Biomedical Applications of Tattoos

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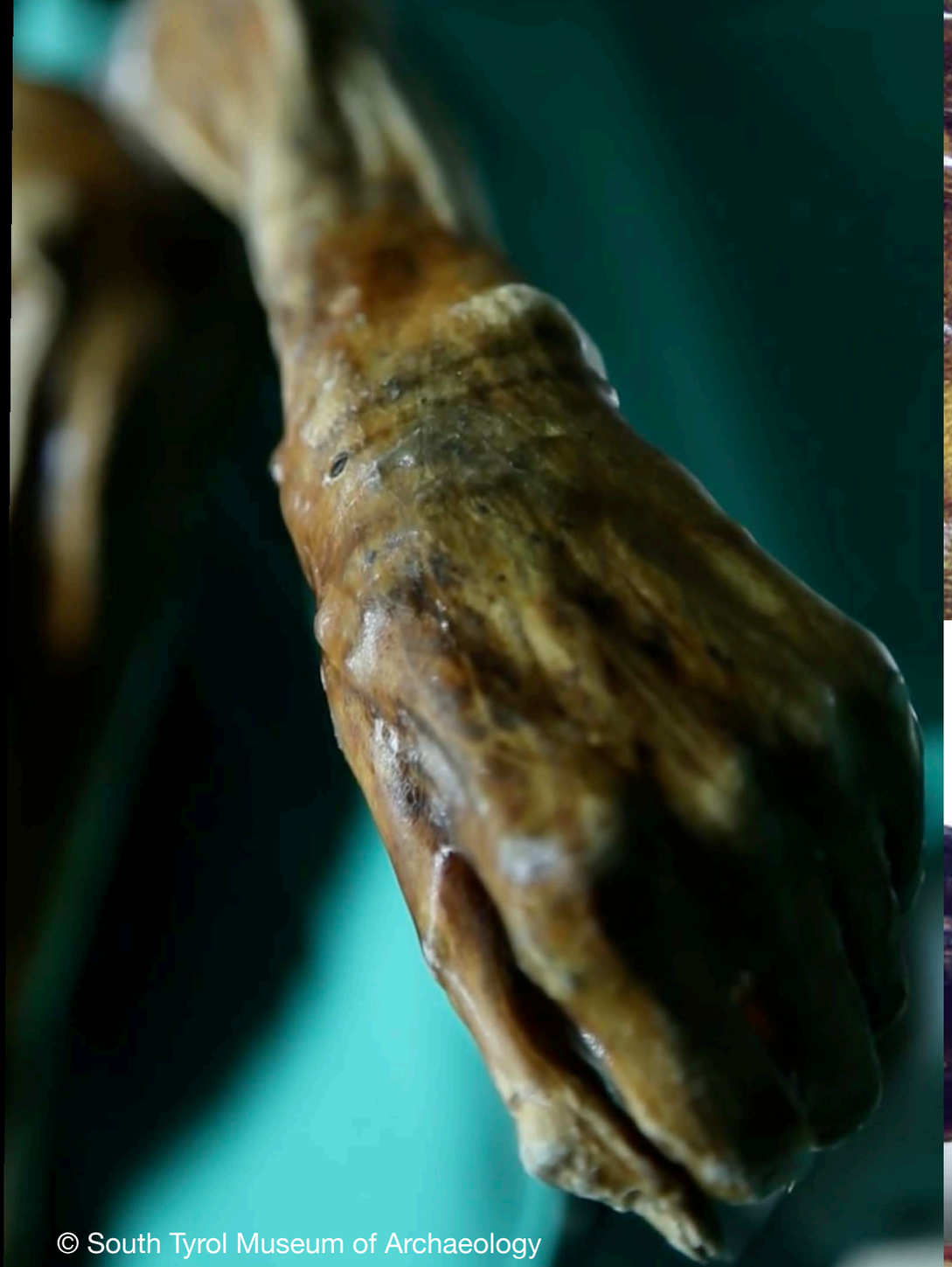
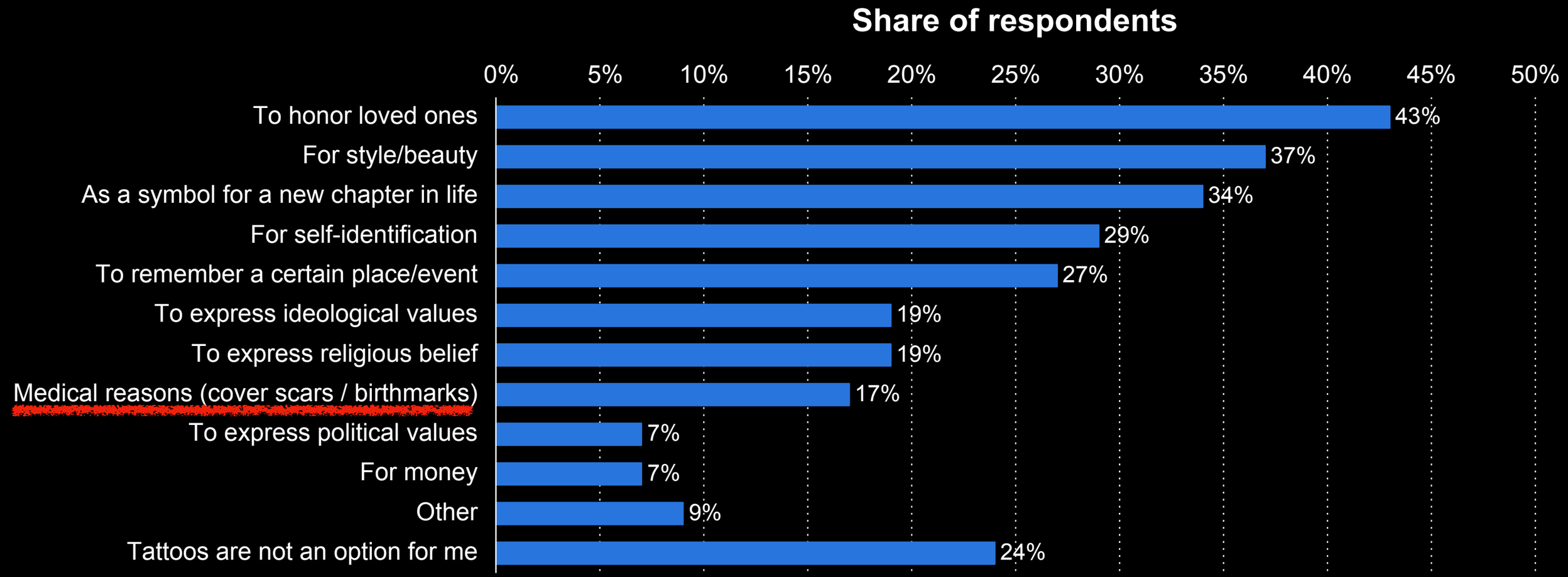
Ötzi



The oldest **tattoos** we've ever seen were for **therapeutic** use


$2B
Why Do People Get Tattoos?
46% of US adults have a tattoo

Why Do People Get Tattoos?

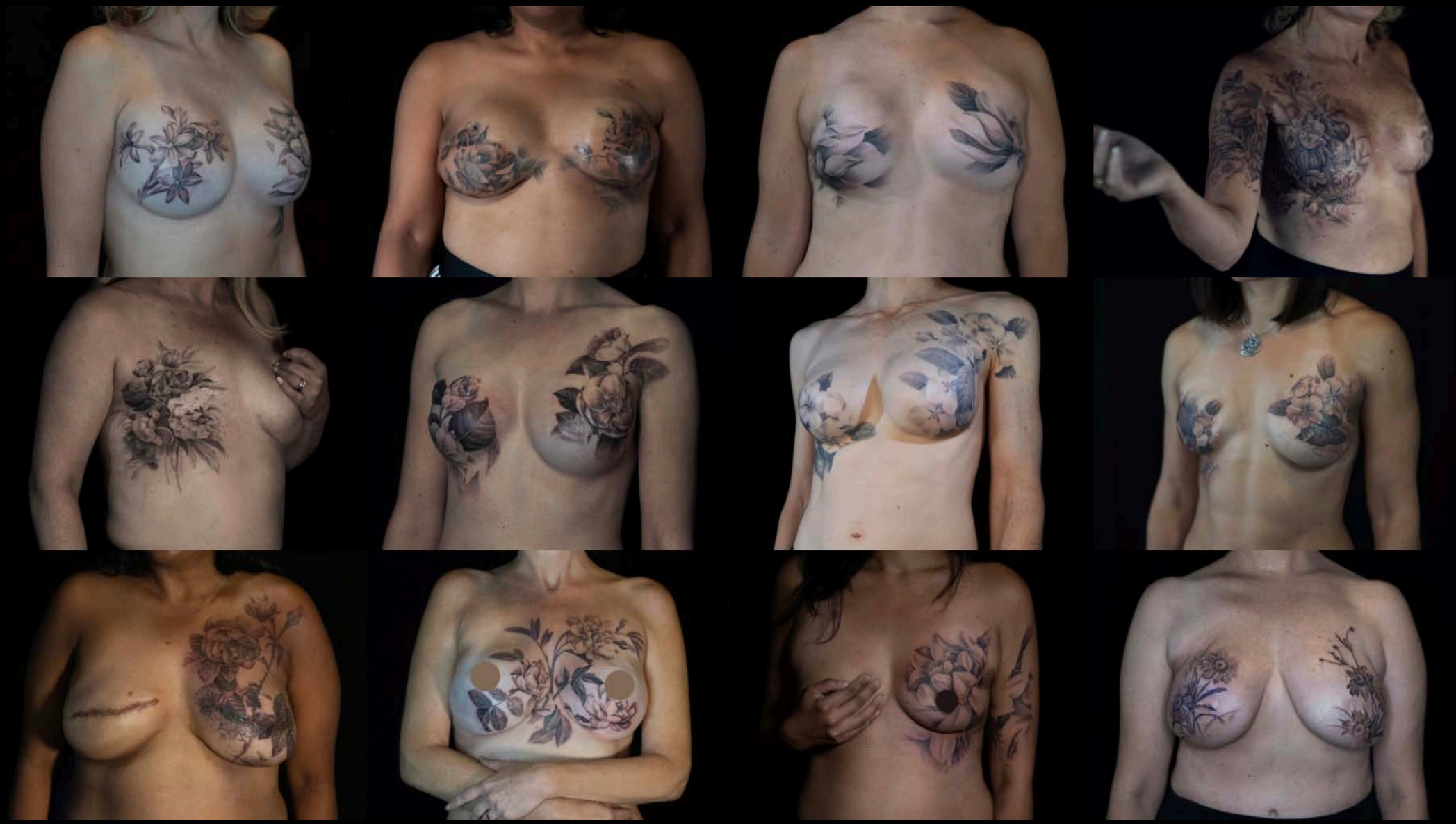


Note(s): United States; December 3 to 10, 2019; 18 years and older; 1021 respondents
Further information regarding this statistic can be found on page 60.
Source(s): Statista Survey; ID 721517

statista

Biomedical Use of Tattoo Pigments

Post-Mastectomy Tattoos



David Allen
allentattoo.com

Biomedical Use of Tattoo Pigments

Medical Aesthetics

Vitiligo Treatment

https://www.debramiller.com.au/vitiligo-treatment-perth/

Reconstructive Surgery

Becker, J. *Plastic and Reconstructive Surgery* **1986**, *77*, 673-675

Concealing Hair Loss

Traquina, A. C. *Dermatologic Surgery* **2001**, *27*, 123–128.

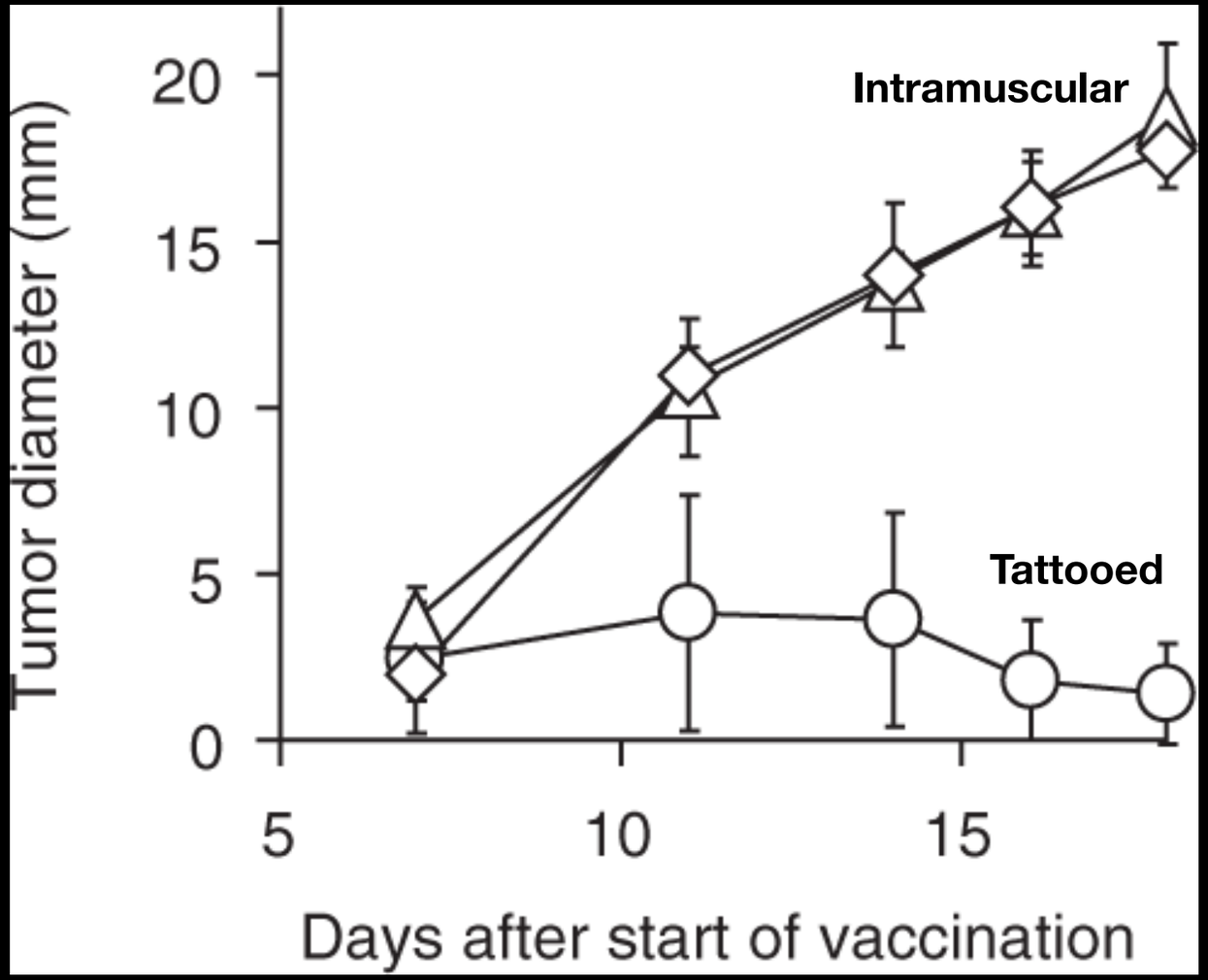
Biomedical Use of Tattoo Pigments

Dermatological Cutaneous Biopsy Site Markers

Chuang, G. S., & Gilchrest, B. A. *Dermatologic Surgery* **2012**, *38*, 479–483.

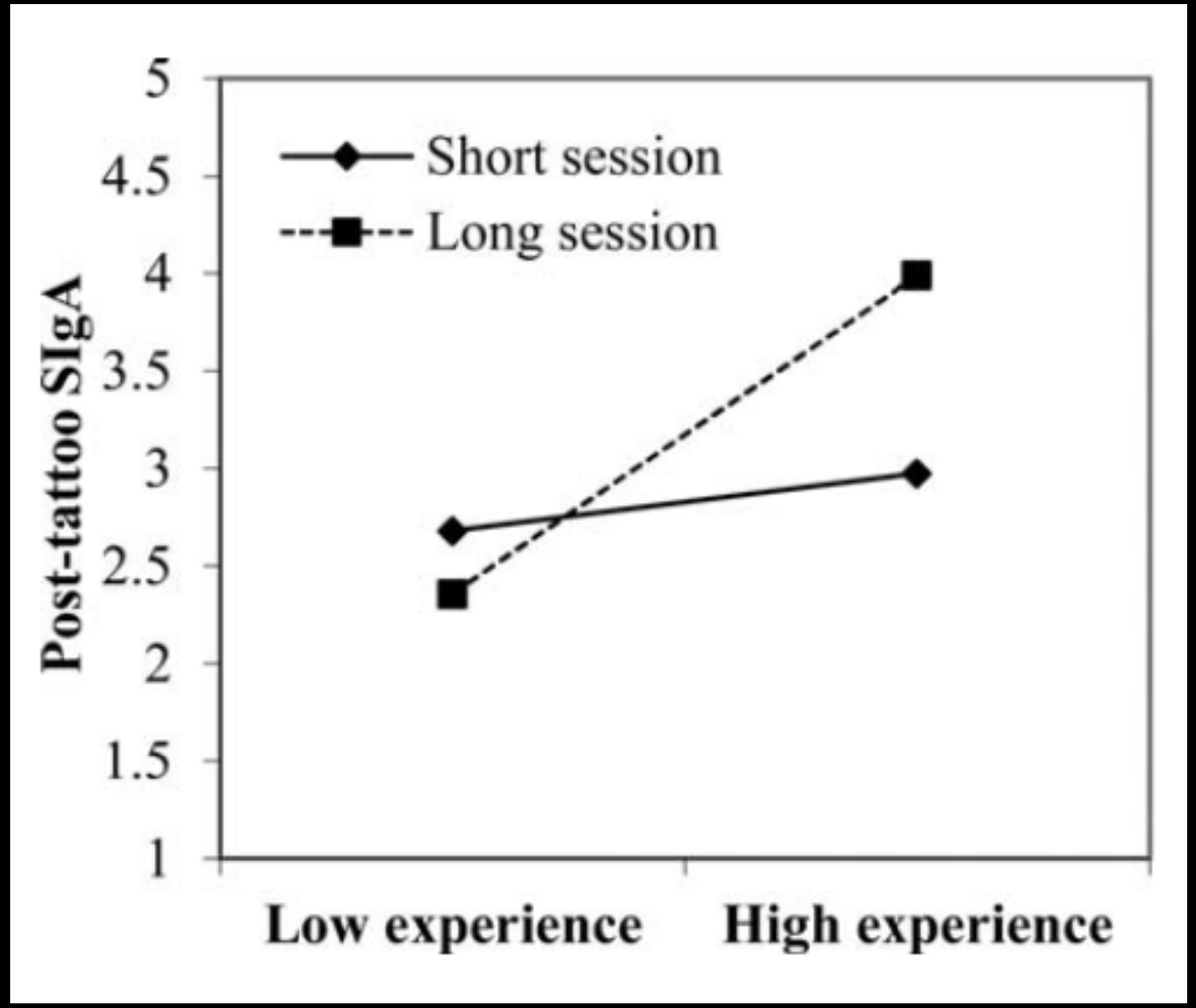
Unintended Health Benefits of Tattoos

DNA Vaccines are more Effective When Tattooed



Bins, A. D., et al. (2005) *Nature Medicine*, 11, 899–904.

Tattoos Innoculate the Immune System to Stress

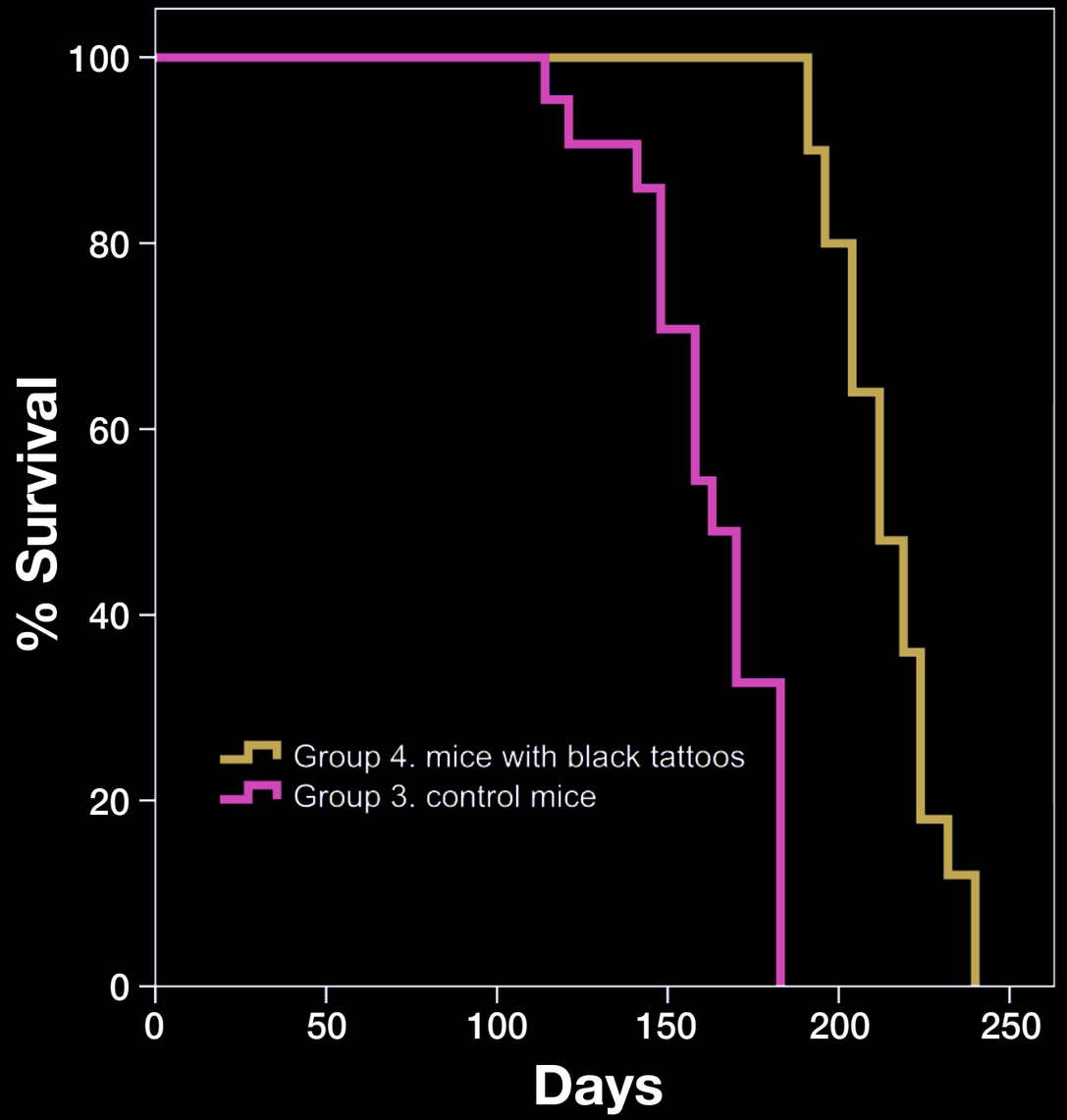


Lynn, C. D., Dominguez, J. T., & DeCaro, J. A. (2016). *Am. J. Hum. Biol.*, 28(5), 603–609.

