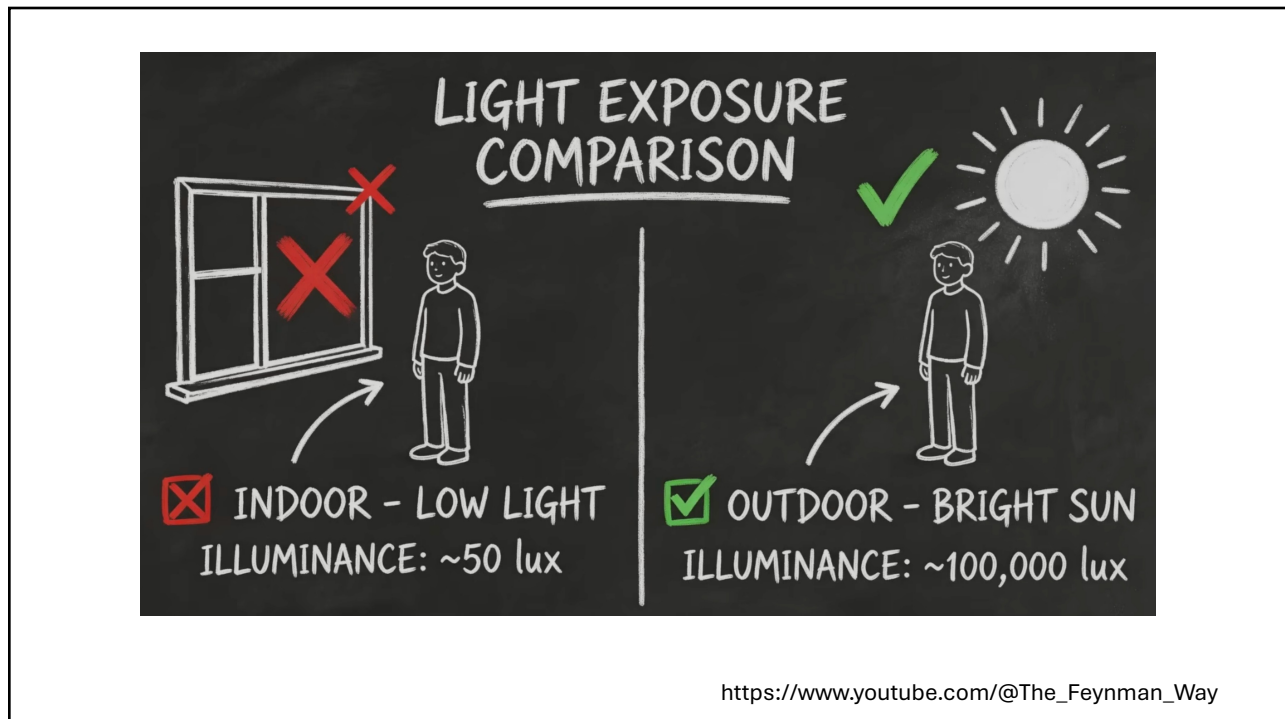
Photons entering the retina via melanopsin: the sole resetting input