Unintended Health Benefits of Tattoos

Black Tattoos Help Prevent Skin Cancer

Squamous Cell Carcinoma



Lerche, C. M., Sepehri, M., Serup, J., Poulsen, T., & Wulf, H. C. (2015). *Photodermatology, Photoimmunology & Photomedicine*, *31*, 261–268.

Main Message

Tattoo pigments can be engineered to confer novel health benefits

“Smart tattoos”

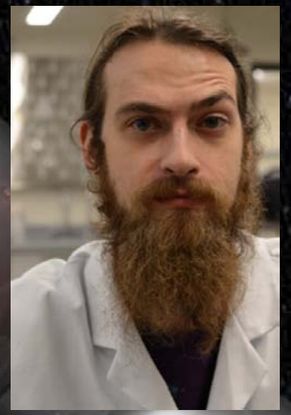
TATTOOS

can give you superpowers

*if we upgrade the technology

Emergent Nanomaterials Lab

Hyejin Kwon
Postdoc



Jesse Butterfield
PhD Student

Karan Dikshit
PhD Student

Kailey Shara
PhD Student

Purnendu
PhD Student

ATLAS

University of Colorado **Boulder**

Paul M. Rady Mechanical Engineering

COLLEGE OF ENGINEERING AND APPLIED SCIENCE

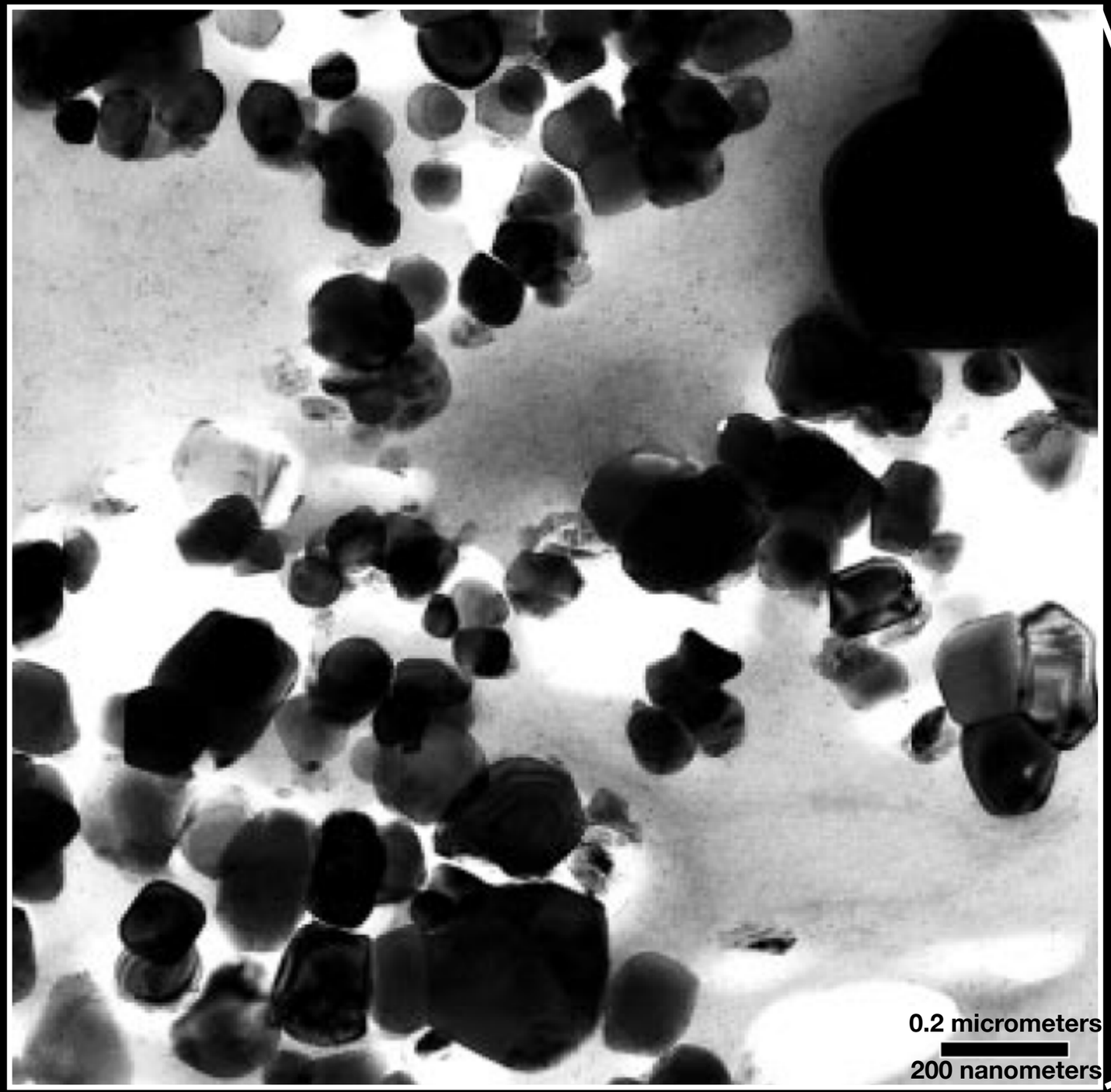
Jennifer Quigley
BS Student

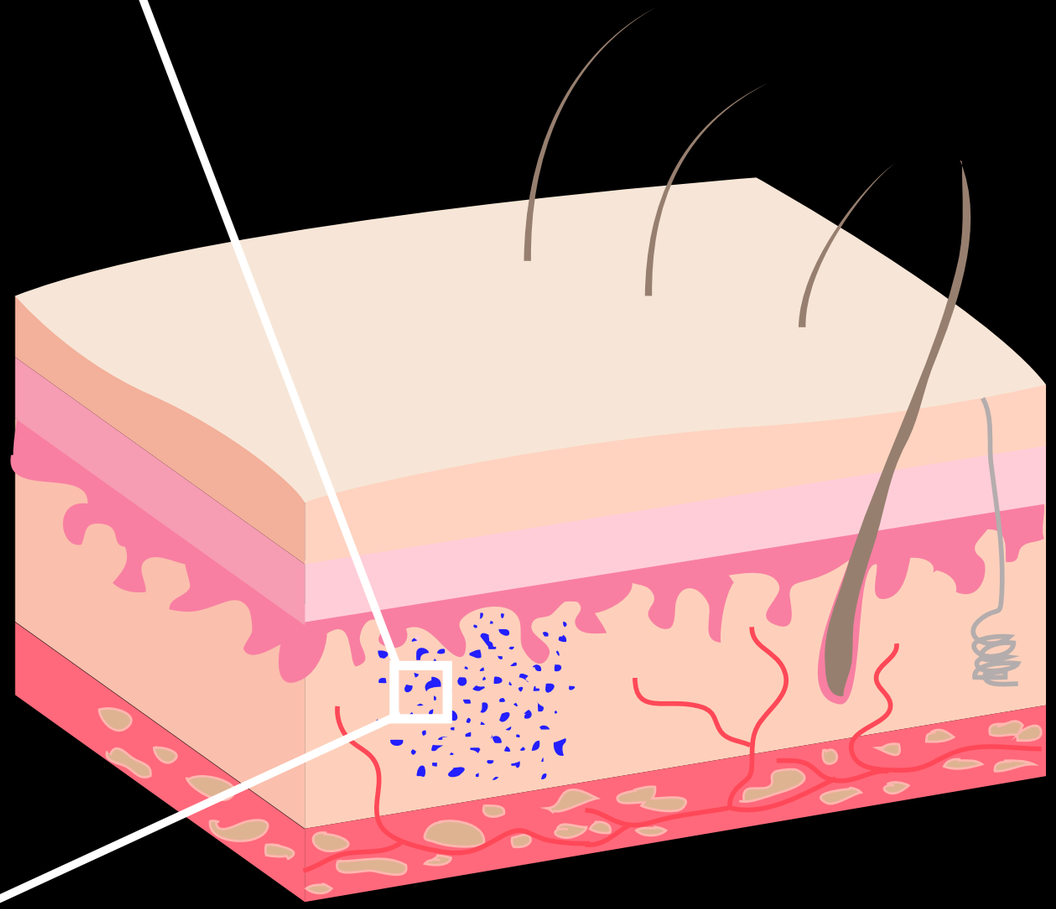
Matthew Kim
BS Student

Jaime Wickersheim
BS Student

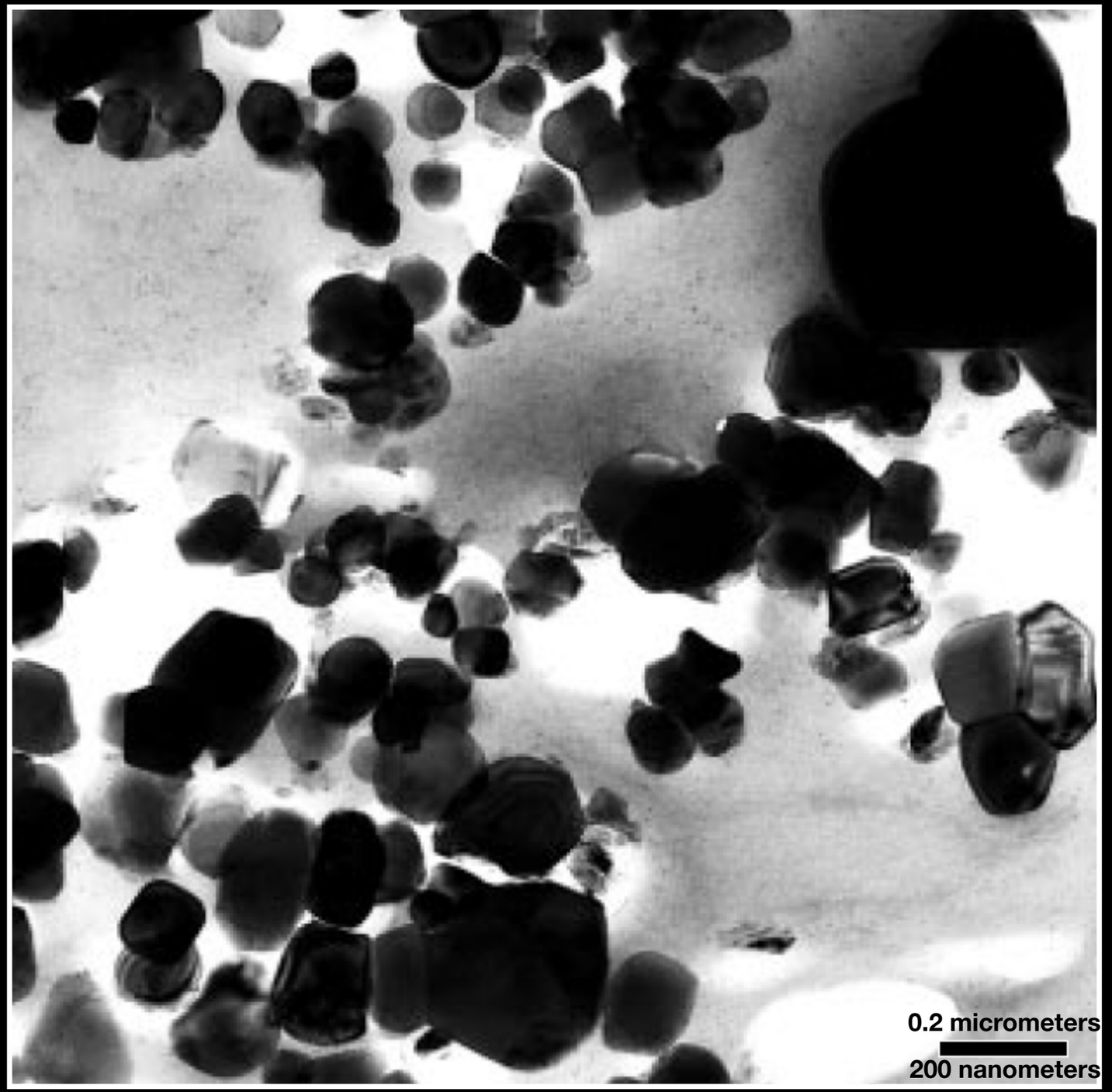
Tattoos are Nanoparticles

Say what they are made of



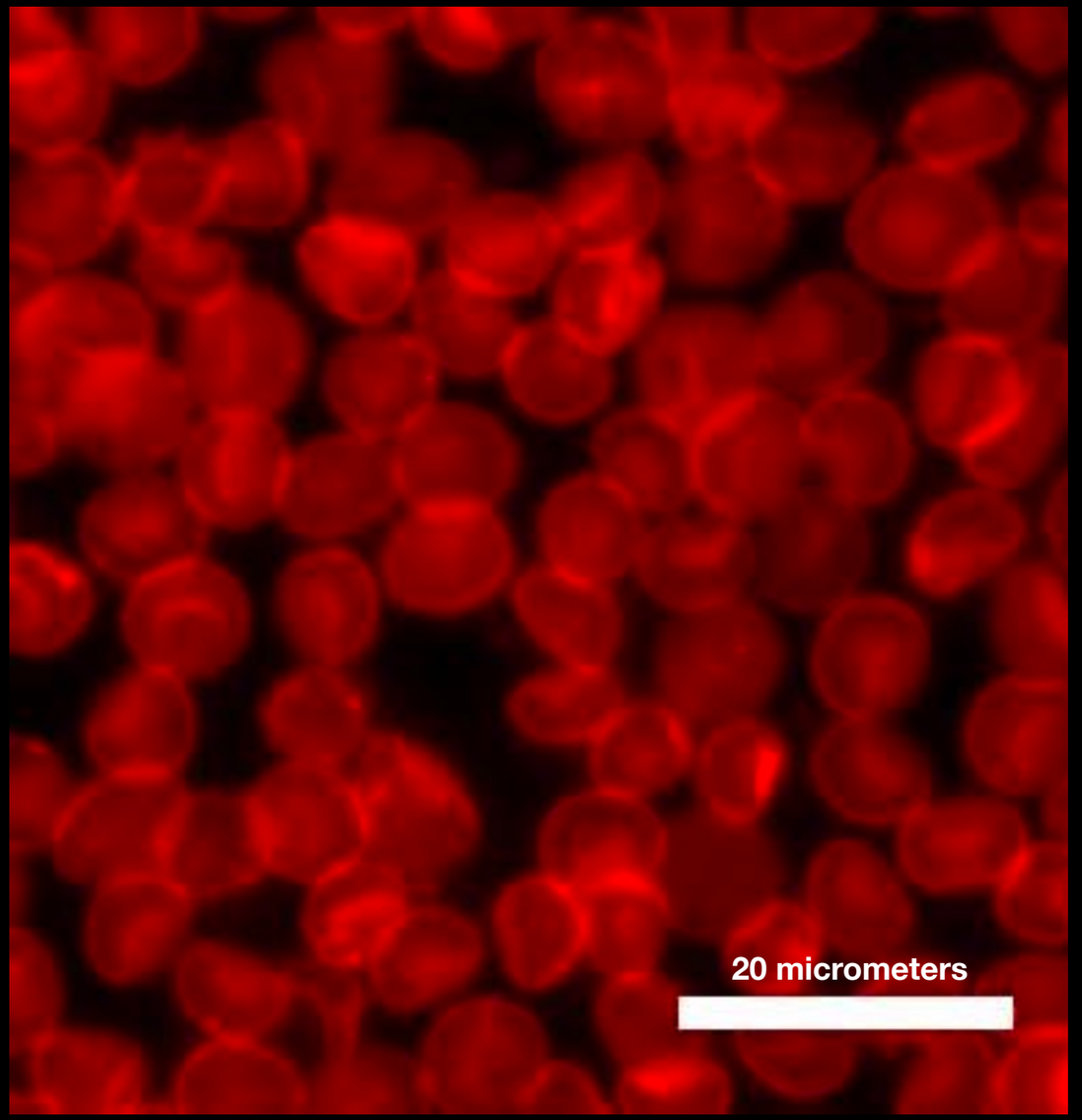


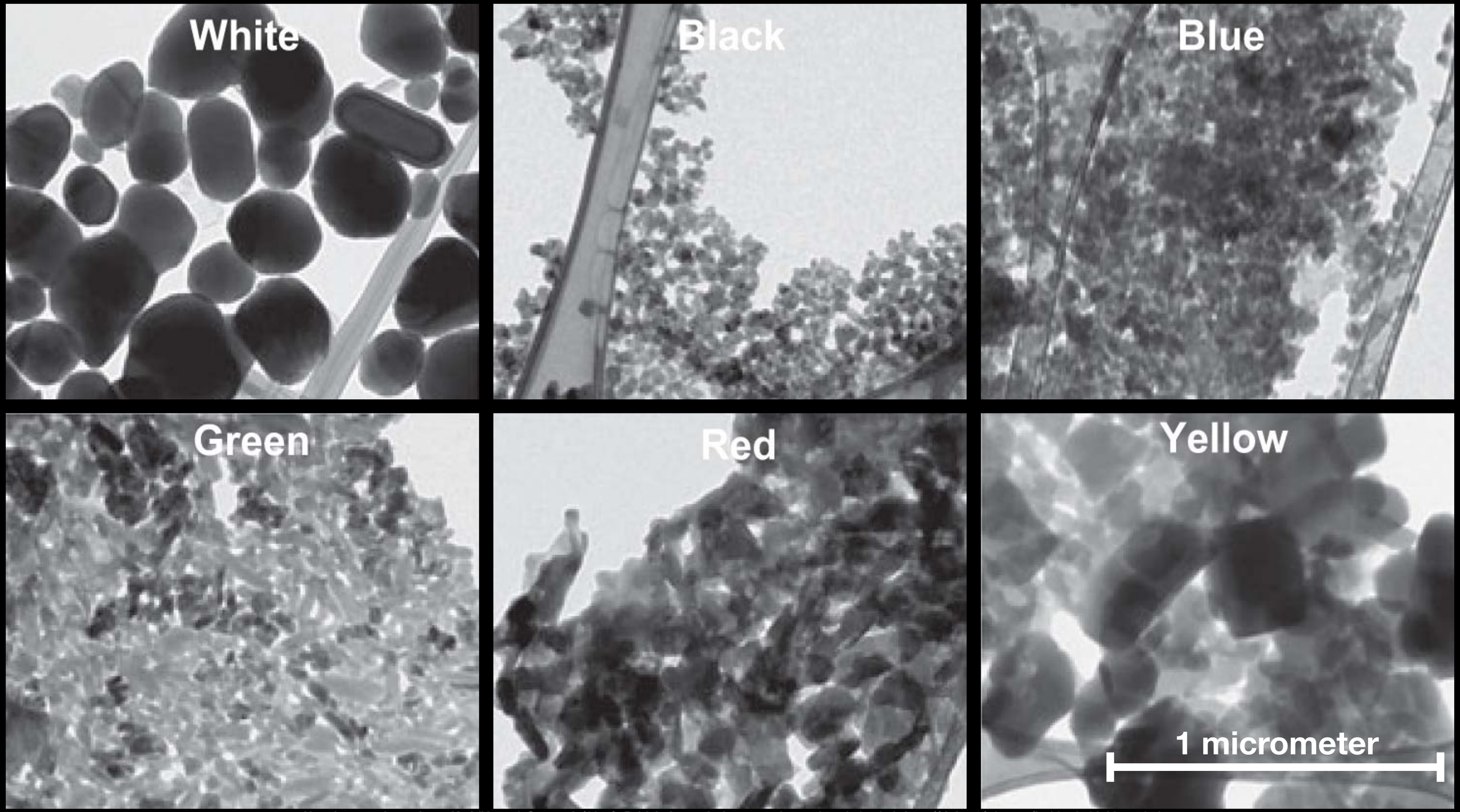
Ross, E. V., Yashar, S., Michaud, N., Fitzpatrick, R., Geronemus, R., Tope, W. D., & Anderson, R. R. (2001). *Archives of Dermatology*, *137*, 33



Ross, E. V., Yashar, S., Michaud, N., Fitzpatrick, R., Geronemus, R., Tope, W. D., & Anderson, R. R. (2001). *Archives of Dermatology*, *137*, 33

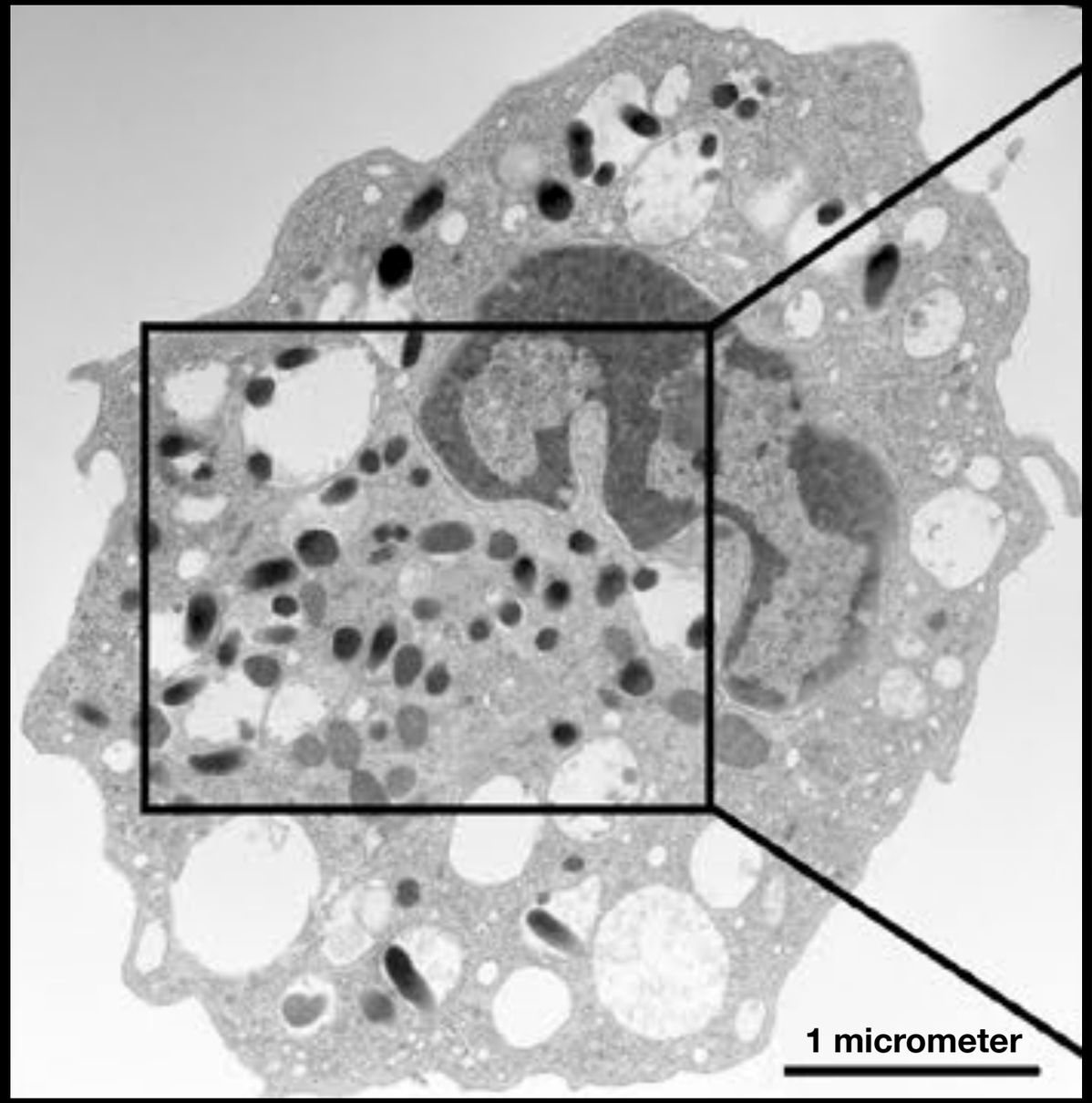
Red Blood Cells



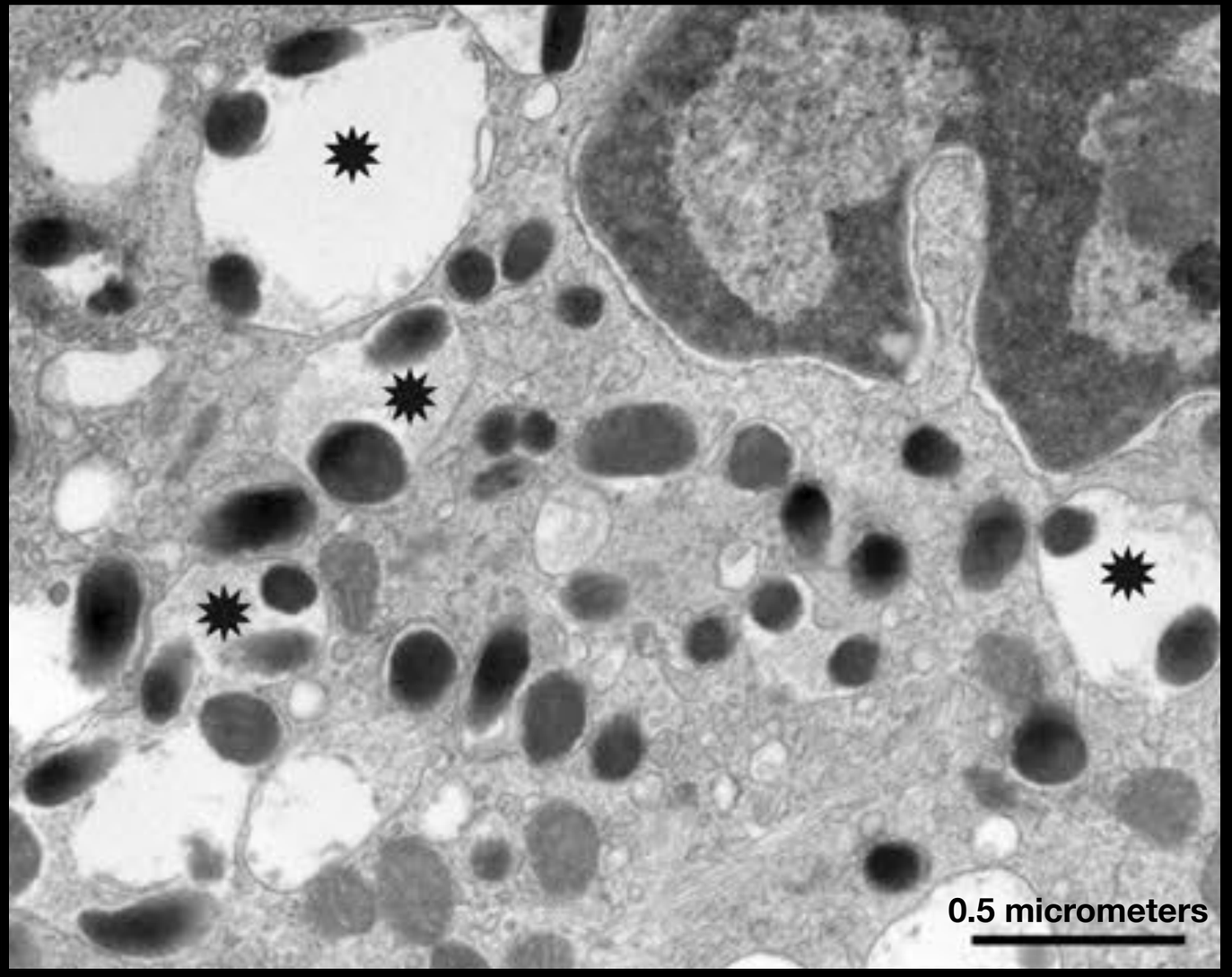


Høgsberg, T., Loeschner, K., Löf, D., & Serup, J. (2011). *British Journal of Dermatology*, 165, 1210–1218. http://doi.org/10.1111/j.1365-2133.2011.10561.x

What makes a tattoo permanent?

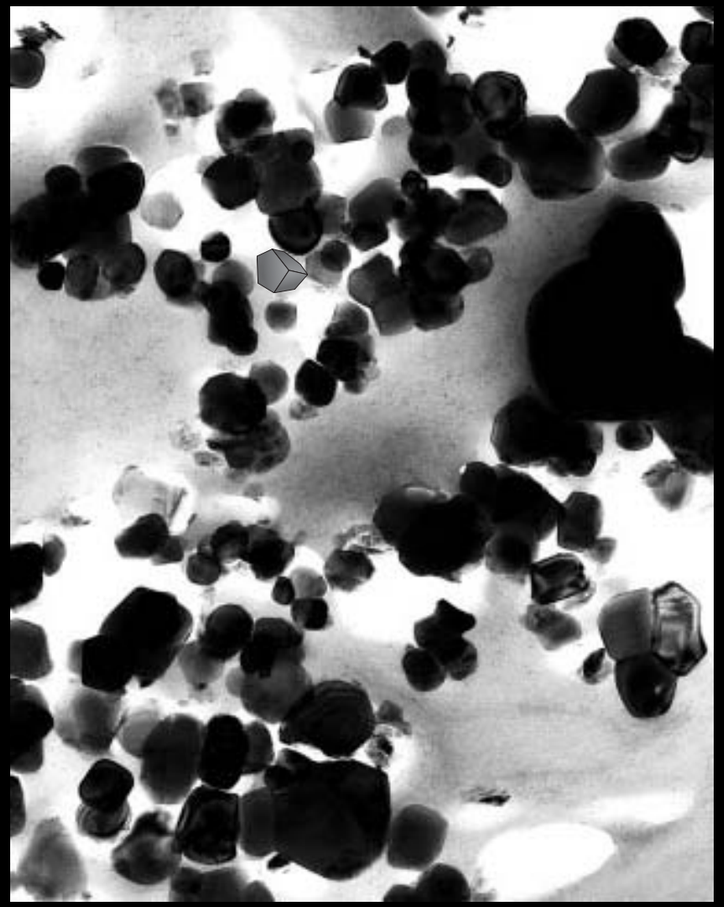


Macrophages eat tattoo pigments, get “stuck”, and die

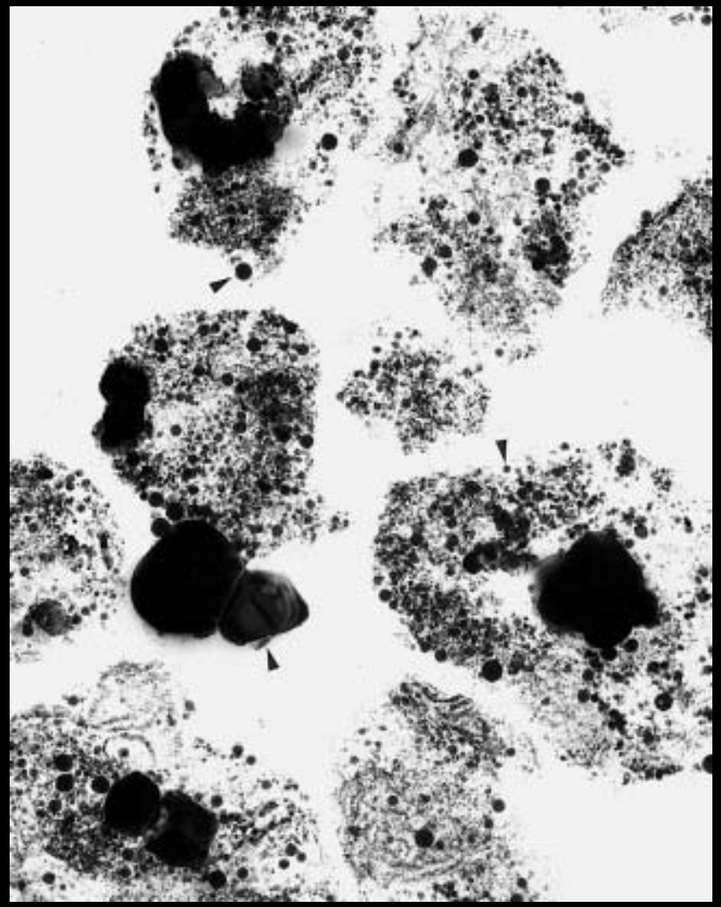


Baranska, A., Shawket, A., Jouve, M., Baratin, M., Malosse, C., Voluzan, O., et al. (2018). Unveiling skin macrophage dynamics explains both tattoo persistence and strenuous removal. The Journal of Experimental Medicine, 215(4), 1115–1133.

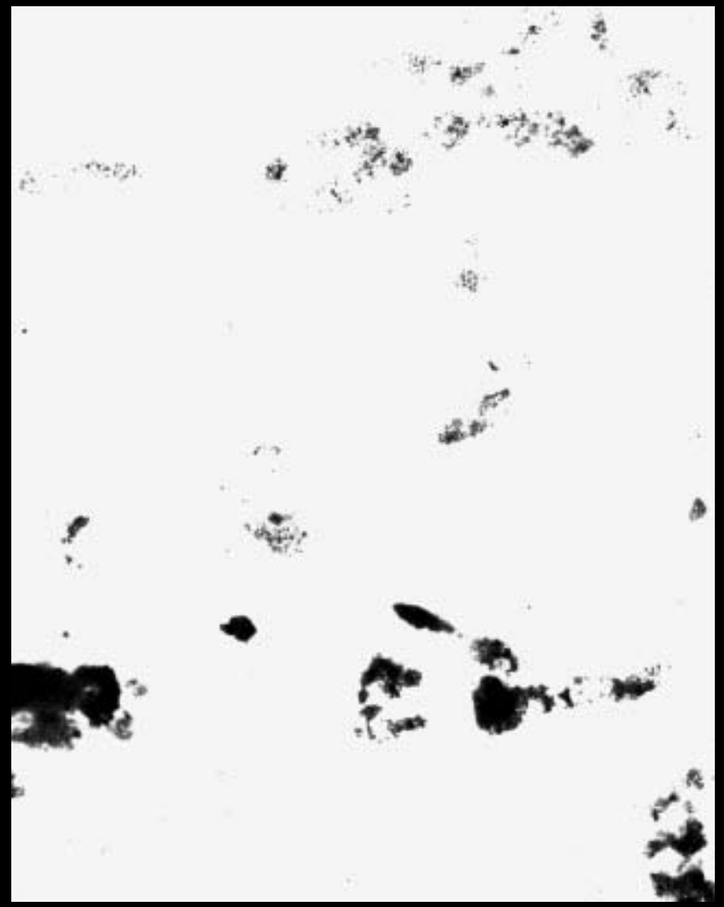
Tattoo Laser Removal Works by Fragmenting Pigments into Tiny Pieces



Laser



Laser

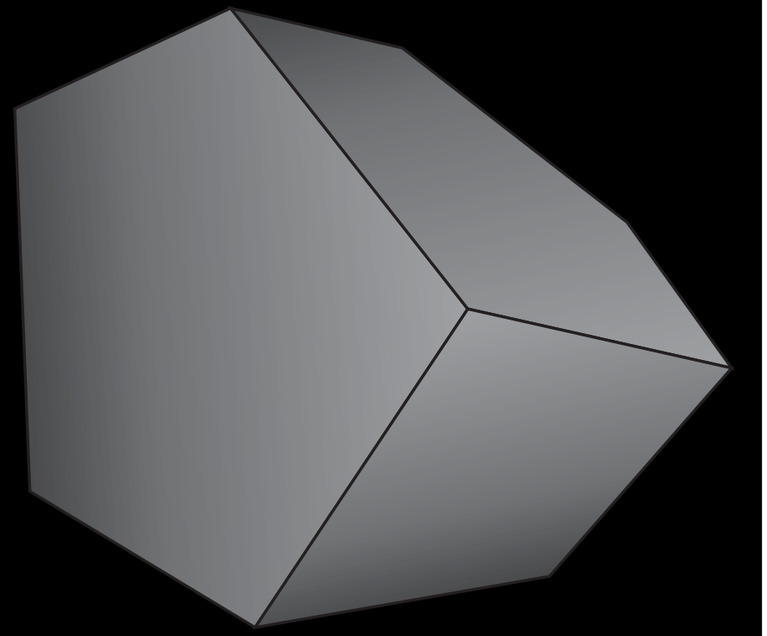


If the pigment is too small: Fading / Impermanent Tattoo
If the pigment is too large: Painful / Harmful Tattoo

Biomedical Engineering of Tattoo Ink

Decorative Tattoos

Scale: 20-900 nm

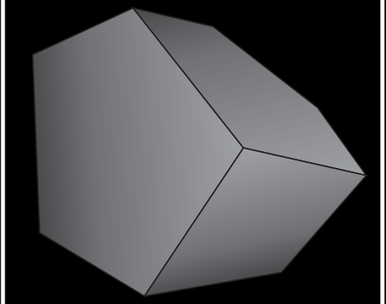


Pigment Granule

Biomedical Engineering of Tattoo Ink

Decorative Tattoos

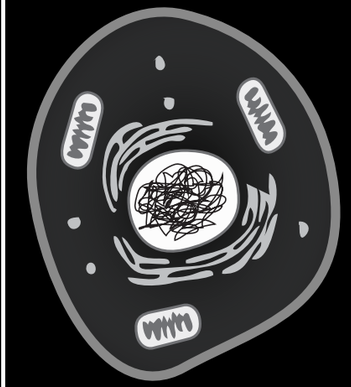
Scale: 20-900 nm



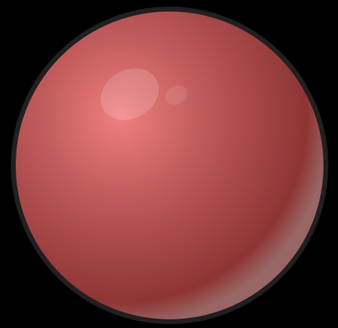
Pigment Granule

Engineered Tattoo "Pigments"

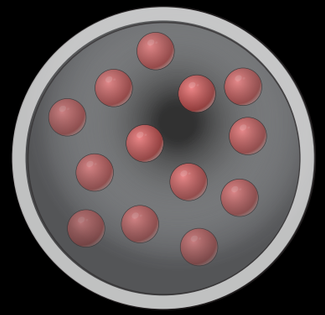
= functional element (e.g., sensor, drug, etc.)