https://www.youtube.com/@The_Feynman_Way

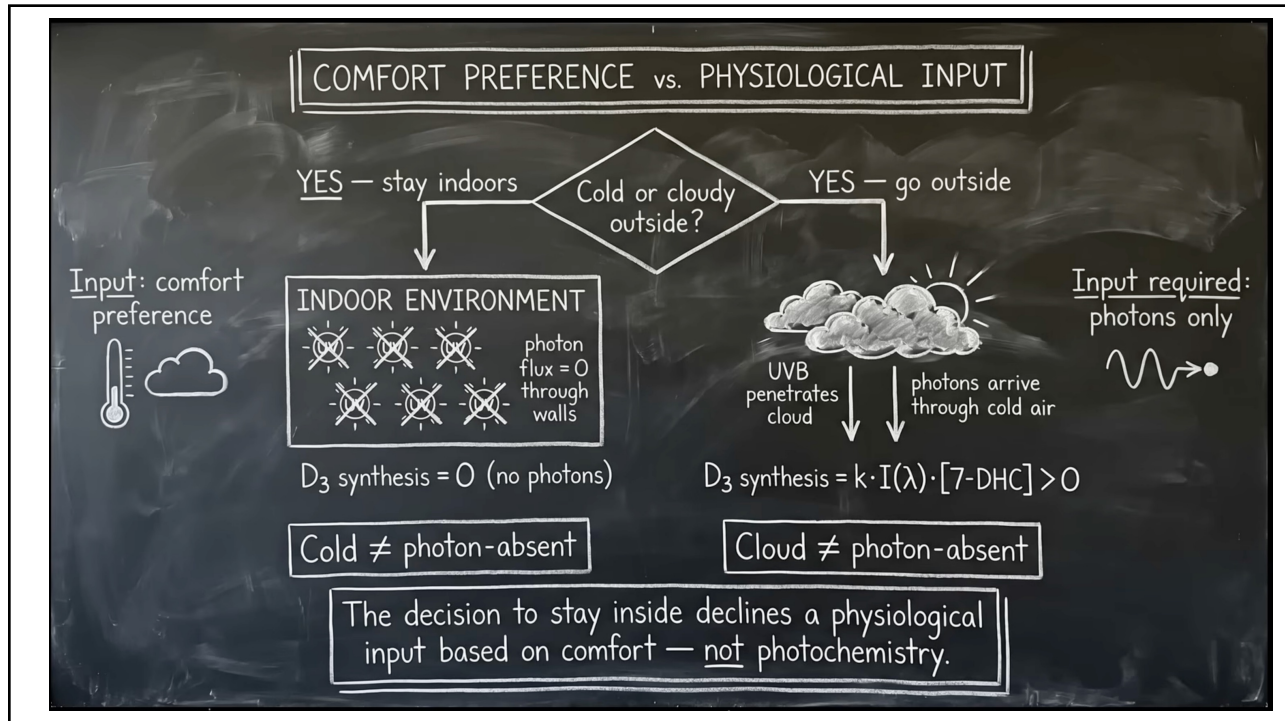
18



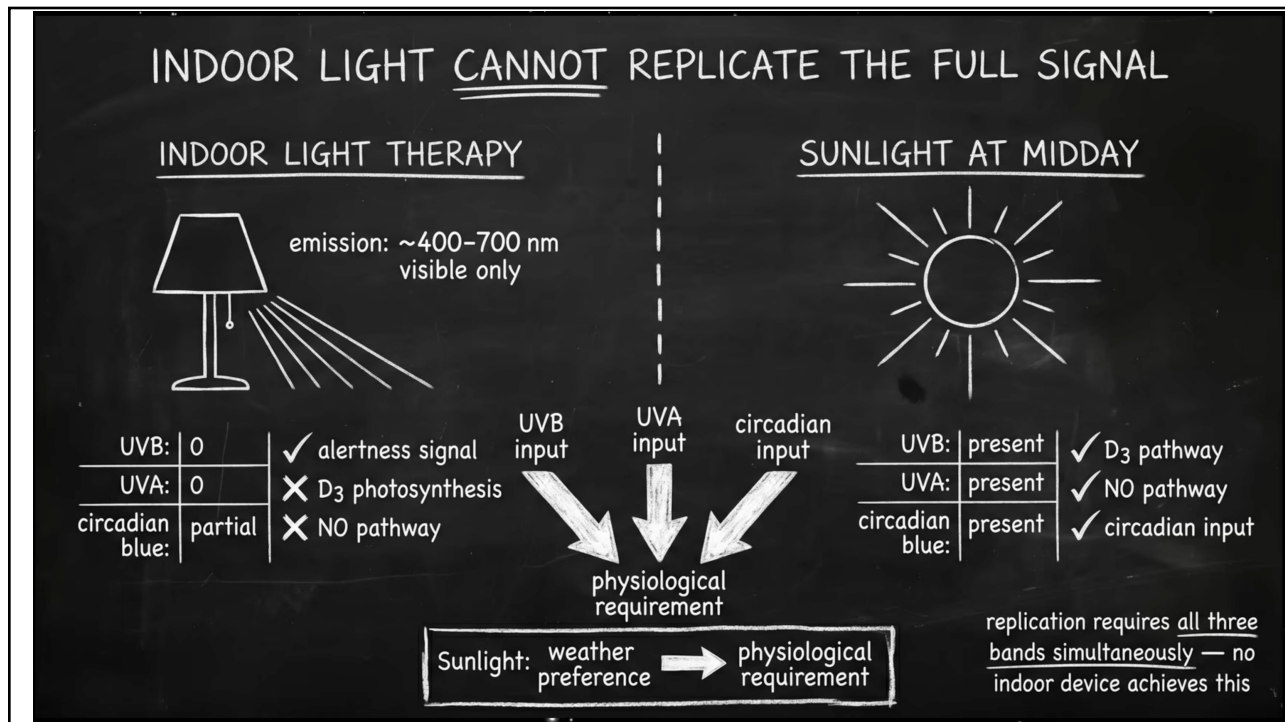
19



20



21



22

GLASS, WINDOWS AND LIGHT FILTERING

50000 lux side

50,000 lux outdoors

glass window

1,000-2,000 lux near window

- UV-A: partially blocked
- UV-B: mostly blocked
- Visible 480nm: partially transmitted
melanopsin peak attenuated