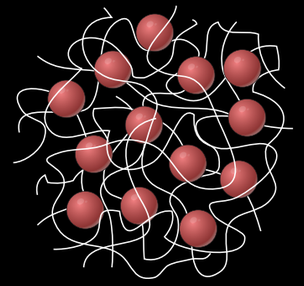
Engineered Cell



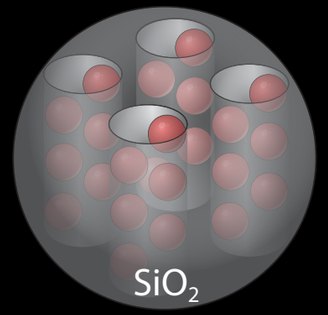
Nano/microparticle



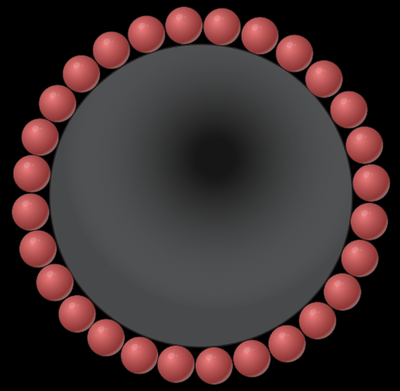
Microcapsule



Hydrogel



Mesoporous silica

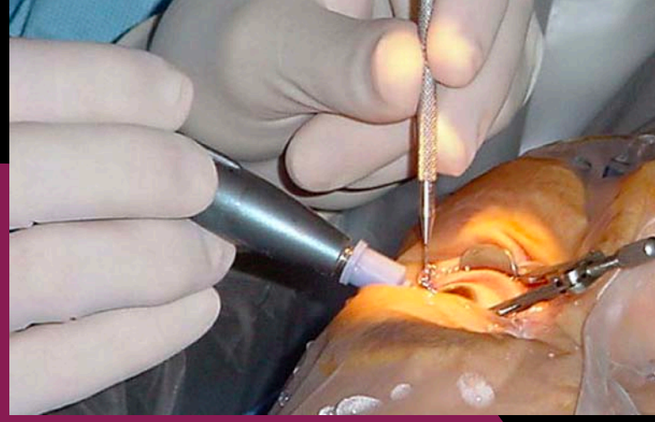


Core-Shell or Coated Particle

Tattoo

Minimally-Invasive Permanent Biomedical Implant

Body Tech



Wearables

Implants

Tattoos

Inexpensive

Non-invasive

Temporary

Discomfort

Inexpensive

Minimally Invasive

Permanent

Comfortable

Expensive

Invasive

Permanent

Comfortable

Anti-Photocarcinogenic Tattoos

The dangers of UV exposure

Sunburn

Aging

Photocarcinogenesis

N Engl J Med (2012), 366:e25

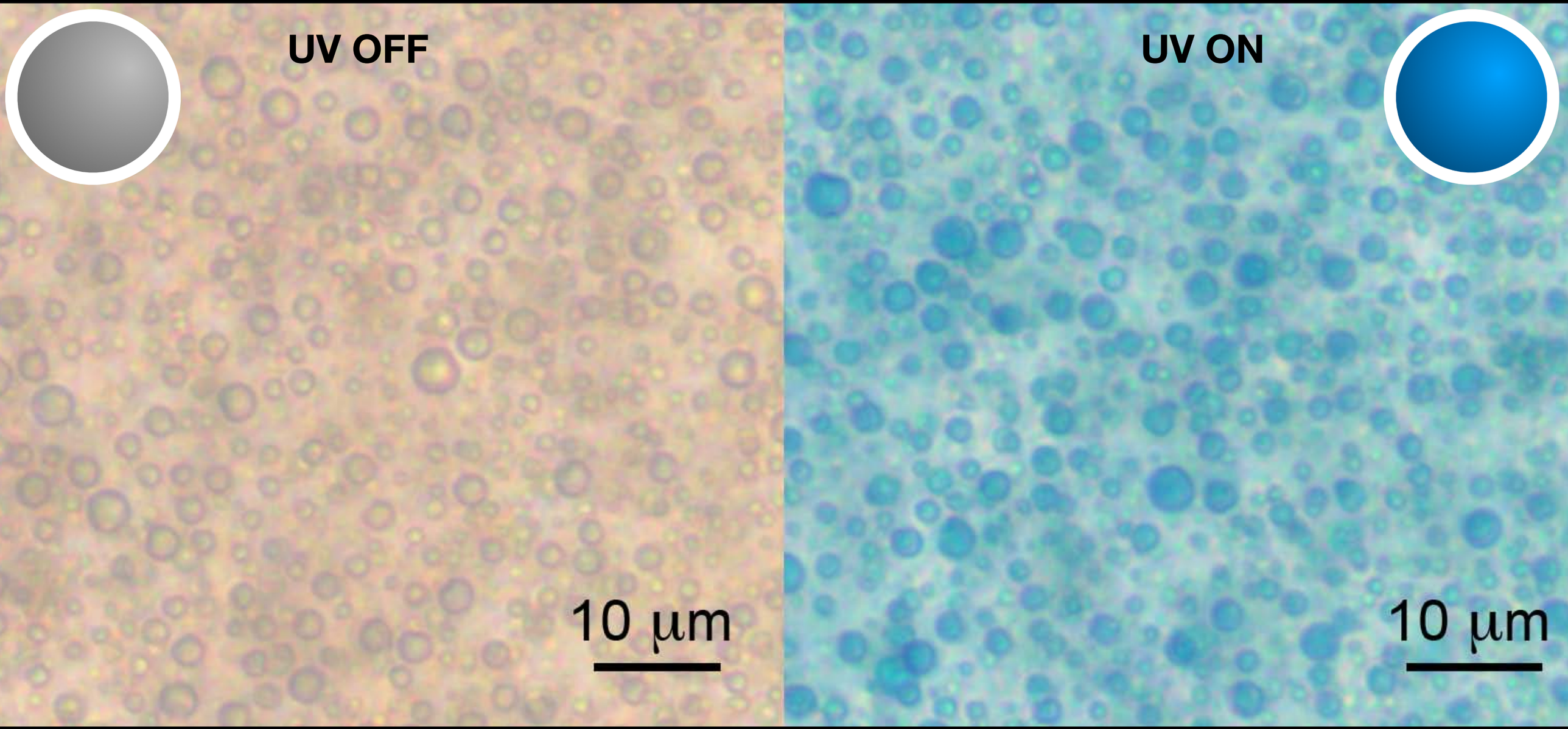
Monitoring and preventing UV exposure

Sunscreen / Sun cream

UV photography

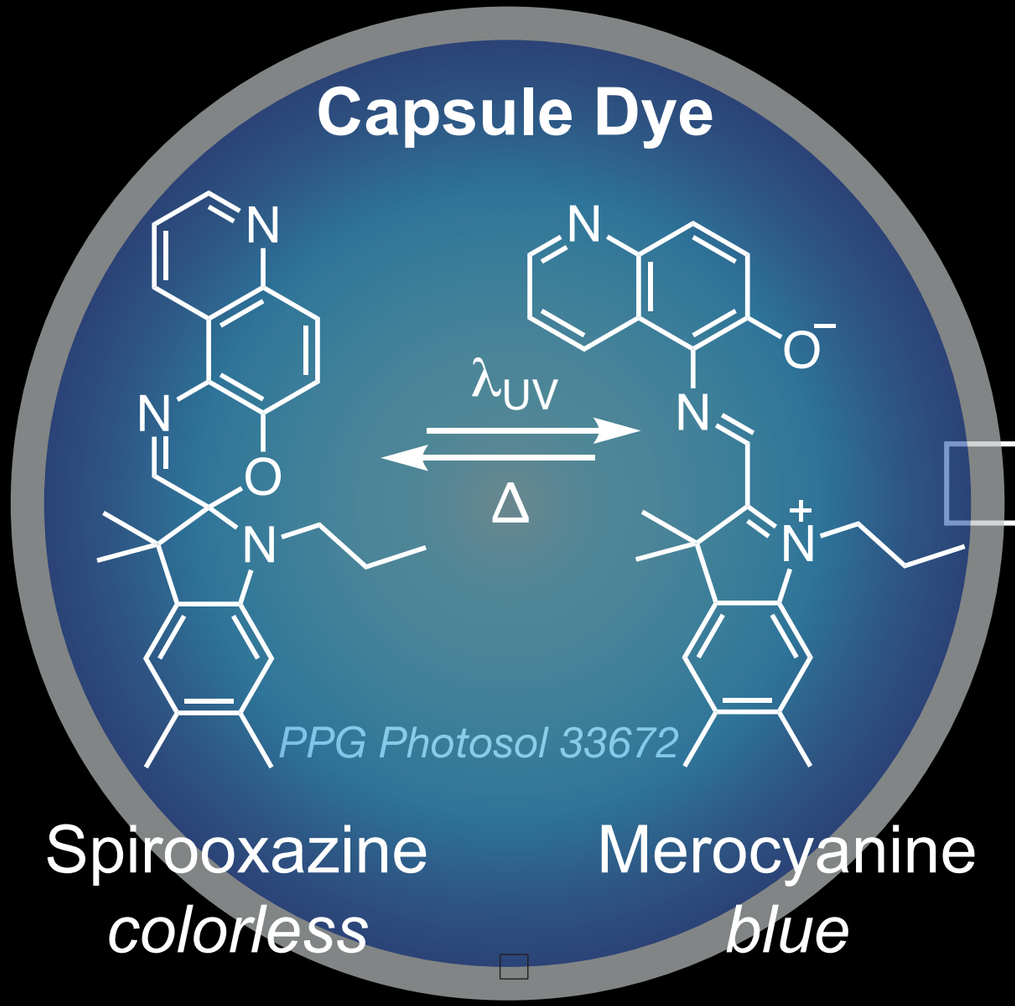
Wearable UV radiometers

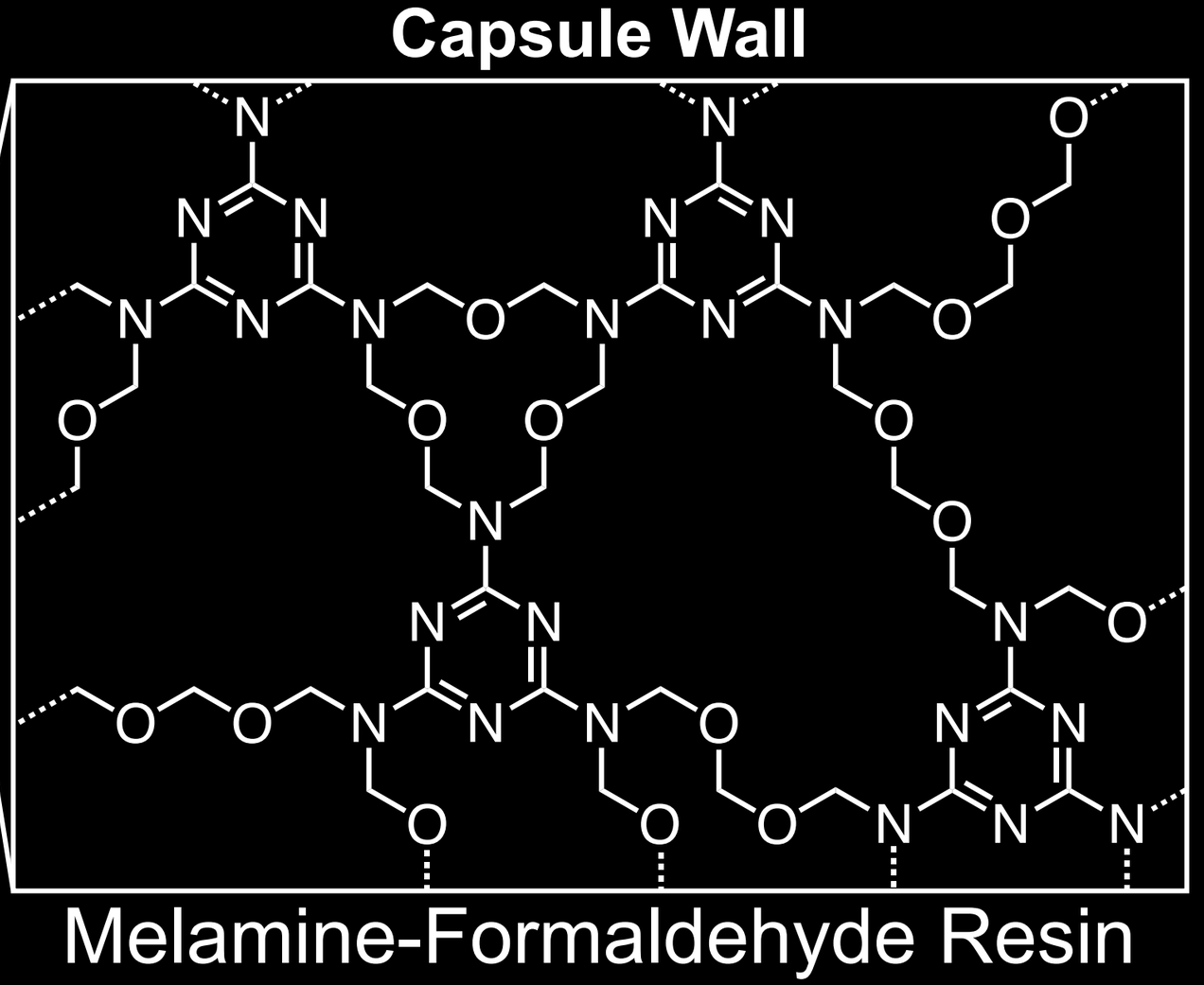
Solar-Powered Microscapsule Tattoo



Butterfield, et al. *ACS Nano* 2020, *14*, 13619–13628.

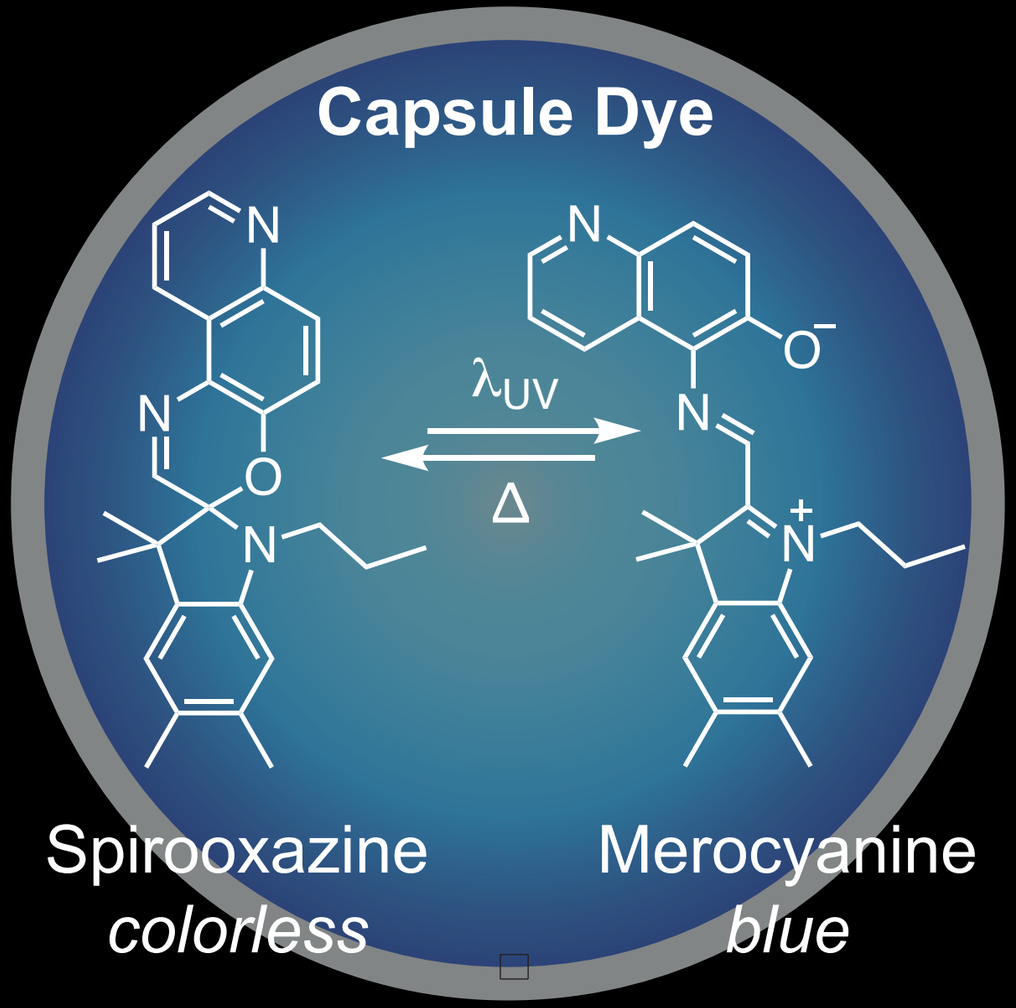
A Microencapsulated UV Radiometer

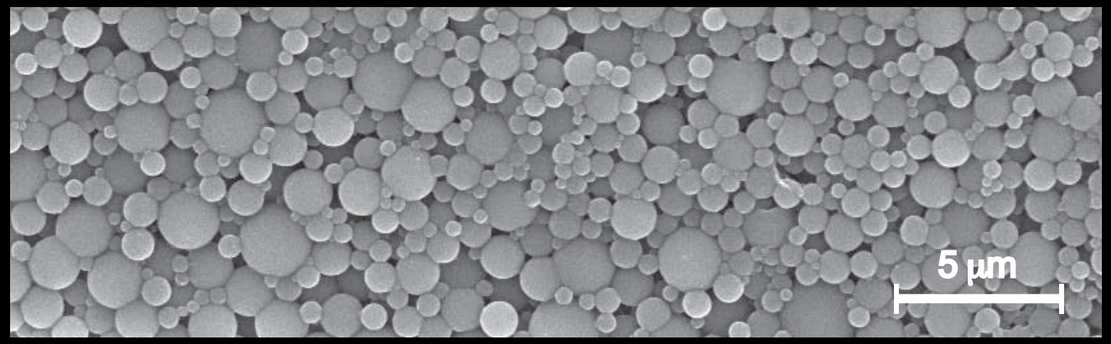


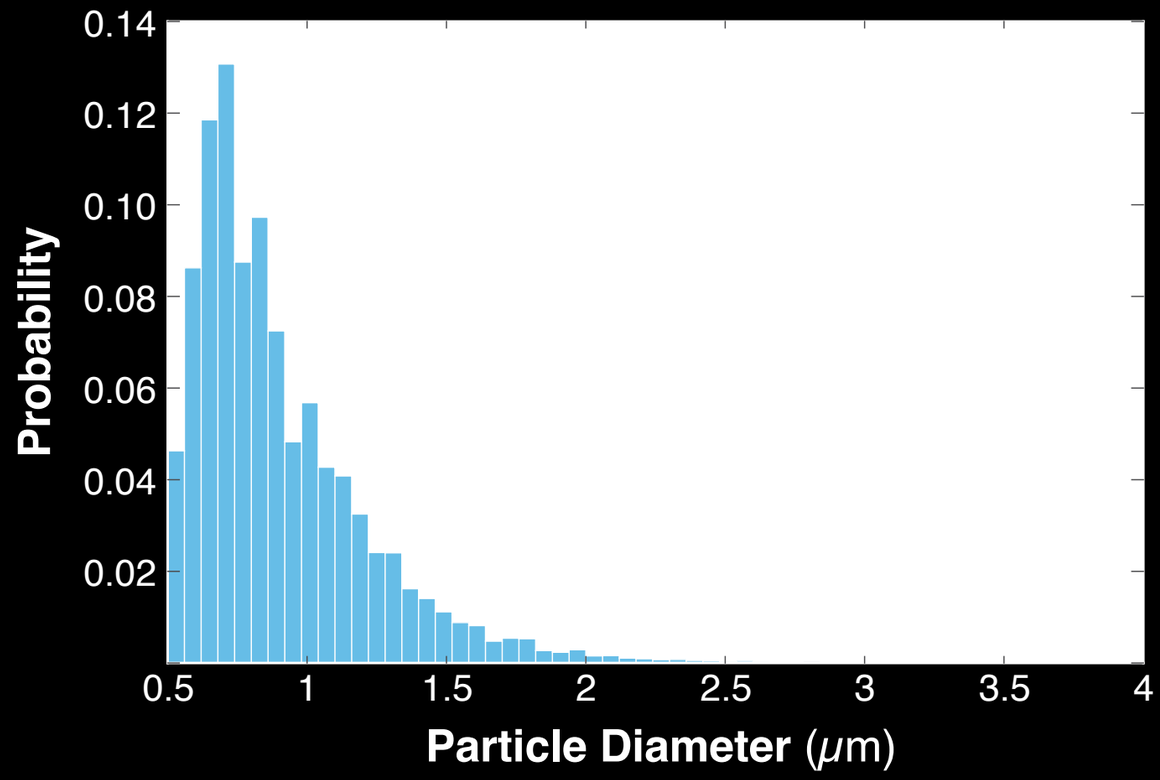


Butterfield, et al. *ACS Nano* 2020, *14*, 13619–13628.

A Microencapsulated UV Radiometer







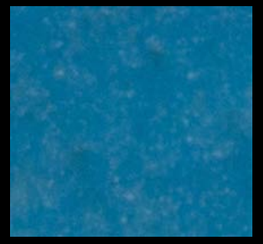
Butterfield, et al. *ACS Nano* 2020, *14*, 13619–13628.

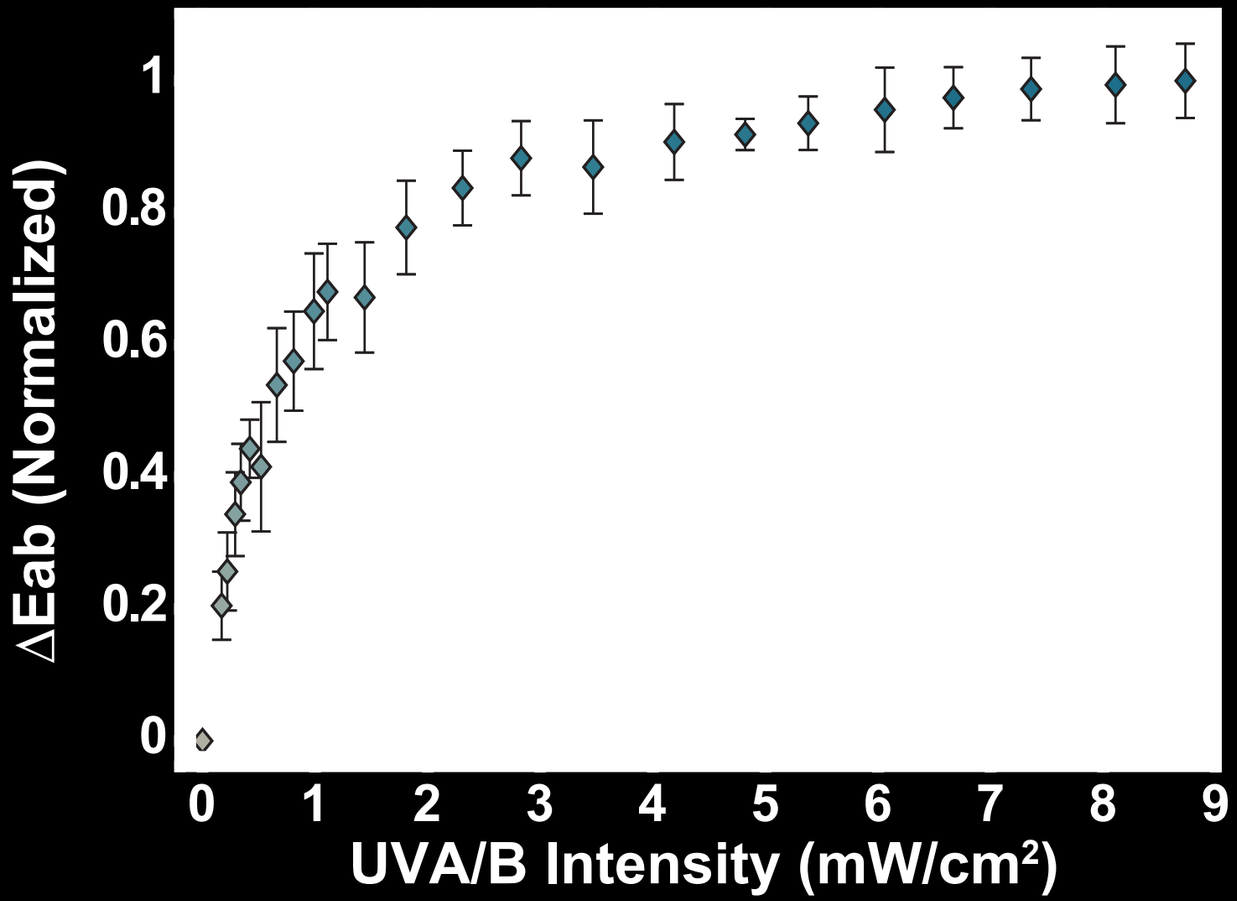
Ex Vivo Porcine Skin Model

Naked-Eye UV Radiometer Tattoo

Try to do it Jesse's way?

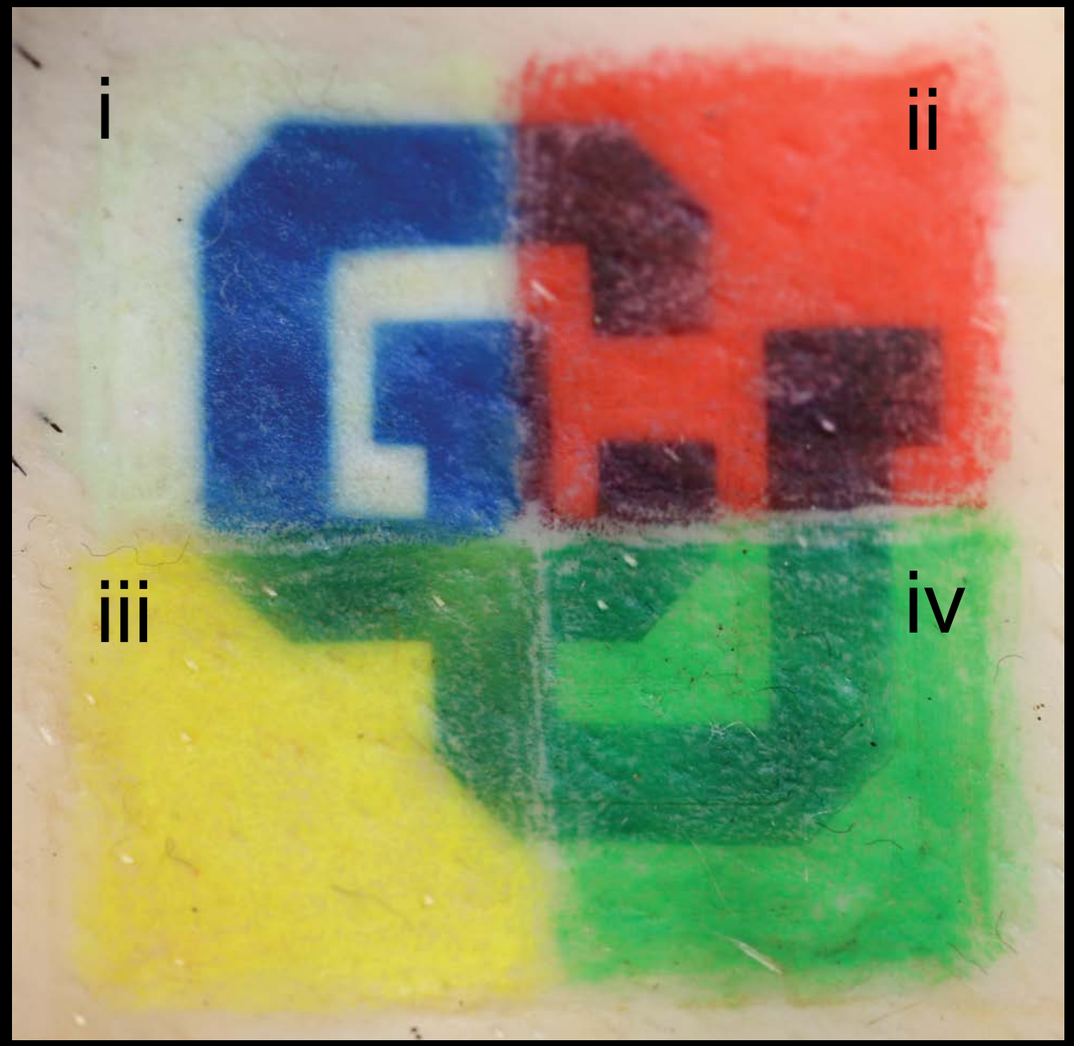
Fix this

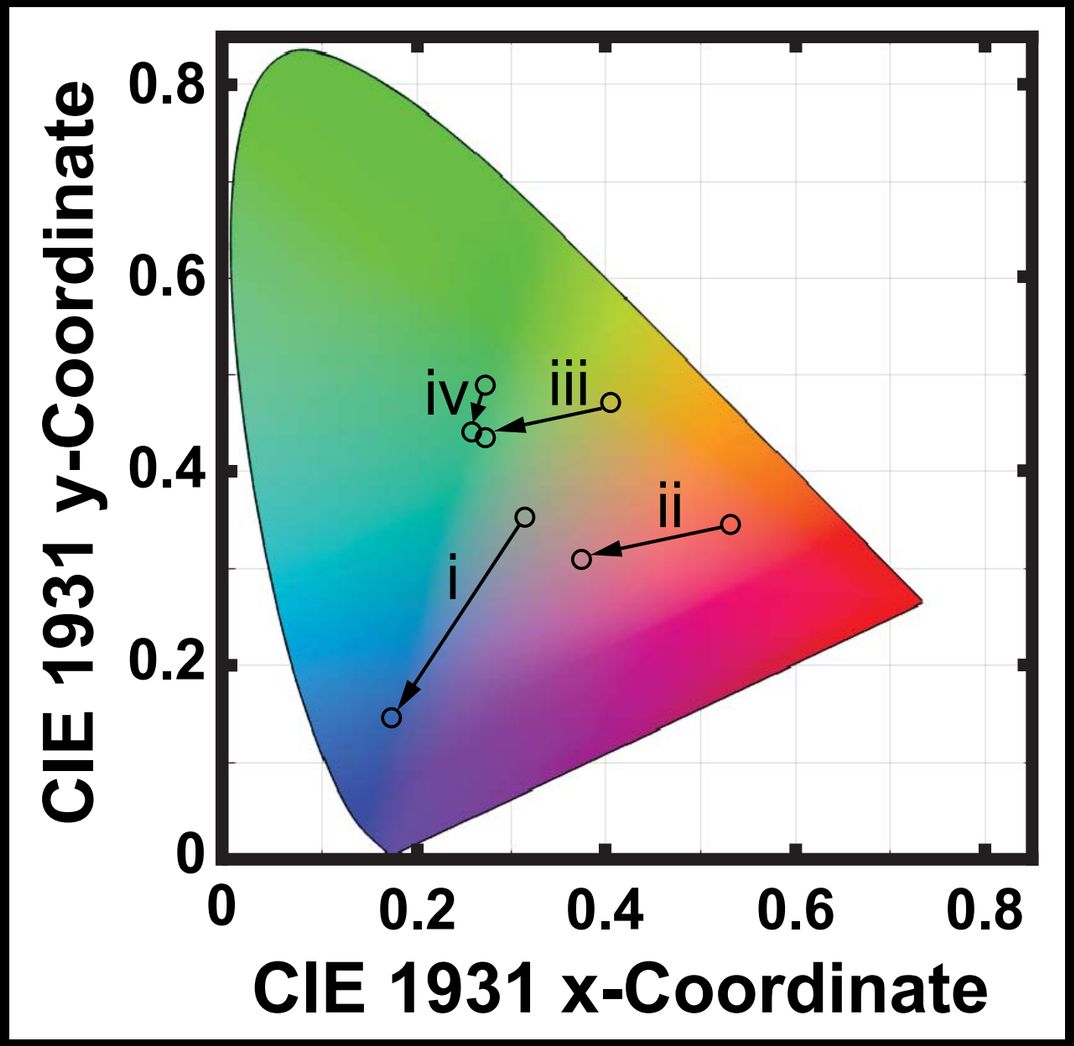
	No Sunscreen No UV	No Sunscreen UV (9 mW/cm²)	SPF 30 UV (9 mW/cm
			
ΔE_{ab}	0	1.0 ± 0.04	0.30 ± 0.15



Butterfield, et al. *ACS Nano* 2020, *14*, 13619–13628.

Pigment Mixtures = More Color Space



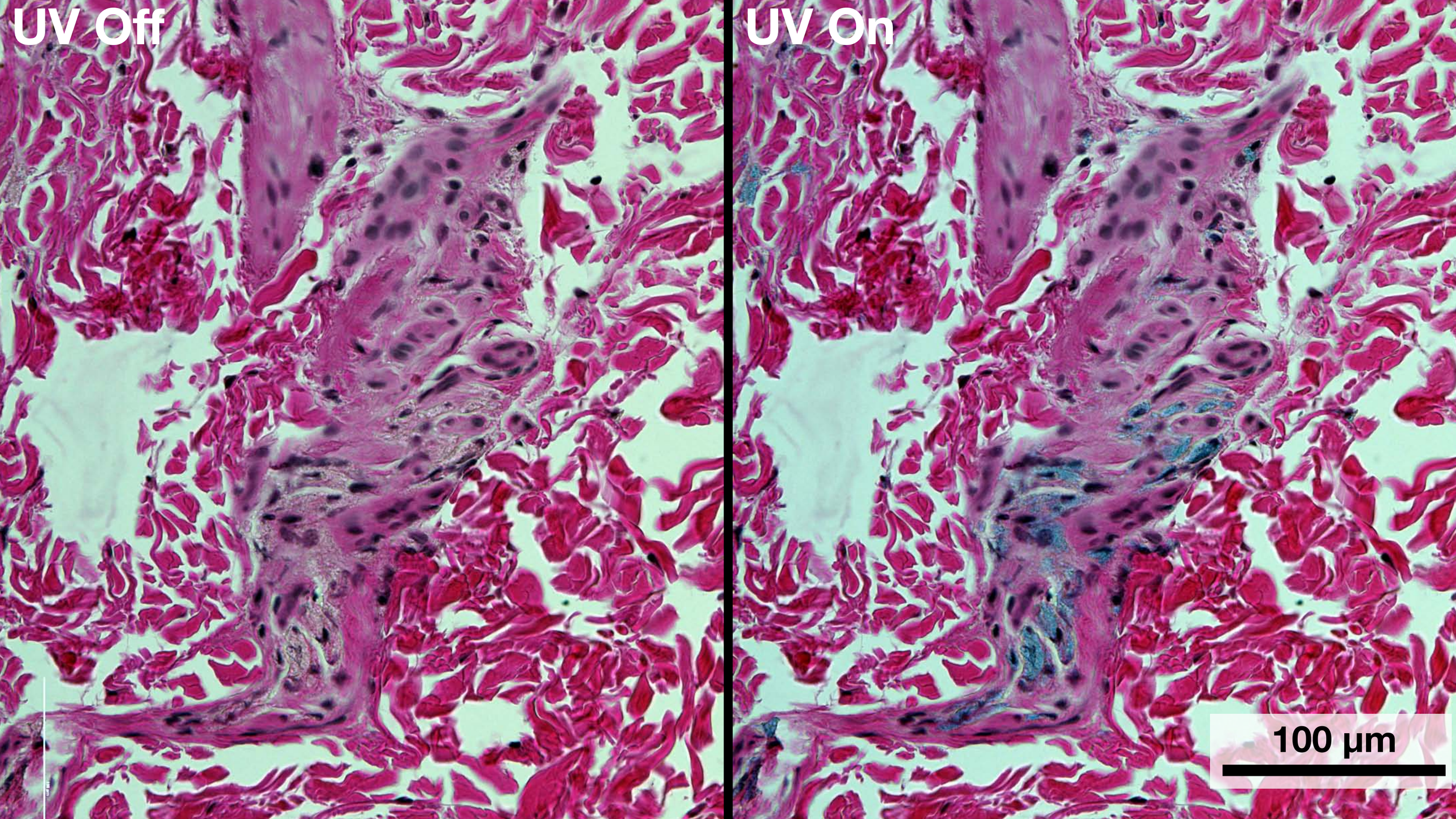


Butterfield, et al. *ACS Nano* 2020, *14*, 13619–13628.

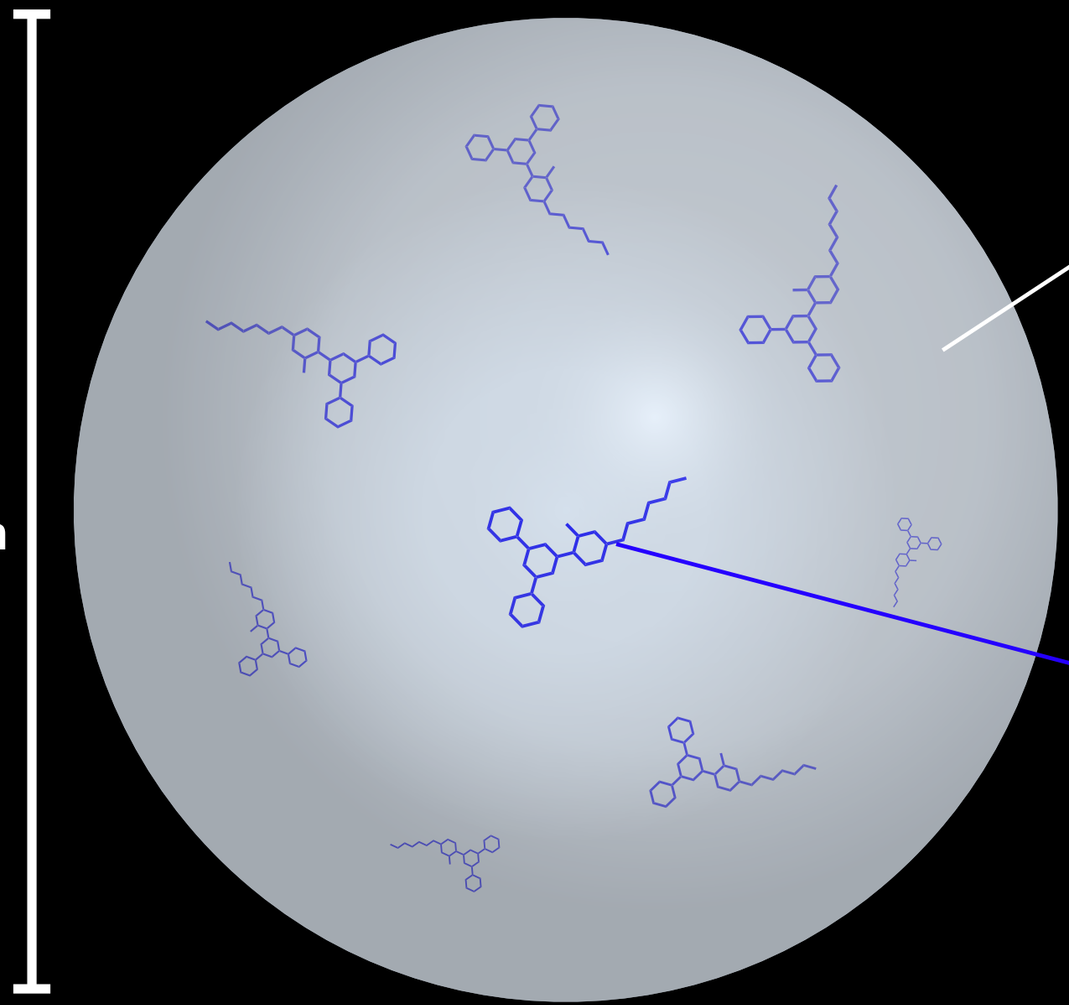
In Vivo Human Skin Model

A Word on Tattoo Safety

- Leuco Dyes = potentially toxic
- Amino resin microcapsules = probably non-toxic
- Estimated microcapsule dosage = 0.1 mg / tattoo
- EPA limit on formaldehyde daily dose is 0.2 mg/kg


UV Off
UV On
100 µm

Second-Generation Ink



Size:
<1 micron

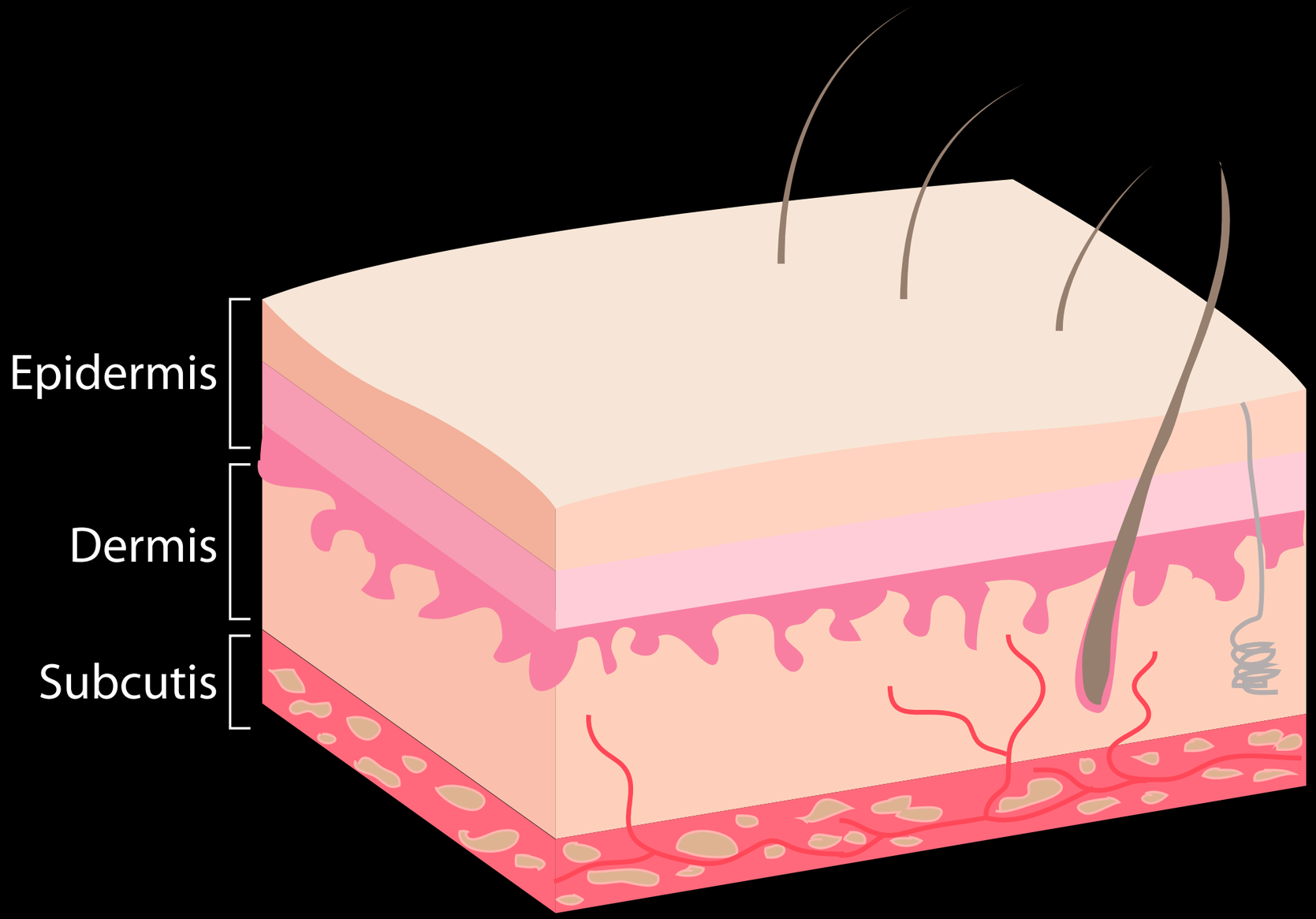
>90%

Biocompatible polymer,
FDA-approved
for injection into skin

<10%

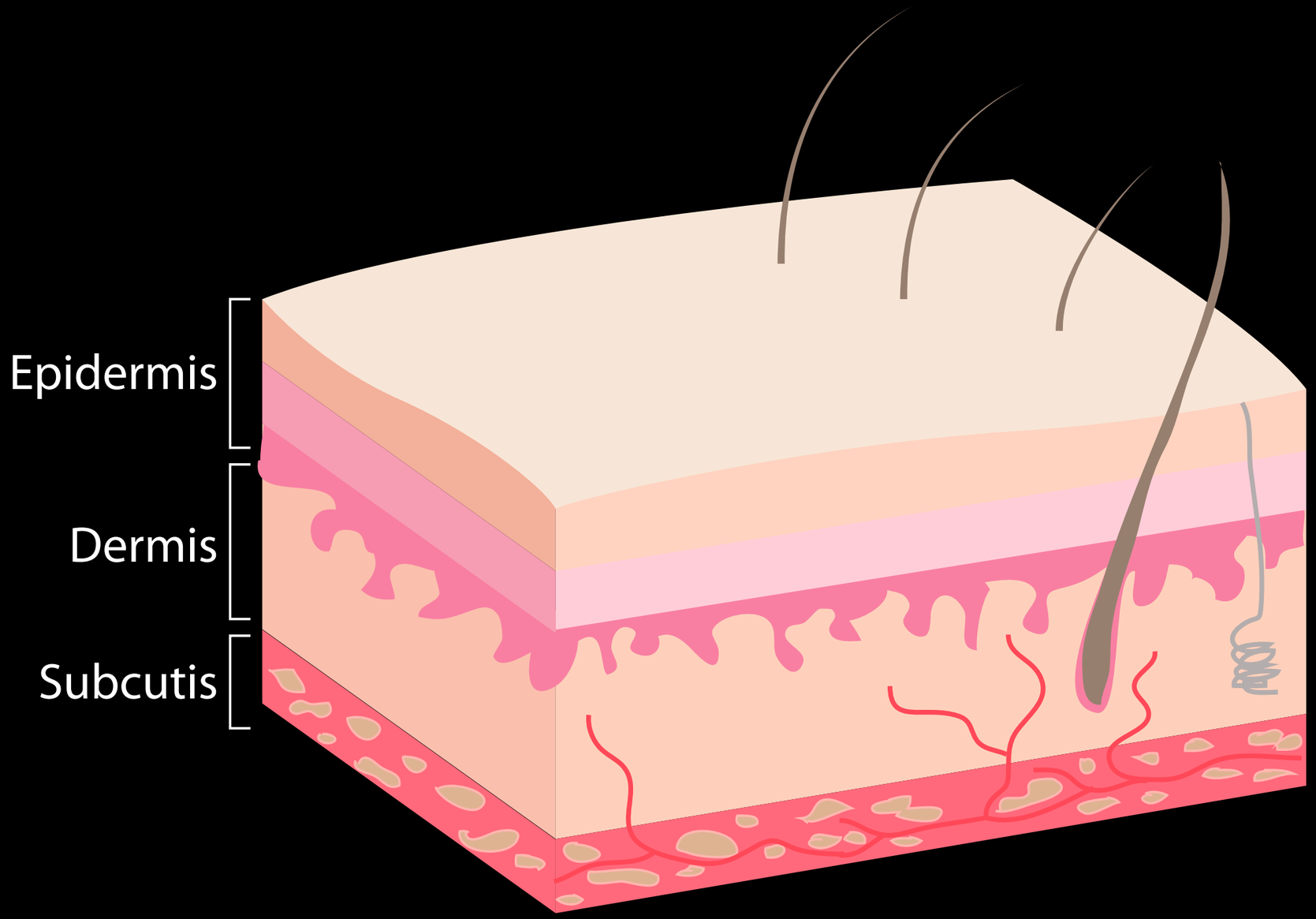
Active ingredients

The three functions of skin



- **Sensing**
- Protection
- Regulation

The three functions of skin

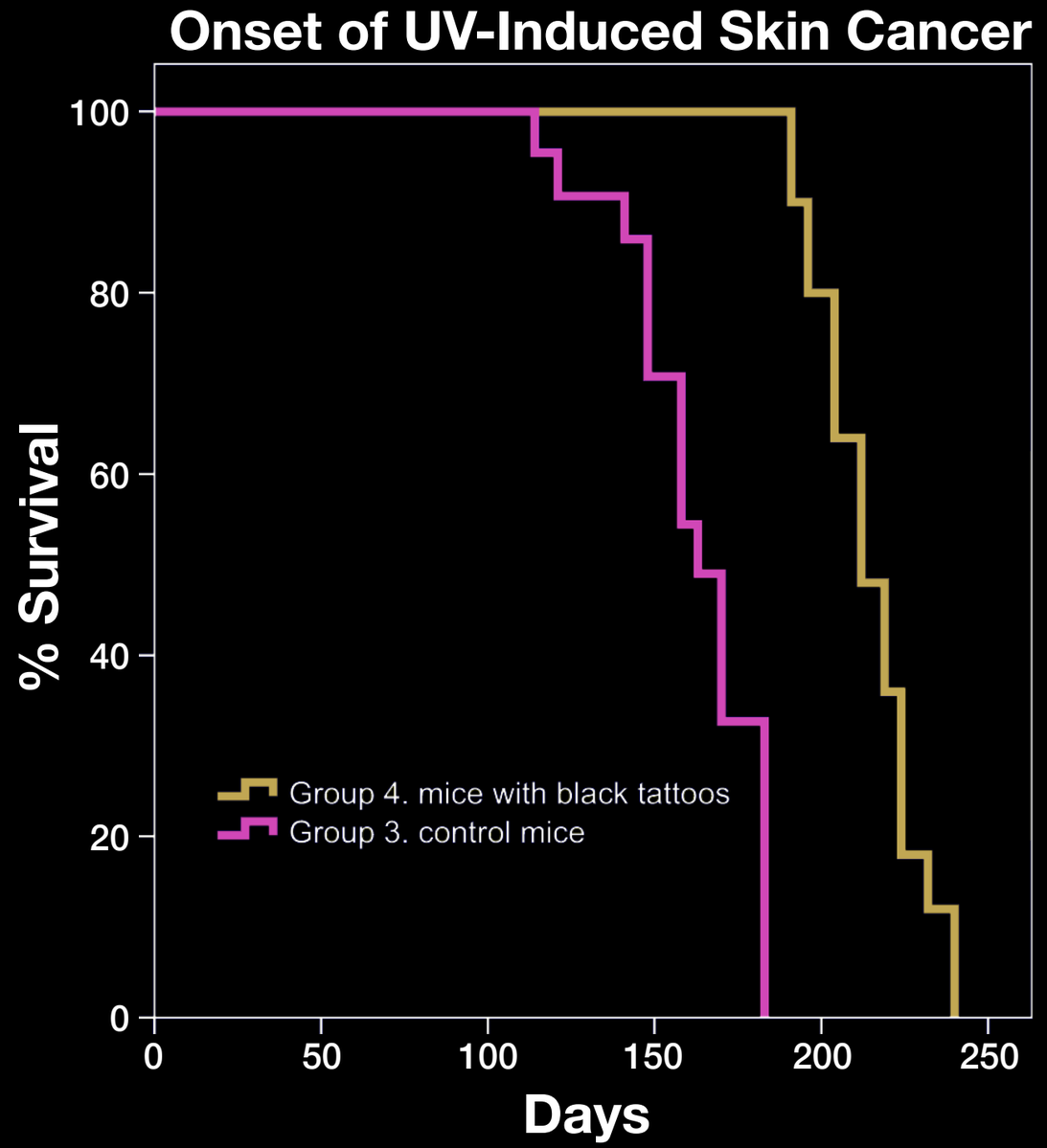


- Sensing

- Protection

- Regulation

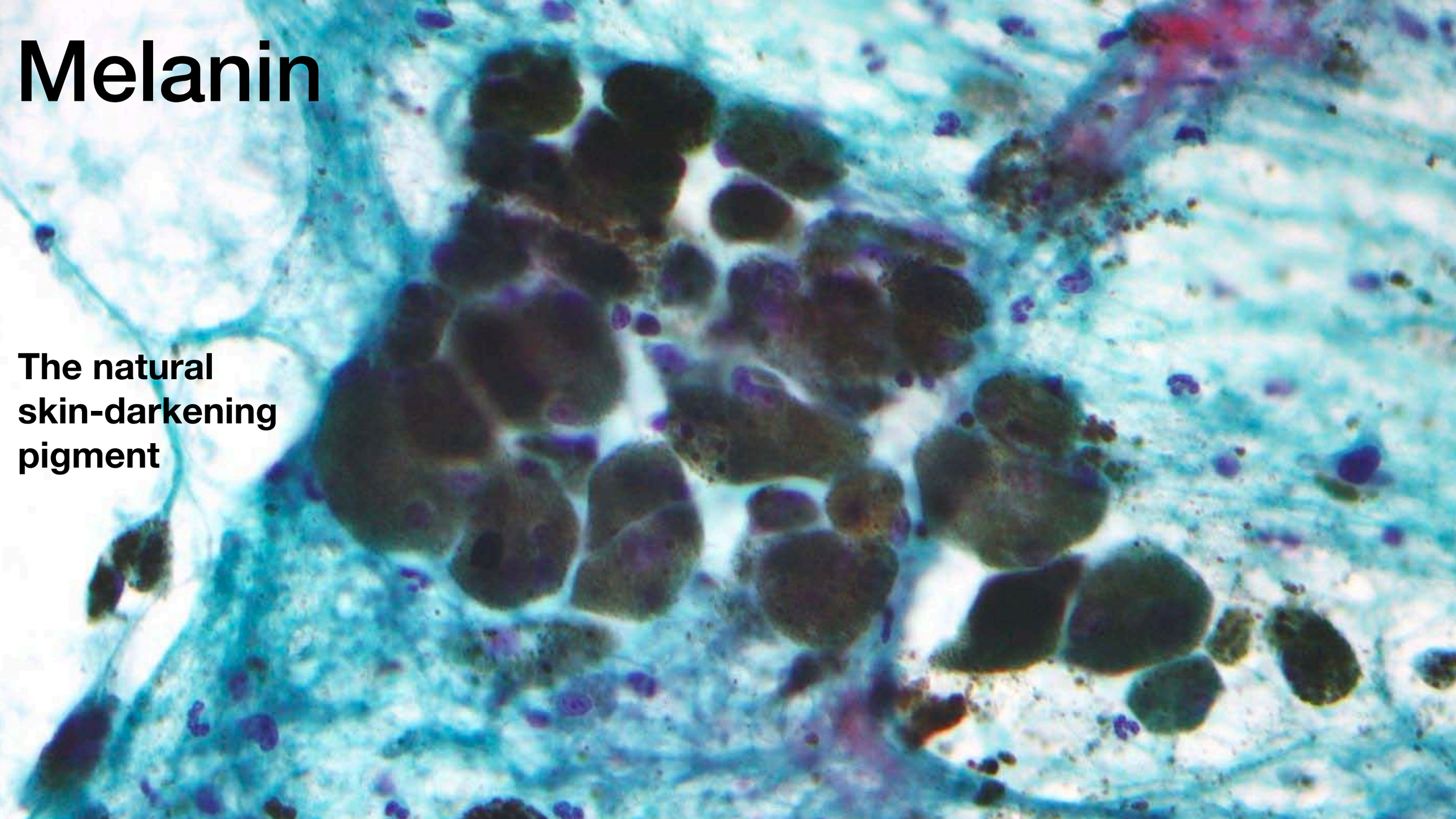
Ordinary Black Tattoos Protect Against Cancer