UV filtered by 380nm

filtered by glass

glass transmission %

Even at the window, intensity drops a fraction of a fraction of outdoor levels

E_o window < E_o outdoor
not equivalent stimuli

Evolution
melanopsin evolved to be calibrated by direct sun exposure, not filtered indoor light

23

SAME PHOTON

UV PHOTON SPLITS

BENEFITS

VITAMIN D

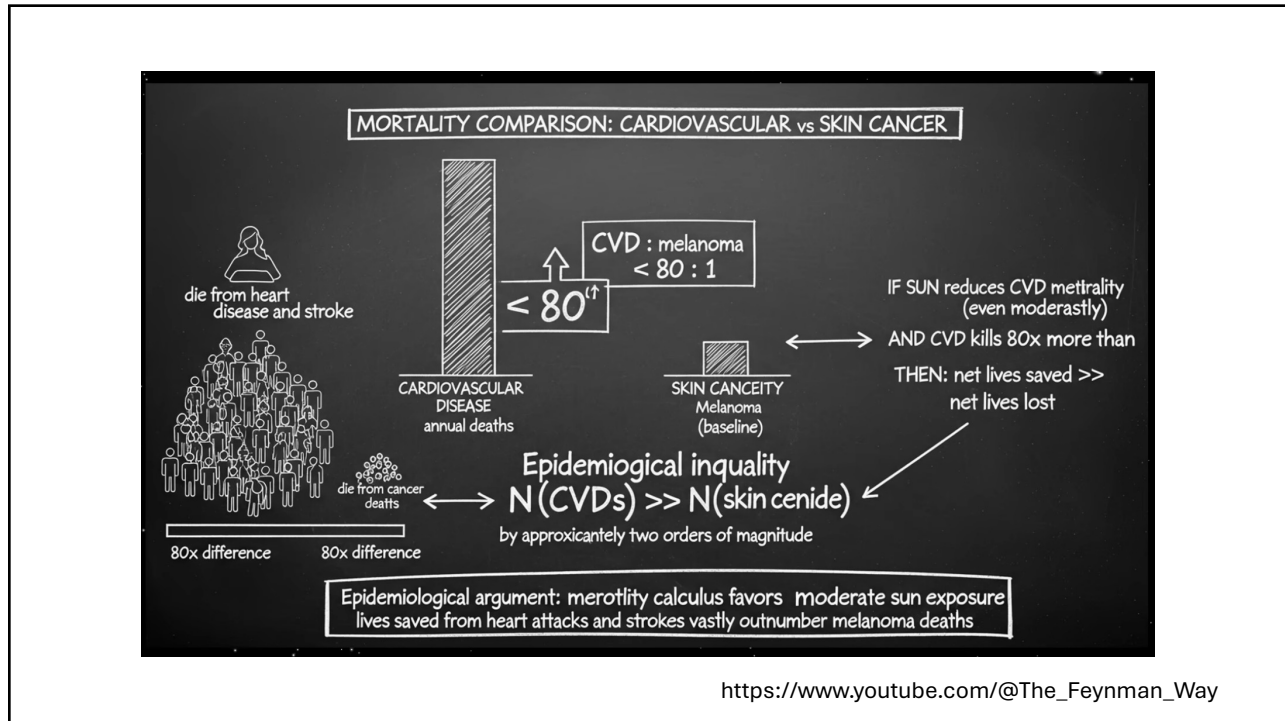
NO (NITRIC OXIDE)