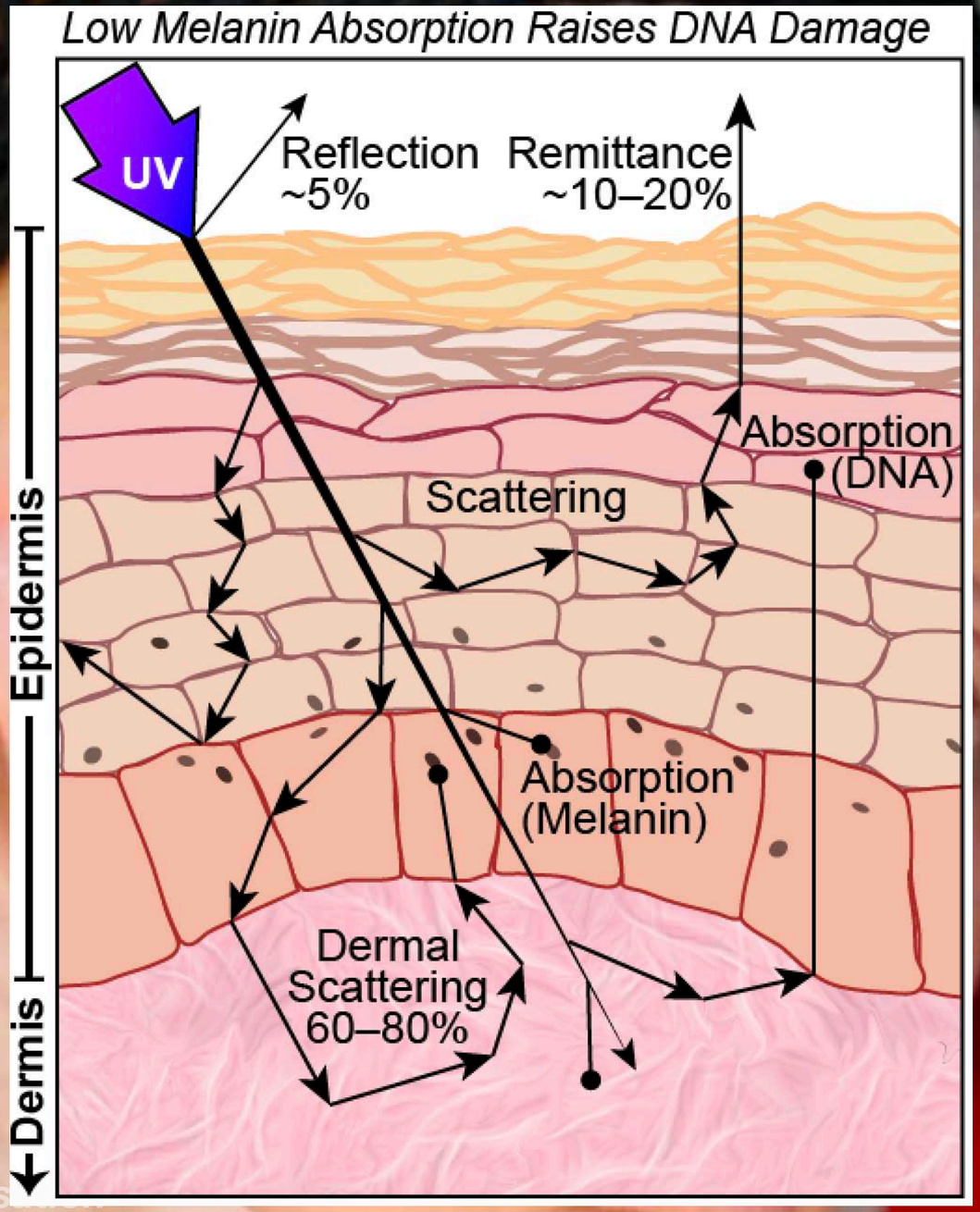
Lerche, C. M., Sepehri, M., Serup, J., Poulsen, T., & Wulf, H. C. (2015). *Photodermatology, Photoimmunology & Photomedicine*, *31*, 261–268.

Melanin

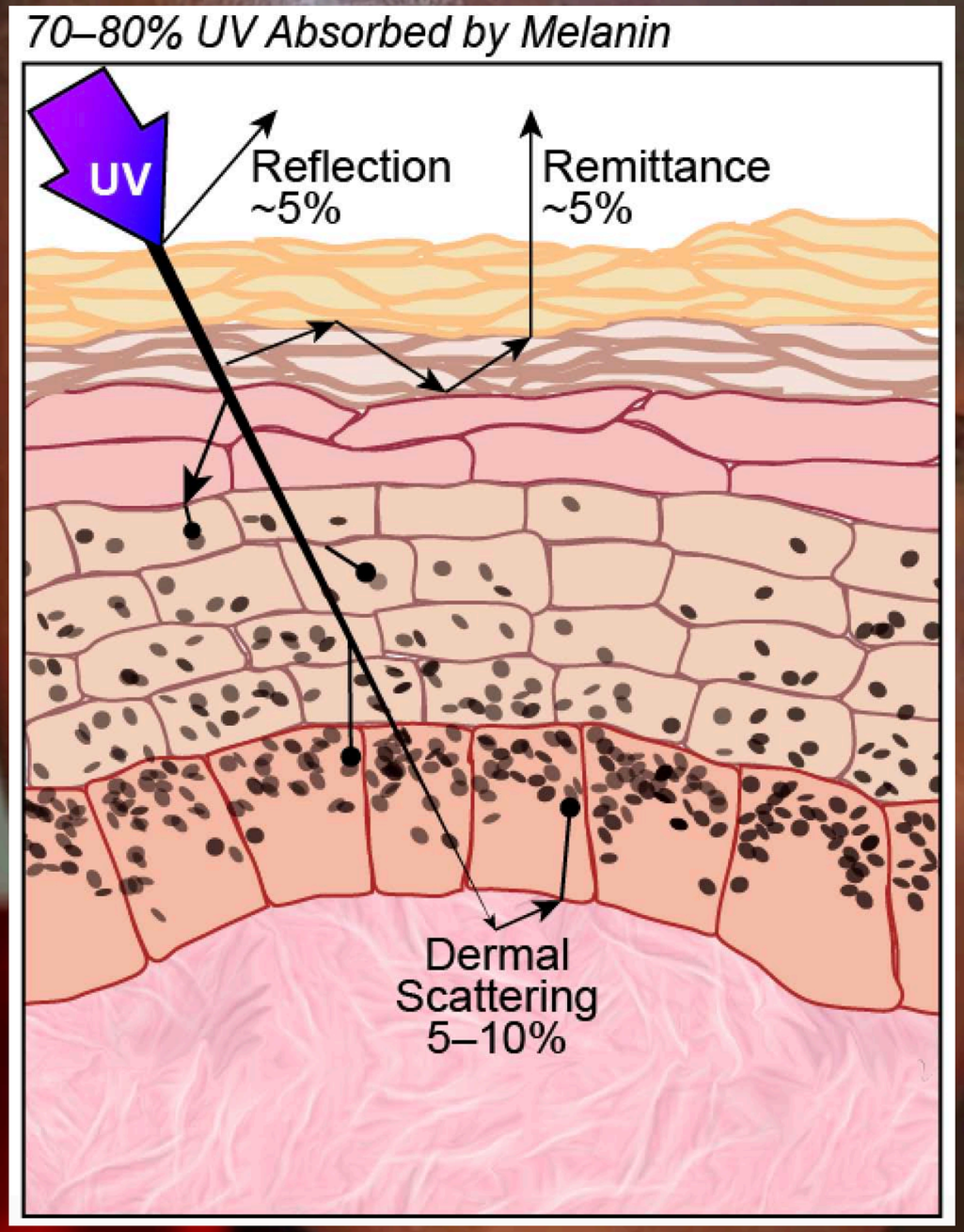
The natural skin-darkening pigment



Light Skin = High Cancer Risk



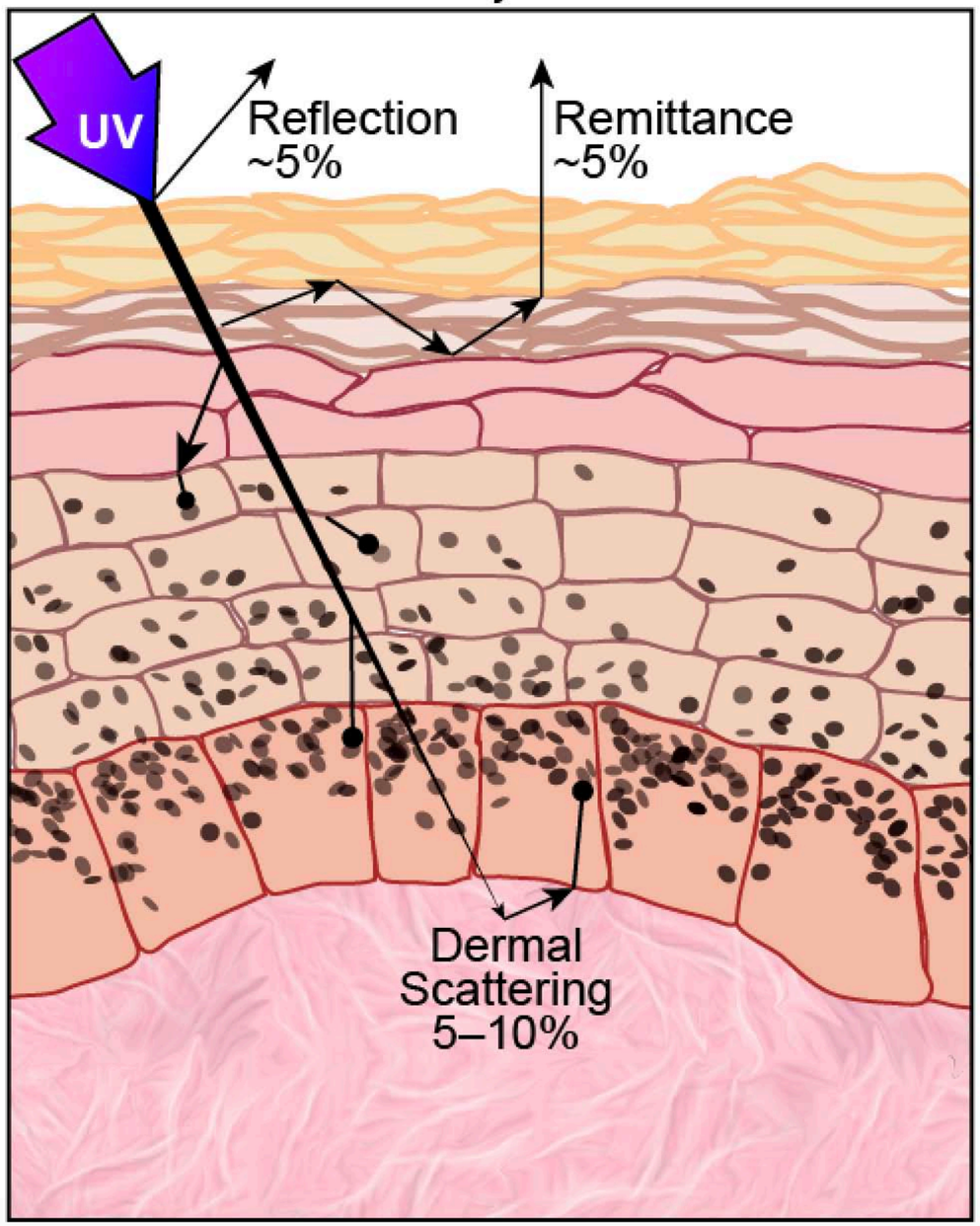
Dark Skin = Low Cancer Risk



HYPOTHESIS

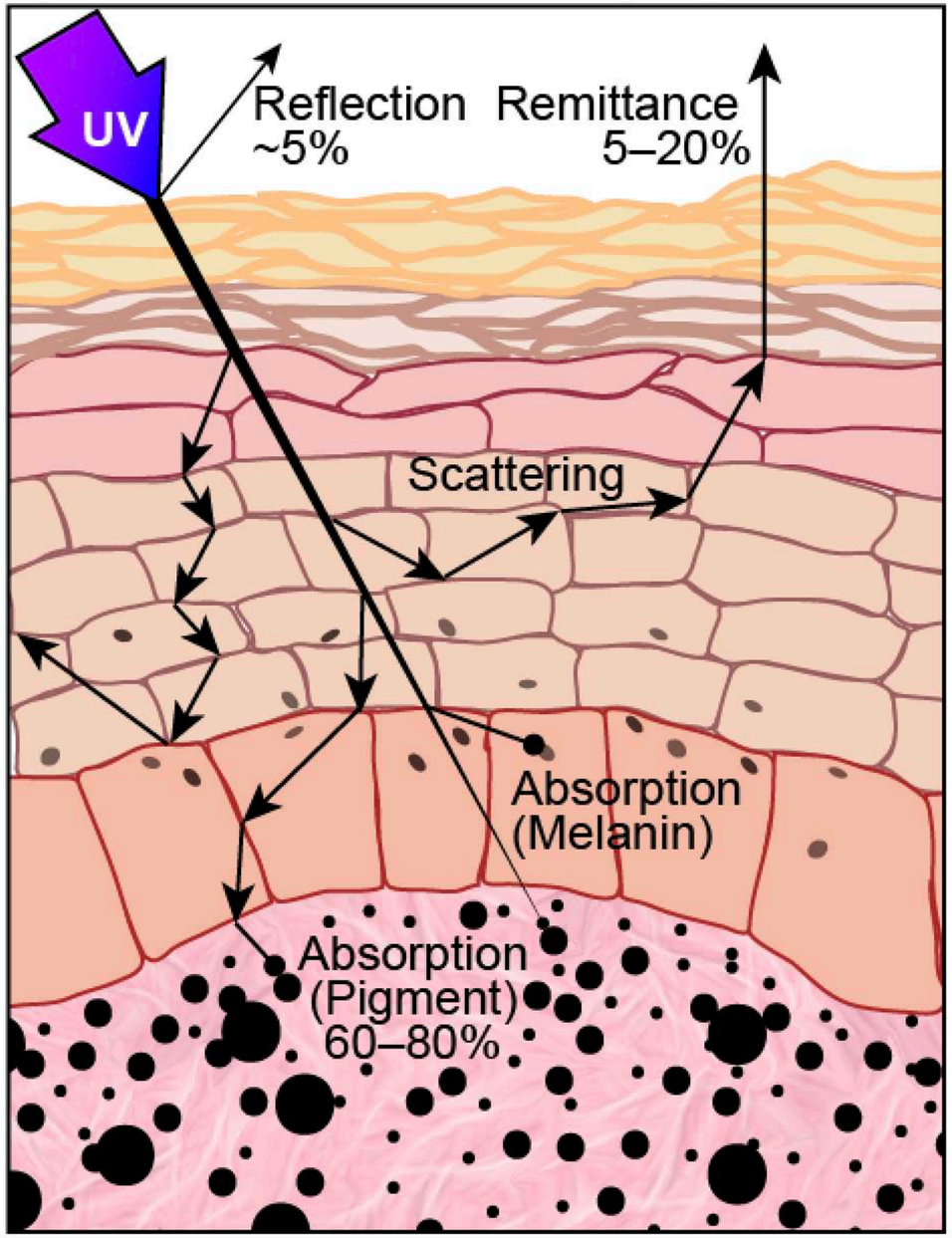
Dark Skin = Low Cancer Risk

70–80% UV Absorbed by Melanin

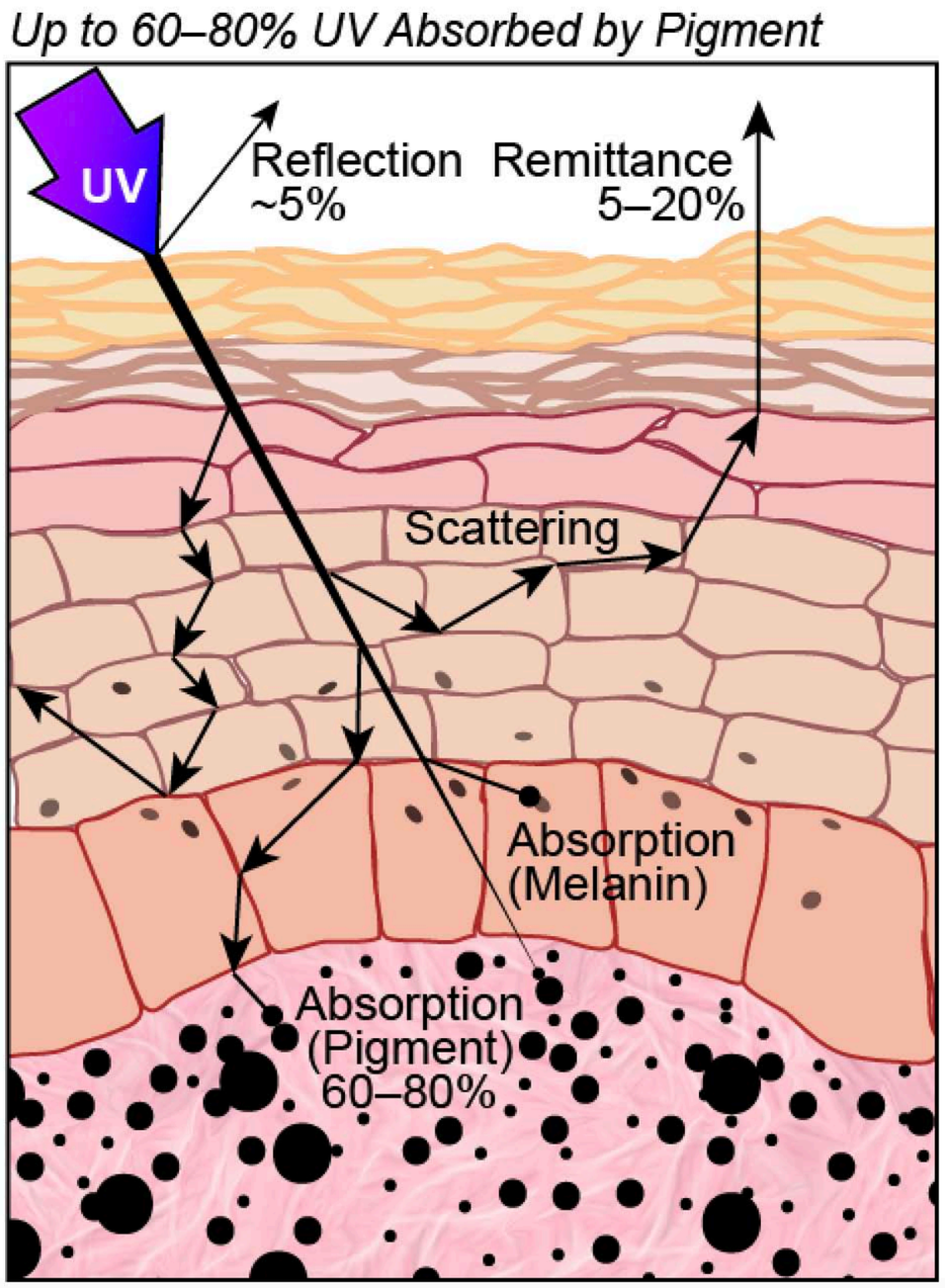


Tattooed Skin = Low Cancer Risk

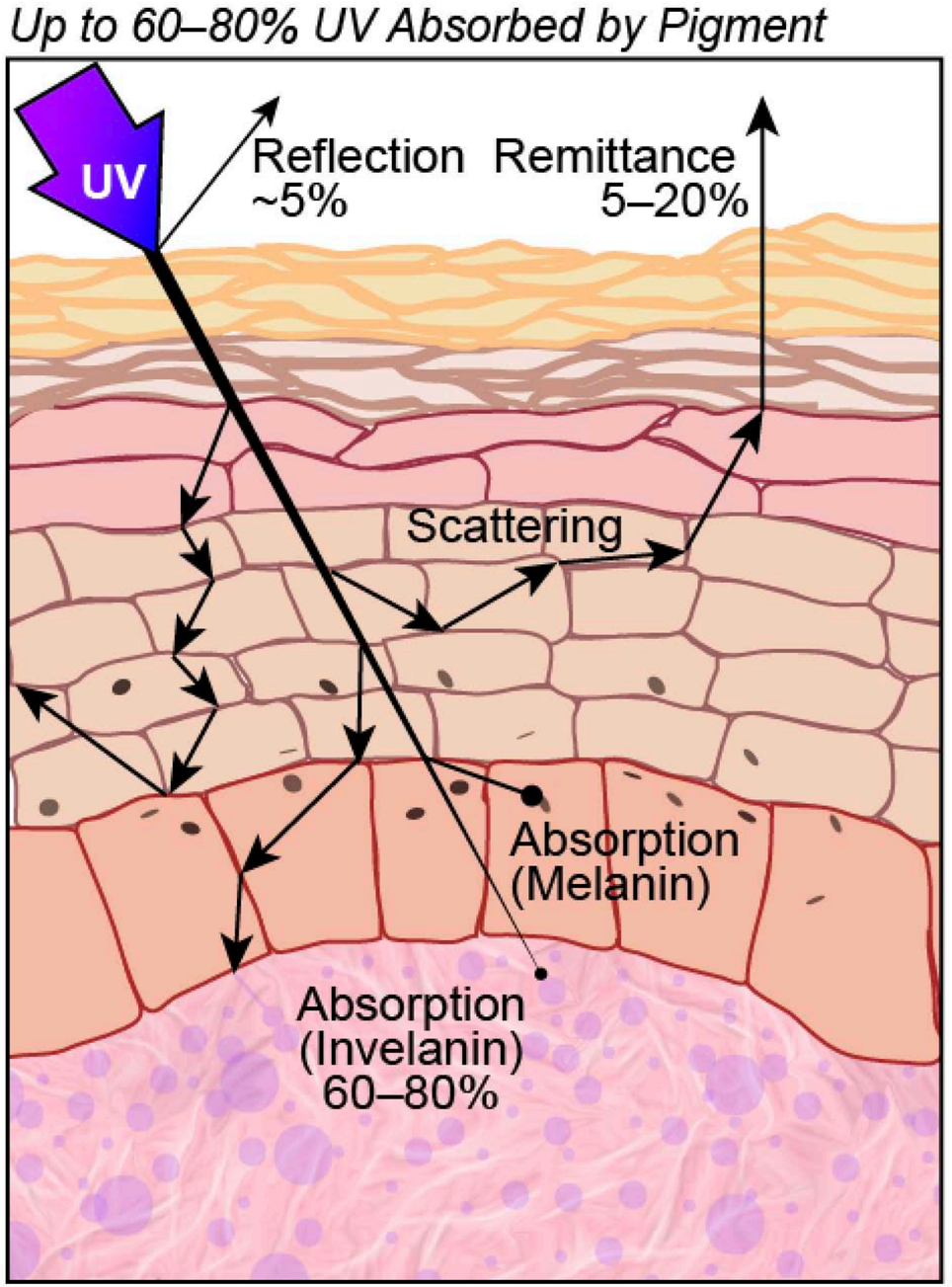
Up to 60–80% UV Absorbed by Pigment



BLACK (UV Absorptive)