RISKS

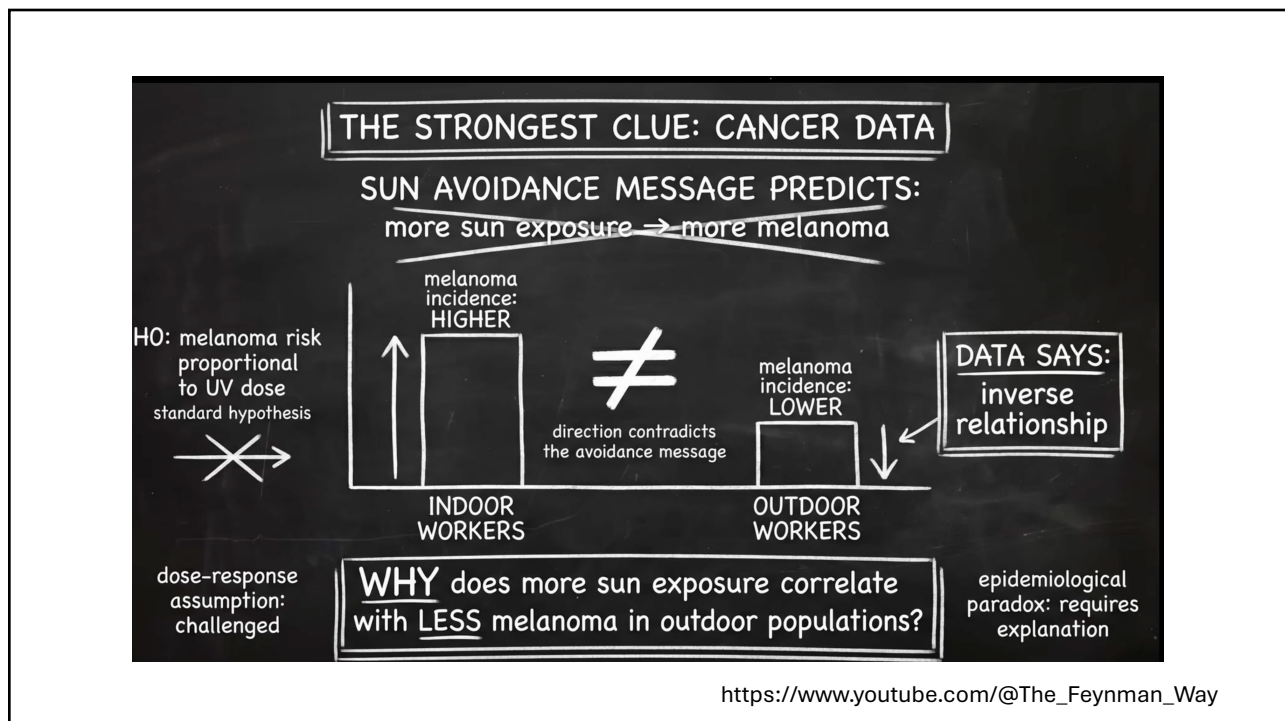
DNA DAMAGE

https://www.youtube.com/@The_Feynman_Way

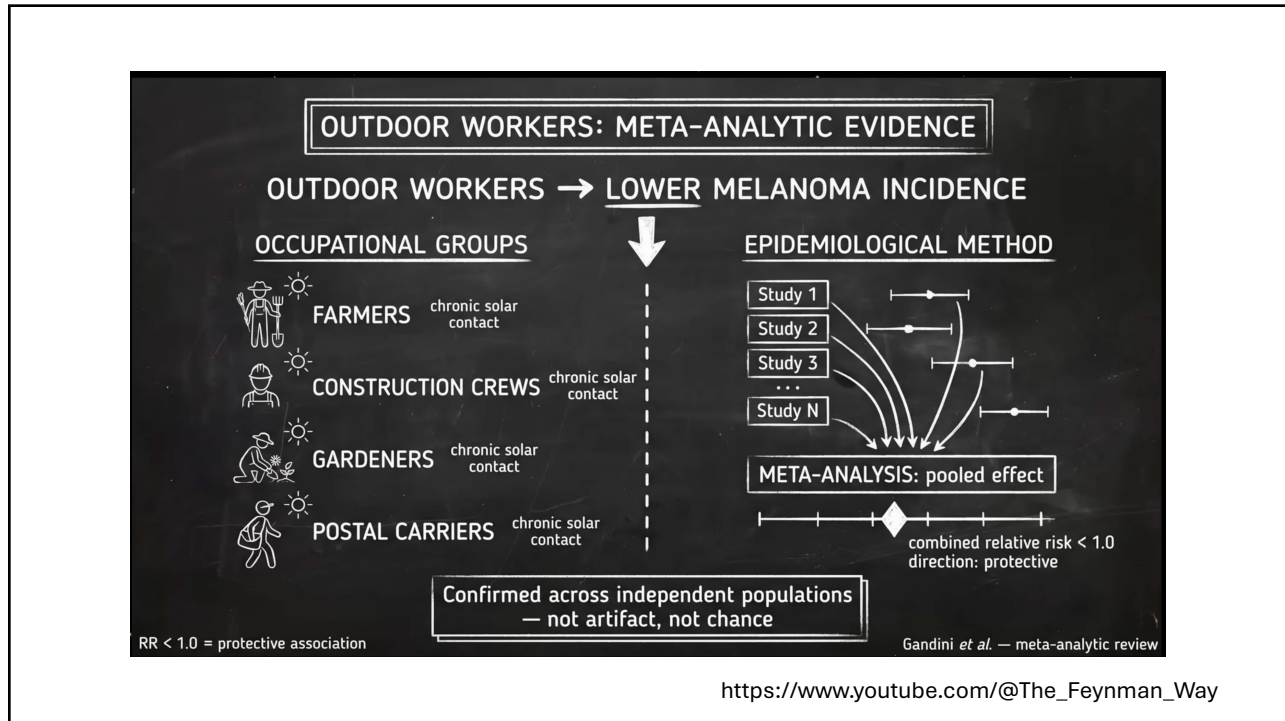
24



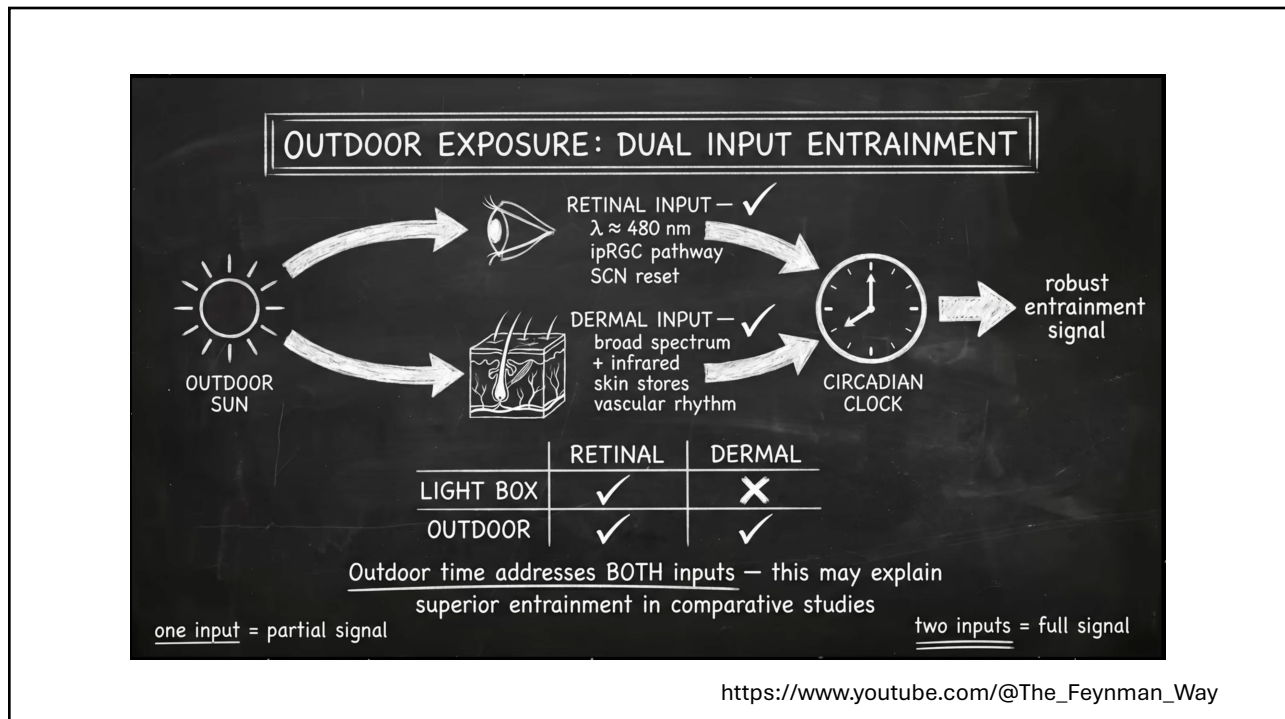
25



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HELIOOTHERAPY: 1920s–1930s MAINSTREAM PRACTICE

$UV_{dose} = I_{UV} \times t \times \cos(\theta)$

I_{UV} = UV intensity
 t = exposure time
 θ = angle of incidence

- Tuberculosis sanatoria: open-air terraces
- Direct sunlight: prescribed treatment
- Mainstream medical practice: documented

UV decreases with latitude

patients: prescribed sun exposure

HELIOOTHERAPY ERA 1900 → 1940

institutionalized sun exposure as medicine

Sun exposure was medicine — the award said so

https://www.youtube.com/@The_Feynman_Way

29

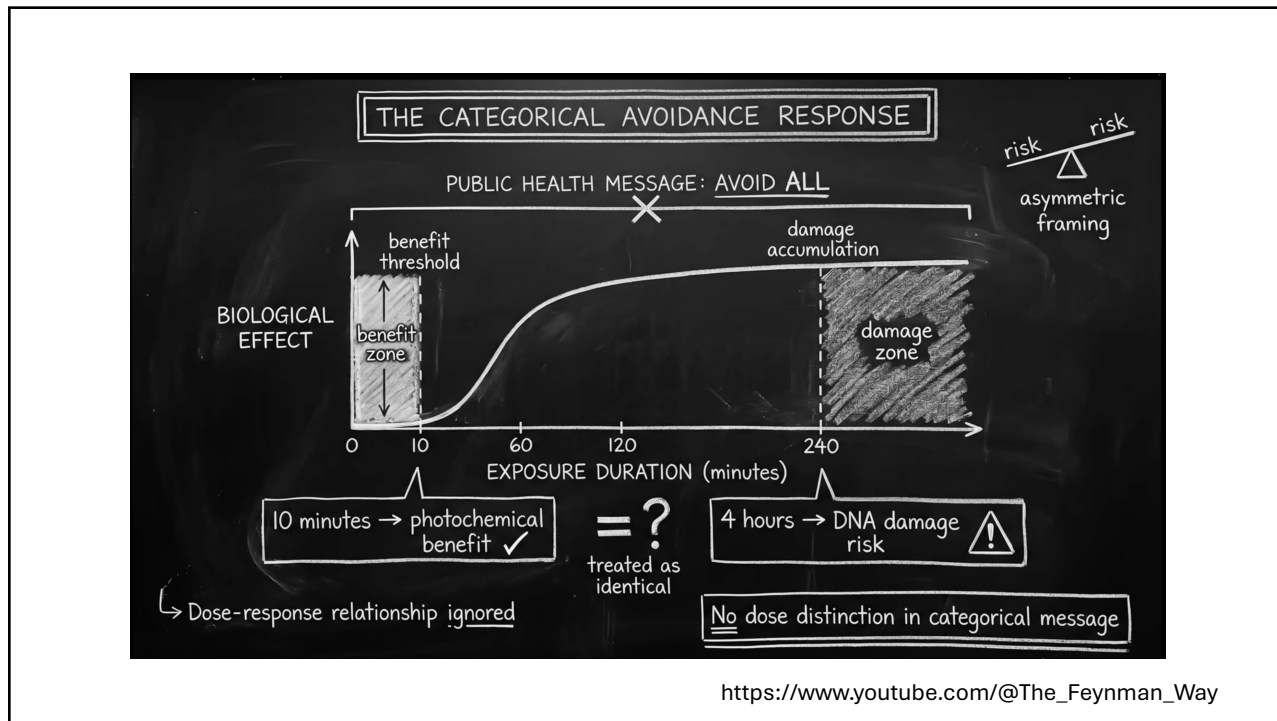
HELIOOTHERAPY PRECISION vs. MODERN AVOIDANCE

<p>HELIOOTHERAPY PROTOCOLS c.1920 ✓</p> <ul style="list-style-type: none"> ✓ Dose specified in minutes and hours ✓ Adjusted for patient skin type ✓ Corrected for latitude of sanatorium ✓ Graduated escalation schedule ✓ Monitored clinical response <p style="text-align: center;"> $D = I_{UV} \times t \times A_{skin} \times \text{correction}(\phi)$ <small>four-variable calibration</small> </p> <div style="text-align: center; margin-top: 10px;"> <p>more scientific rigor</p> </div>	<p>MODERN AVOIDANCE MESSAGE ?</p> <ul style="list-style-type: none"> ✗ No dose specification ✗ No skin-type differentiation ✗ No latitude adjustment ✗ Binary: avoid or protect ✗ No graduated protocol <p style="text-align: center;"> "Avoid the sun. Wear sunscreen." <small>zero-variable instruction</small> </p>
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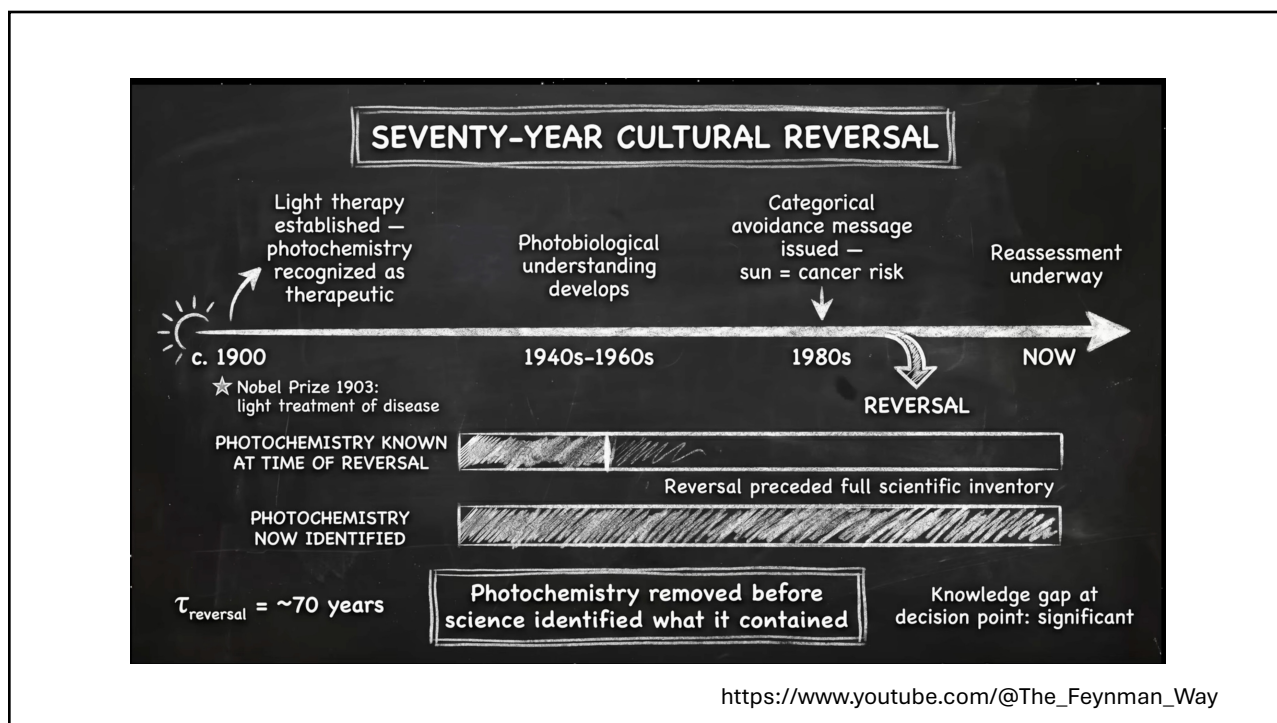
Dose precision present in 1920 — absent in current public messaging