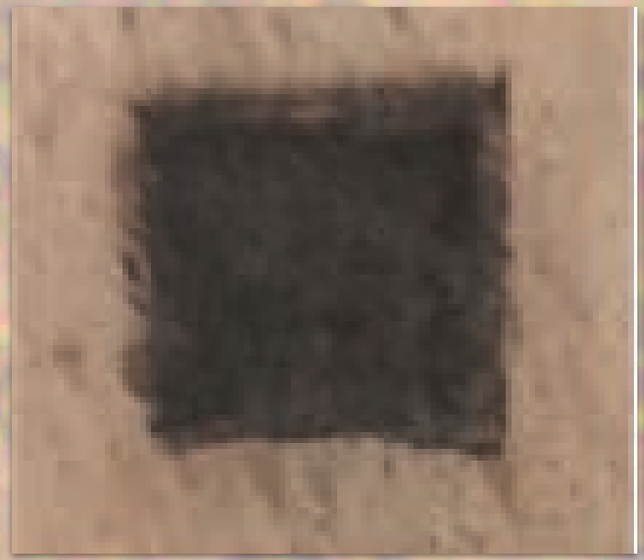
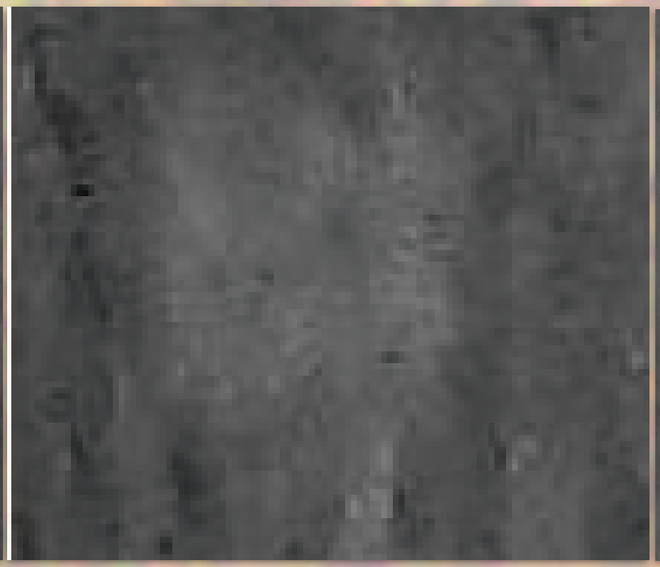
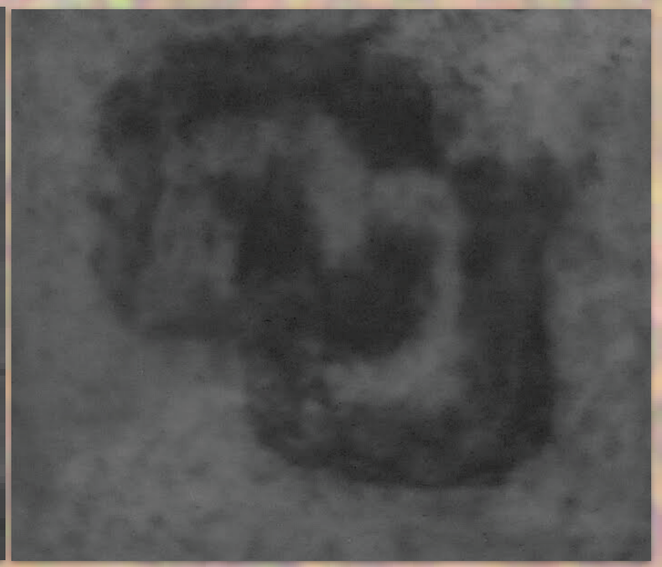


INVISIBLE (UV Absorptive)

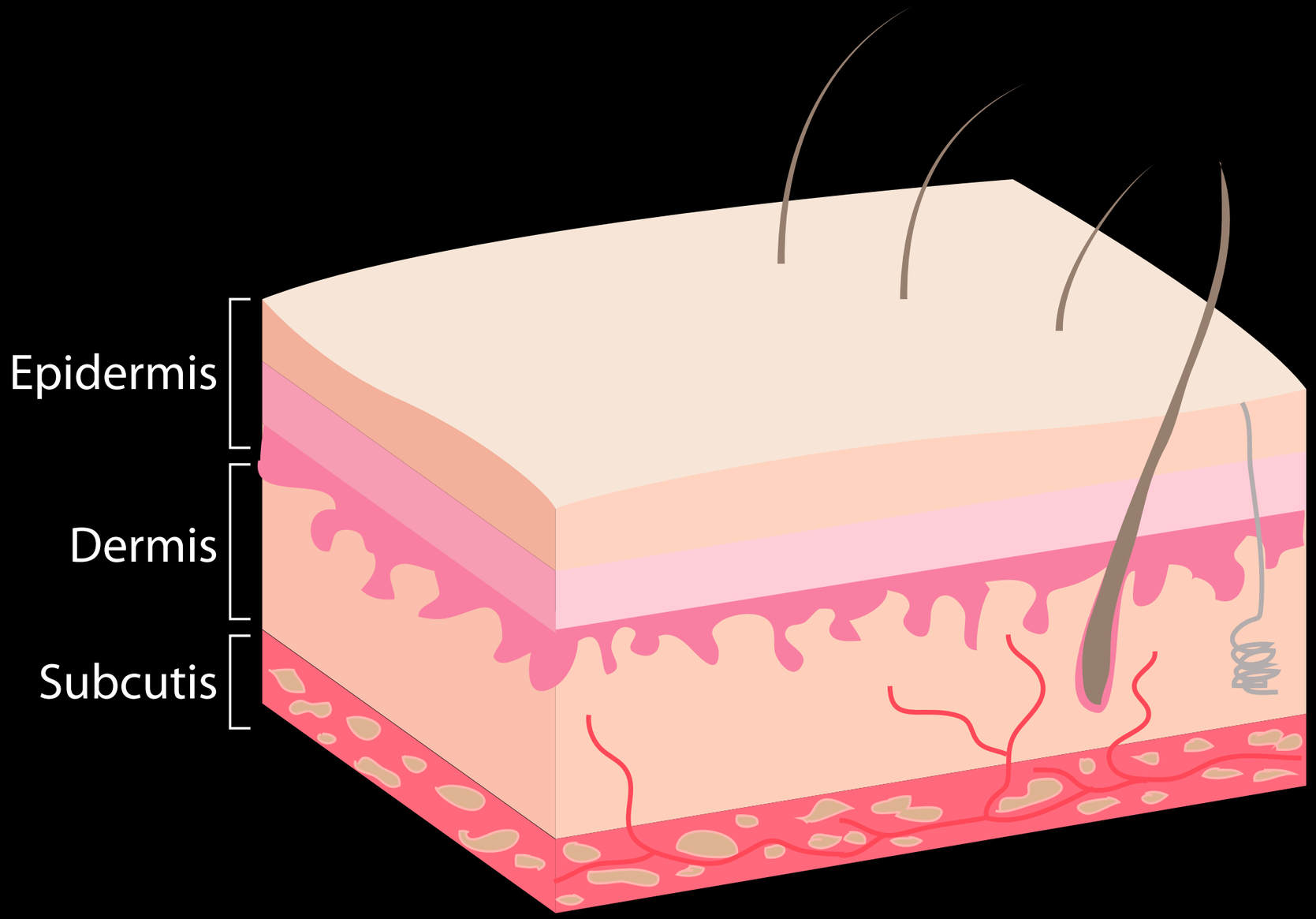


Invelanin

Invisible + Melanin

	Black *Carbon Black*	**PDMS** *Not UV Absorptive*	**Invelanin** *Invisible + Melanin*
Visible Photos →			
UV Photos →			