https://www.youtube.com/@The_Feynman_Way

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32

CHRONIC MODERATE SUB-ERYTHEMAL EXPOSURE

MON dose per day: constant, moderate TUE WED THU FRI

erythema threshold (MED = 1)
always sub-erythema
cumulative dose: linear accumulation

<p>WHO</p> <ul style="list-style-type: none"> - farmers - construction - gardeners - postal carriers <p><i>sub-erythema: below reddening threshold</i></p>	<p>WHAT</p> <ul style="list-style-type: none"> - chronic, moderate - year-round solar contact $D_{daily} < MED$ $D_{annual} = \text{high by accumulation}$ 	<p>RESULT</p> <ul style="list-style-type: none"> - melanoma incidence: \downarrow below indoor baseline
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Regularity + moderation = protection.
Irregularity + intensity = risk.

UVB spectrum 290-315 nm

https://www.youtube.com/@The_Feynman_Way

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SUDDEN HIGH-DOSE EXPOSURE: UNPREPARED SKIN

beach holiday begins

INDOOR WORKER: weeks of zero exposure

HIGH INTENSITY UV
UV index = 8-11

intense radiation - no adaptive protection

thin, unadapted epidermis
melanin: baseline only

Melanin: insufficient

Repair enzymes: resting state only

Epidermal barrier: thin

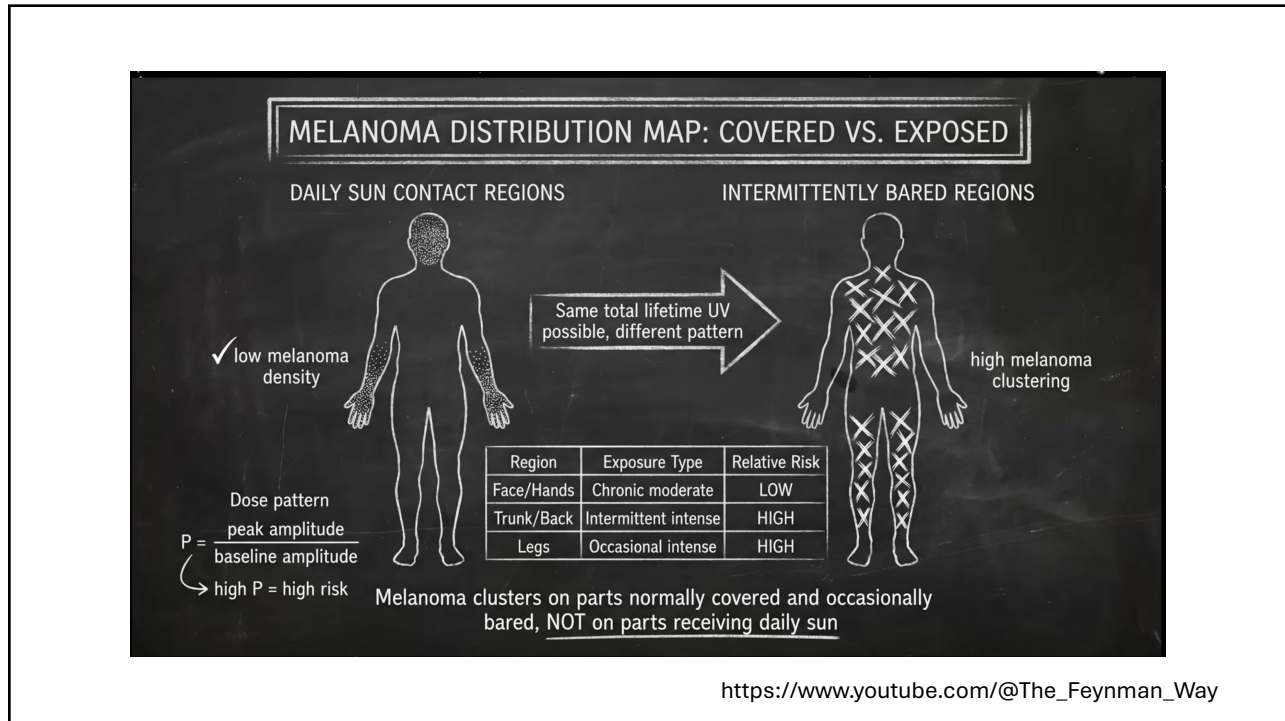
Damage rate $D(t) \gg$ Repair rate $R(t)$

lesions accumulate
repair capacity: fixed at baseline

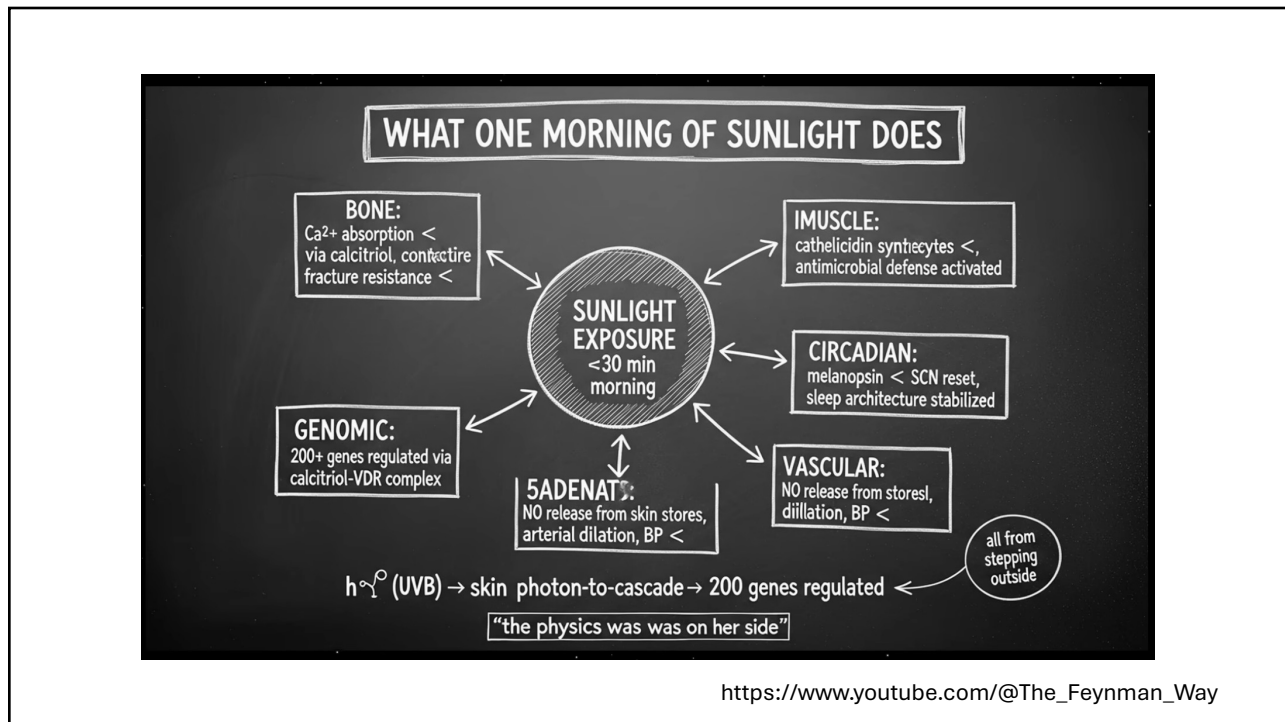
Unprepared system meets high-intensity signal

https://www.youtube.com/@The_Feynman_Way

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35



WHAT 10-20 MINUTES ACCOMPLISHES

✓	VITAMIN D₃ SYNTHESIS	$\text{Rate}_{D_3} = E_{UVB} < [7\text{-DHC}]$	Near-maximal synthesis achieved at 15 min
✓	NITRIC OXIDE RELEASE	$\text{NO flux} = k_{NO} < [\text{RSNO}]_{\text{dermal}}$	Significant NO released from dermal reservoirs
✓	Phase shift $\varphi = f(E_e \text{ illuminance}, t_e \text{ exspsorin})$		
✓	CIRCADIAN ENTRAINMENT (eyes)		Robust phototraiment <i>via</i> IPRGC melanopsin
✓	SEROTONIN STIMULATION	$[5\text{-HT}]_{\text{brain}} < k_s < E_s \text{ retinal}$	Meaningful serotonin elevation
✓	DNA REPAIR CAPACITY	$D(t) = R(t): \text{net lesion cleantaned}$	Within skin daily repair capacity



arms → ← face
→ ←

https://www.youtube.com/@The_Feynman_Way