The three functions of skin

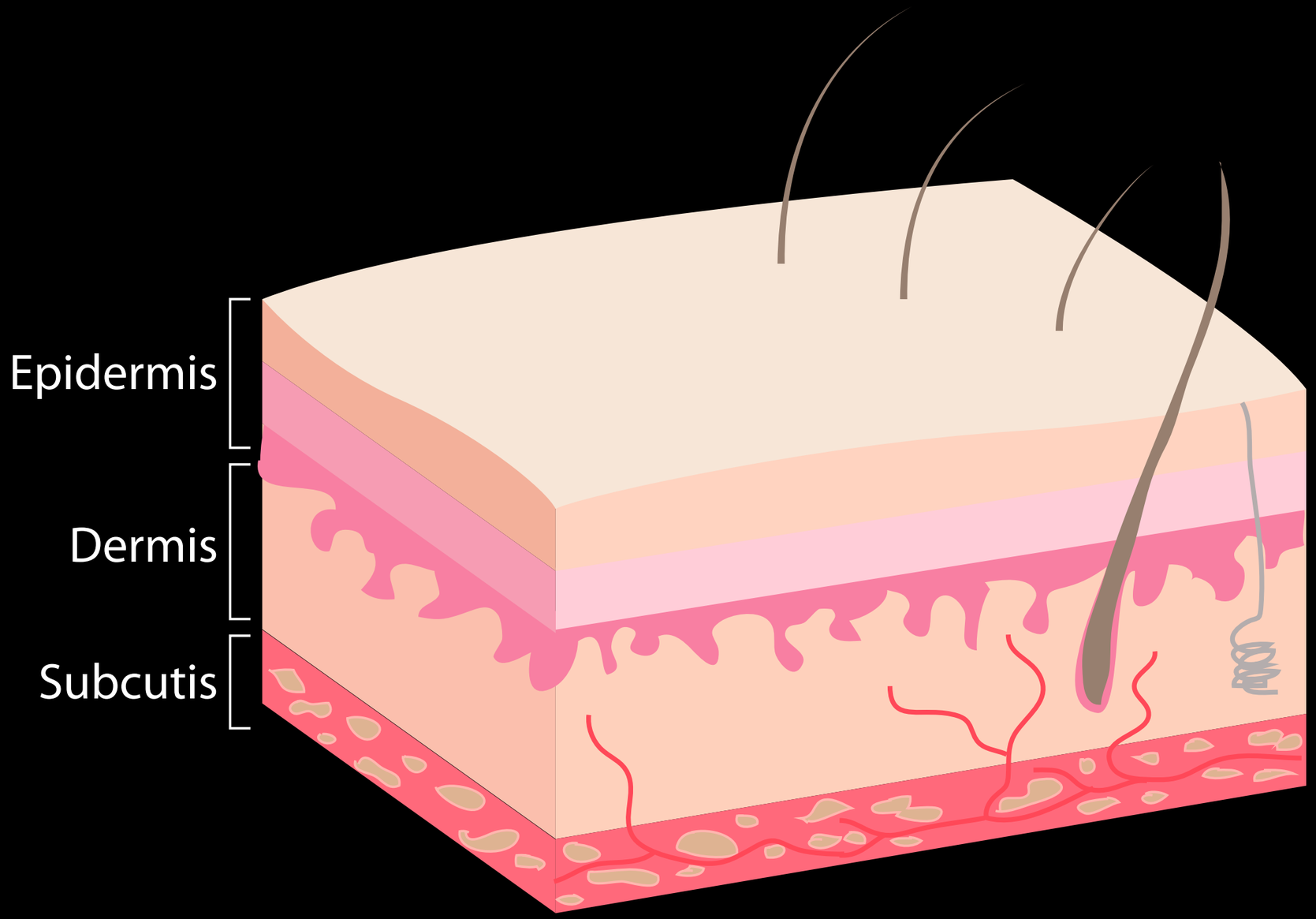


- Sensing

- Protection

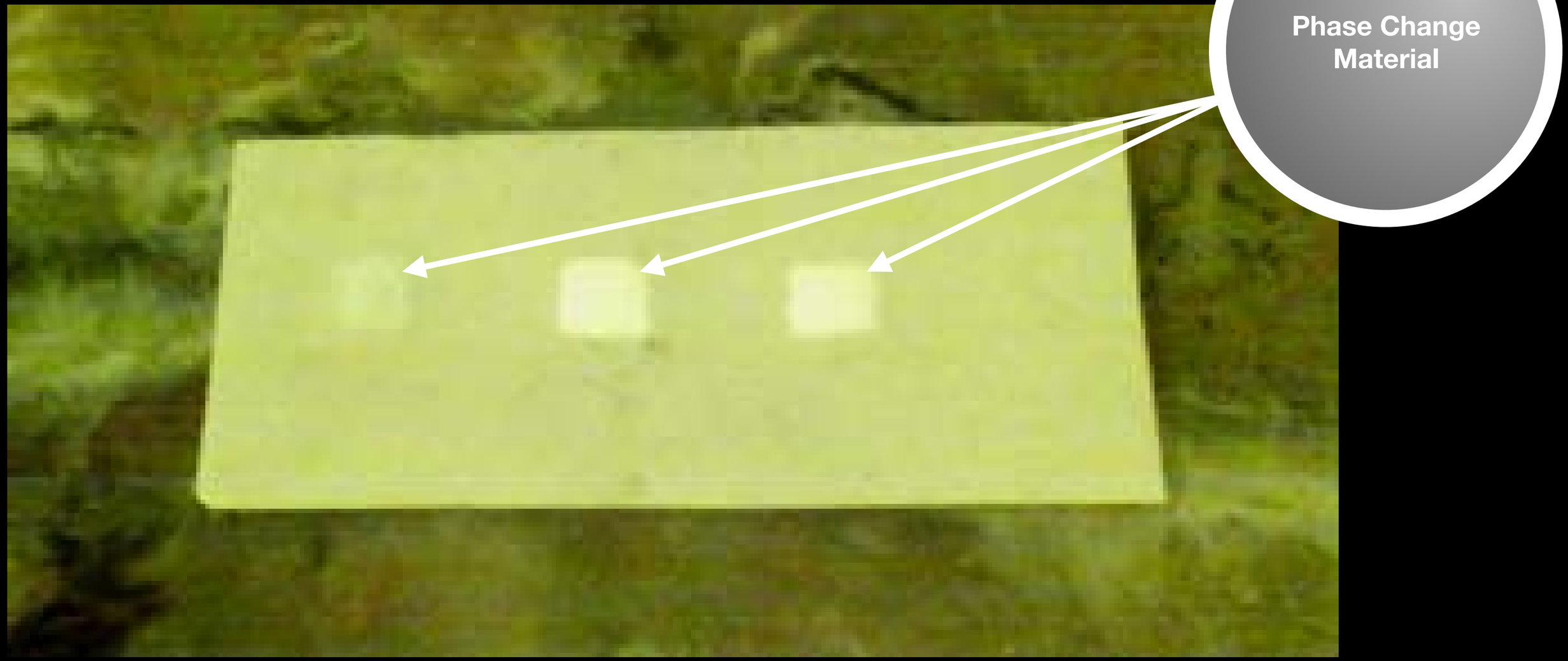
- Regulation

The three functions of skin

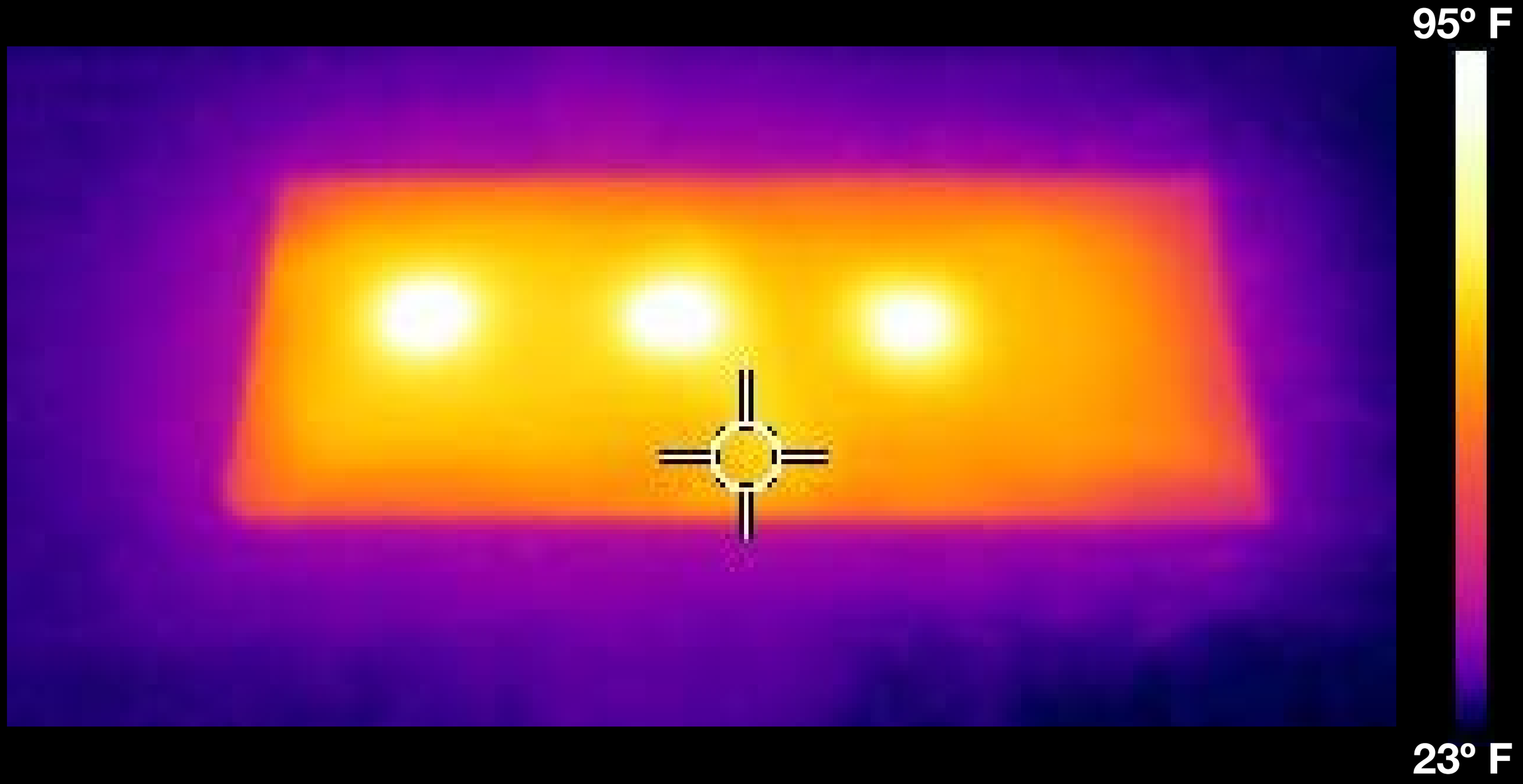


- Sensing
- Protection
- **Regulation**

A temperature regulation tattoo



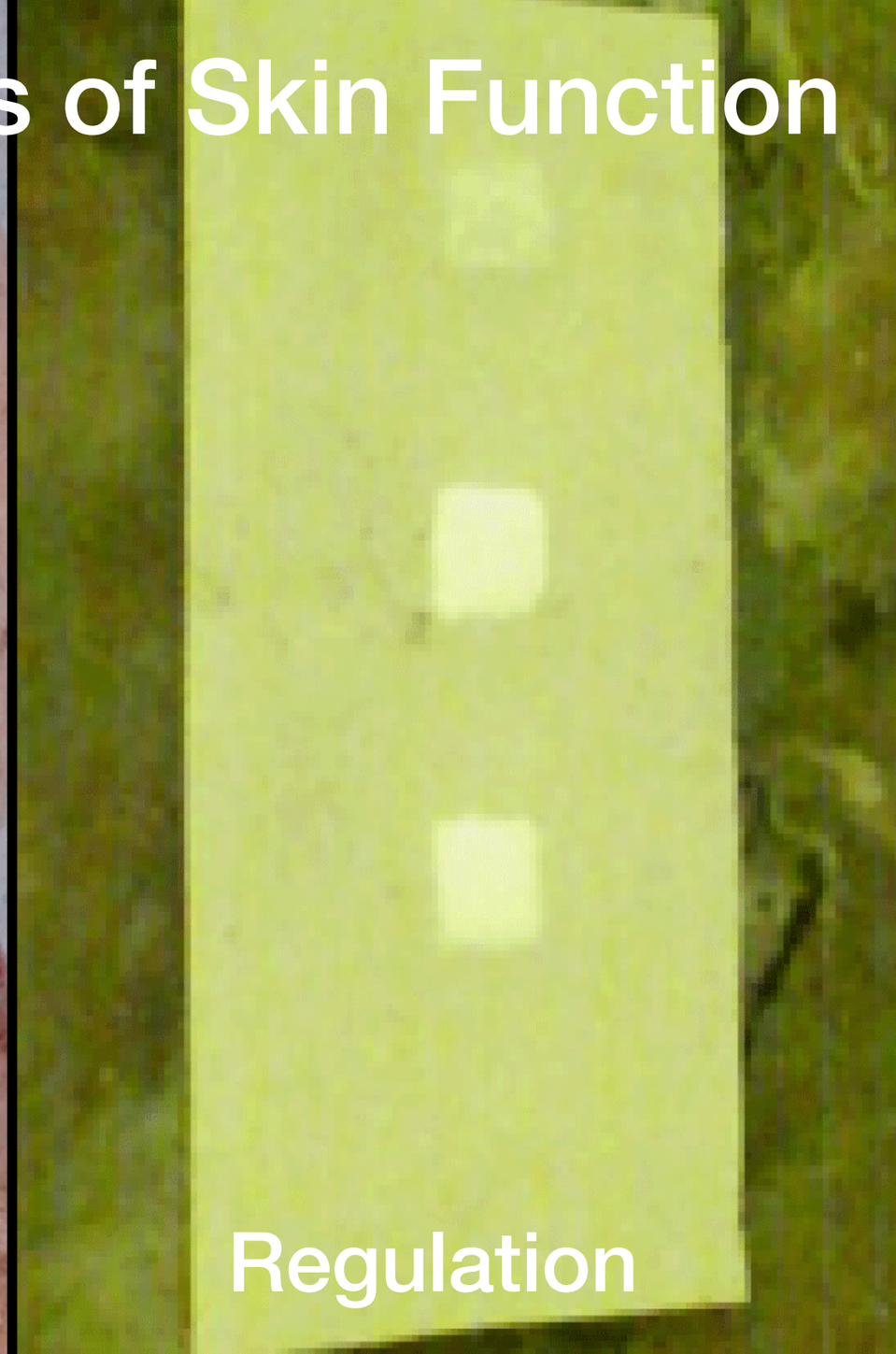
A temperature regulation tattoo



Tattoos Enhance All 3 Domains of Skin Function

Sensing

Protection



Regulation

The Future of Smart Tattoos

Sensing

Energy

Heat

X-rays

Gamma rays

Magnetic fields

Electric fields

Biosensing

Glucose

Lactose

Hydration

Alcohol

pH

Cancer

Protection

Radiation

UV rays

X-rays

Gamma rays

Injury

Bruises

Cuts / Scrapes

Infection

Regulation

Temperature

Biochemistry

Hormones

Mood

Medication

Devices

Games

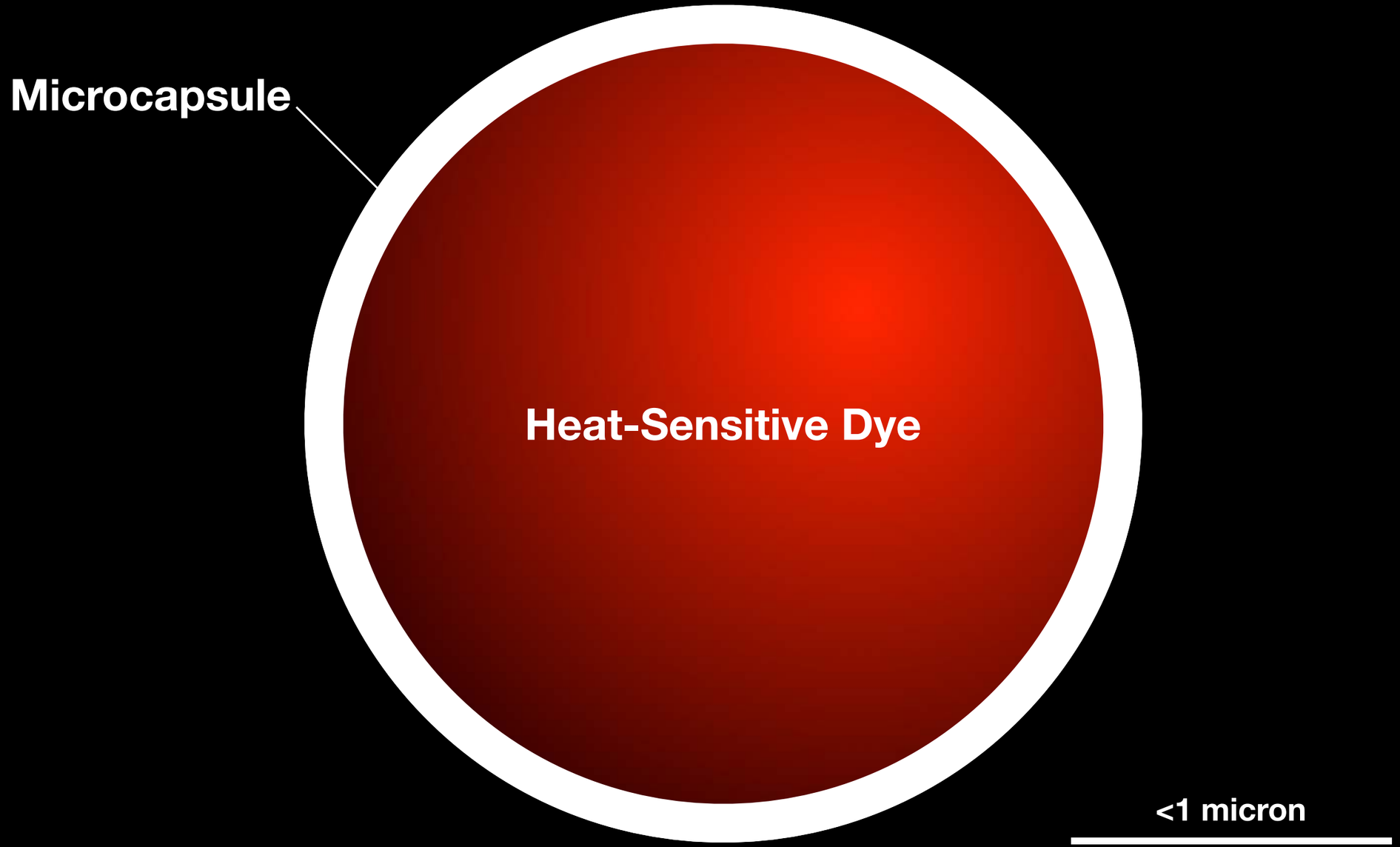
Human-Computer Interfaces

Brainwaves

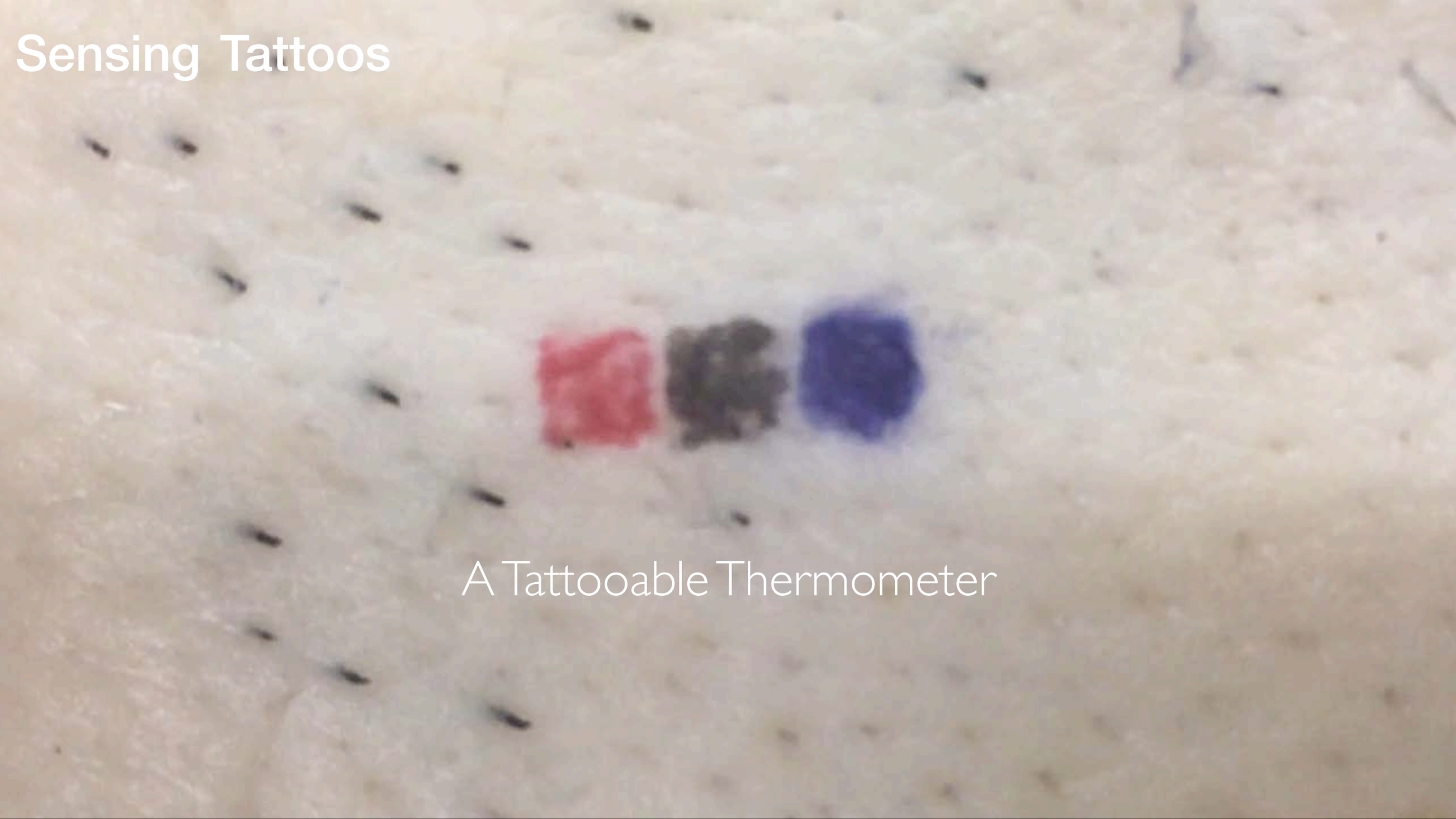
Sensing Tattoos

Energy

Sensing Tattoos

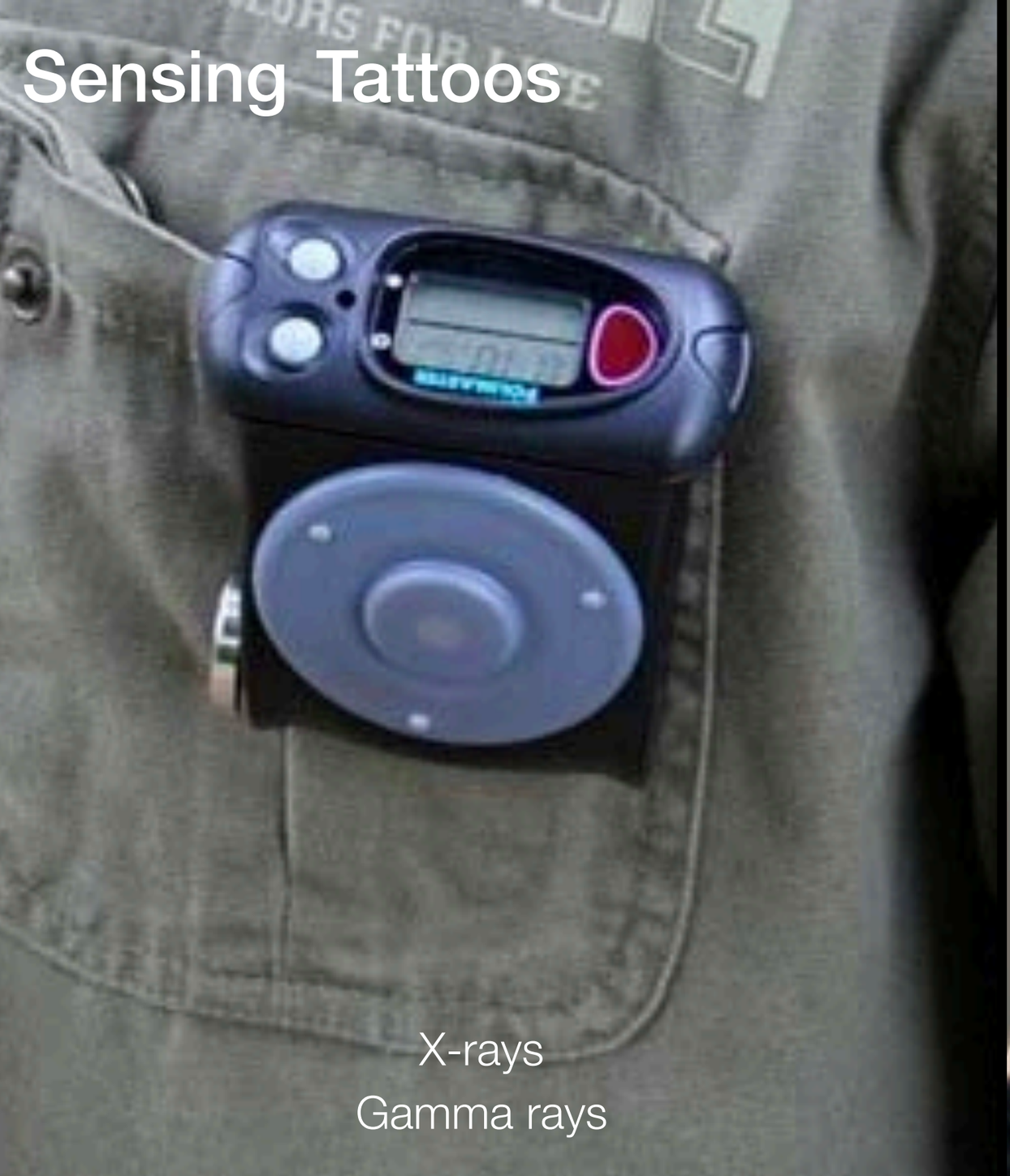


Sensing Tattoos



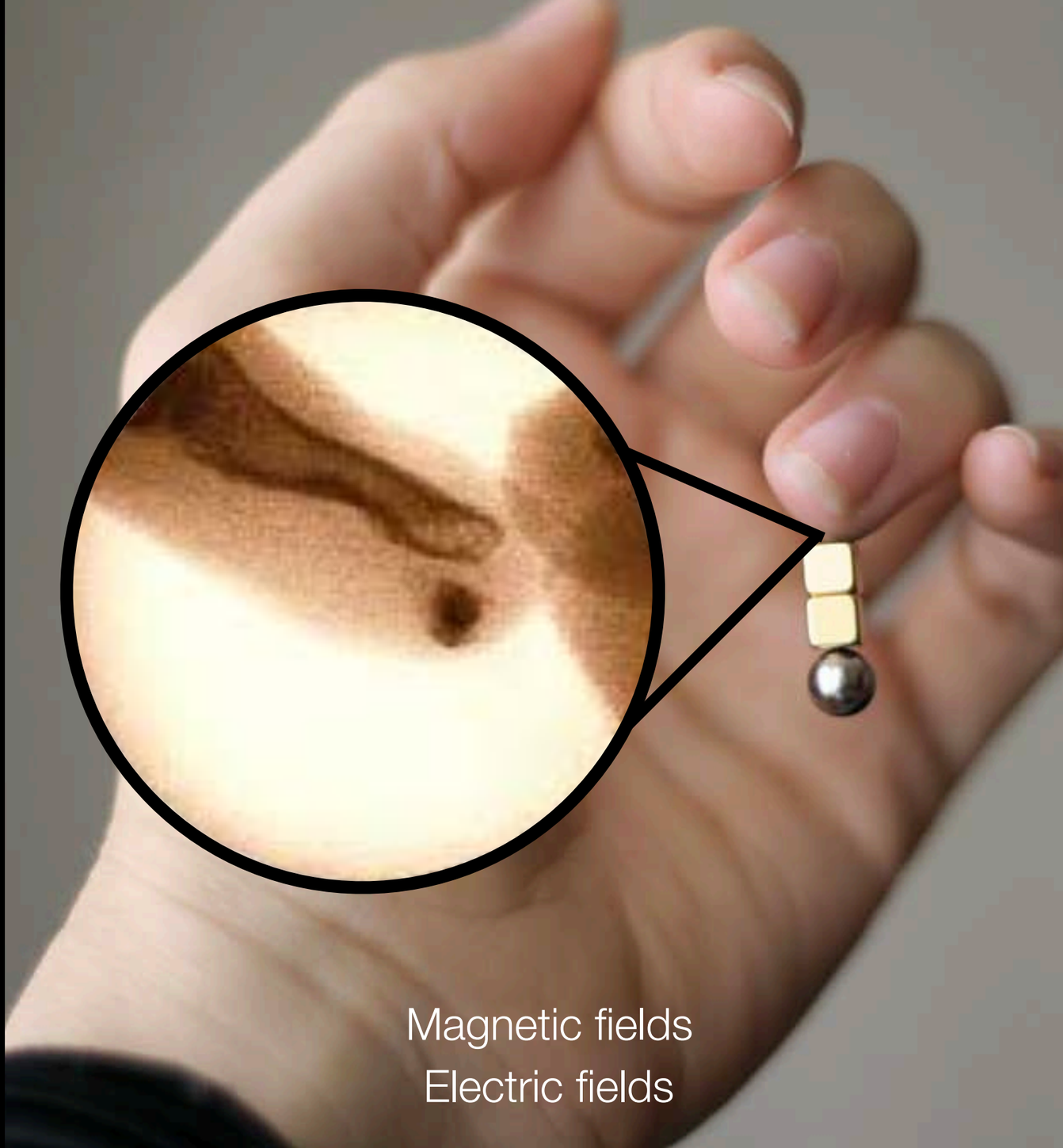
A Tattooable Thermometer

Sensing Tattoos



X-rays

Gamma rays

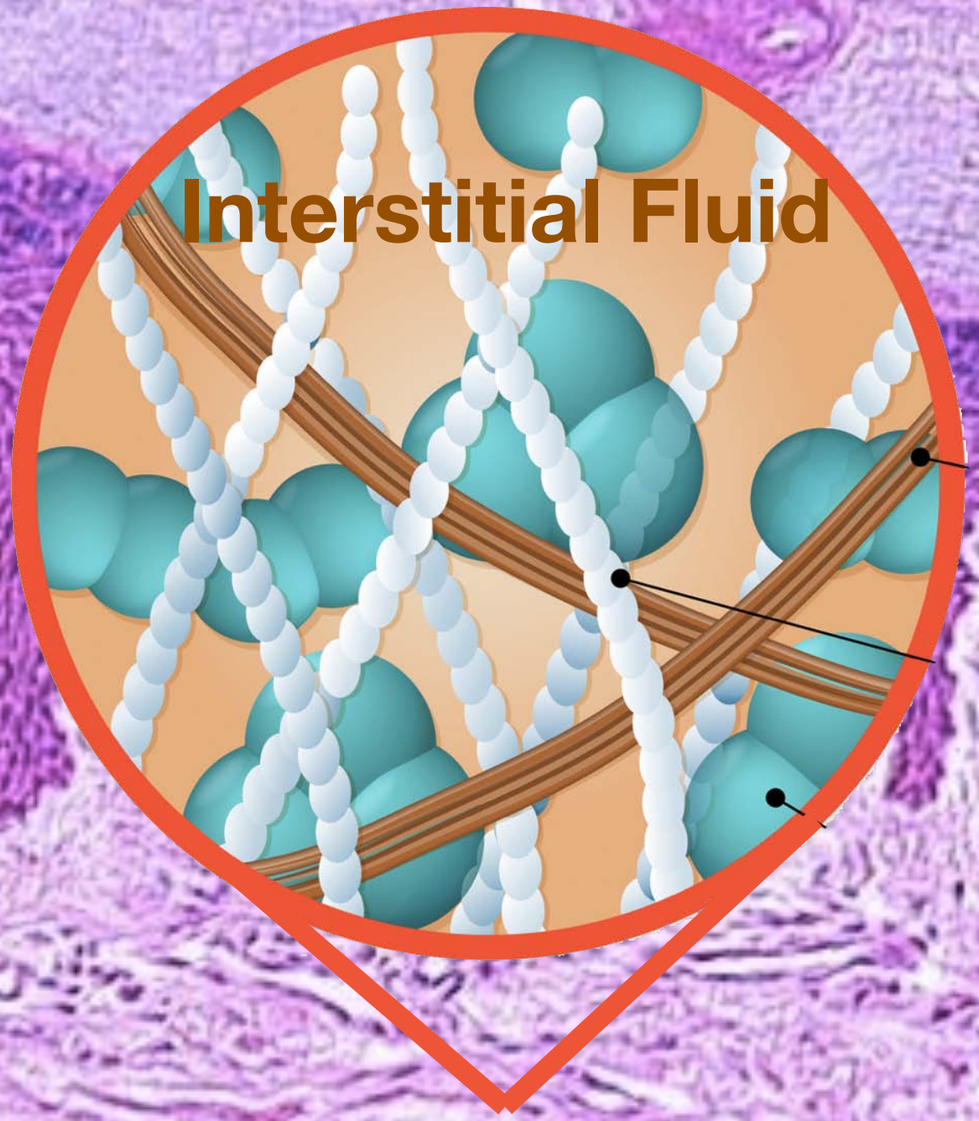


Magnetic fields

Electric fields

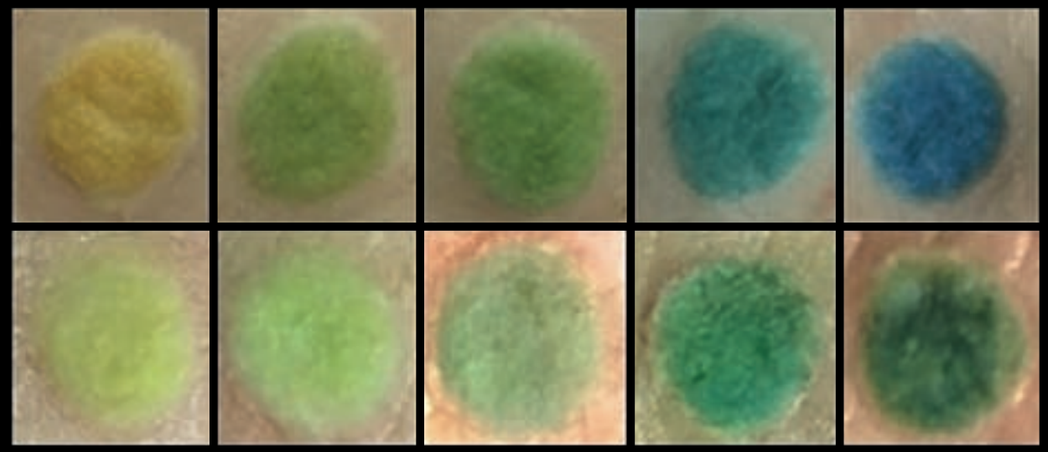
BioSensing Tattoos

Epidermis



Dermis

BioSensing Tattoos



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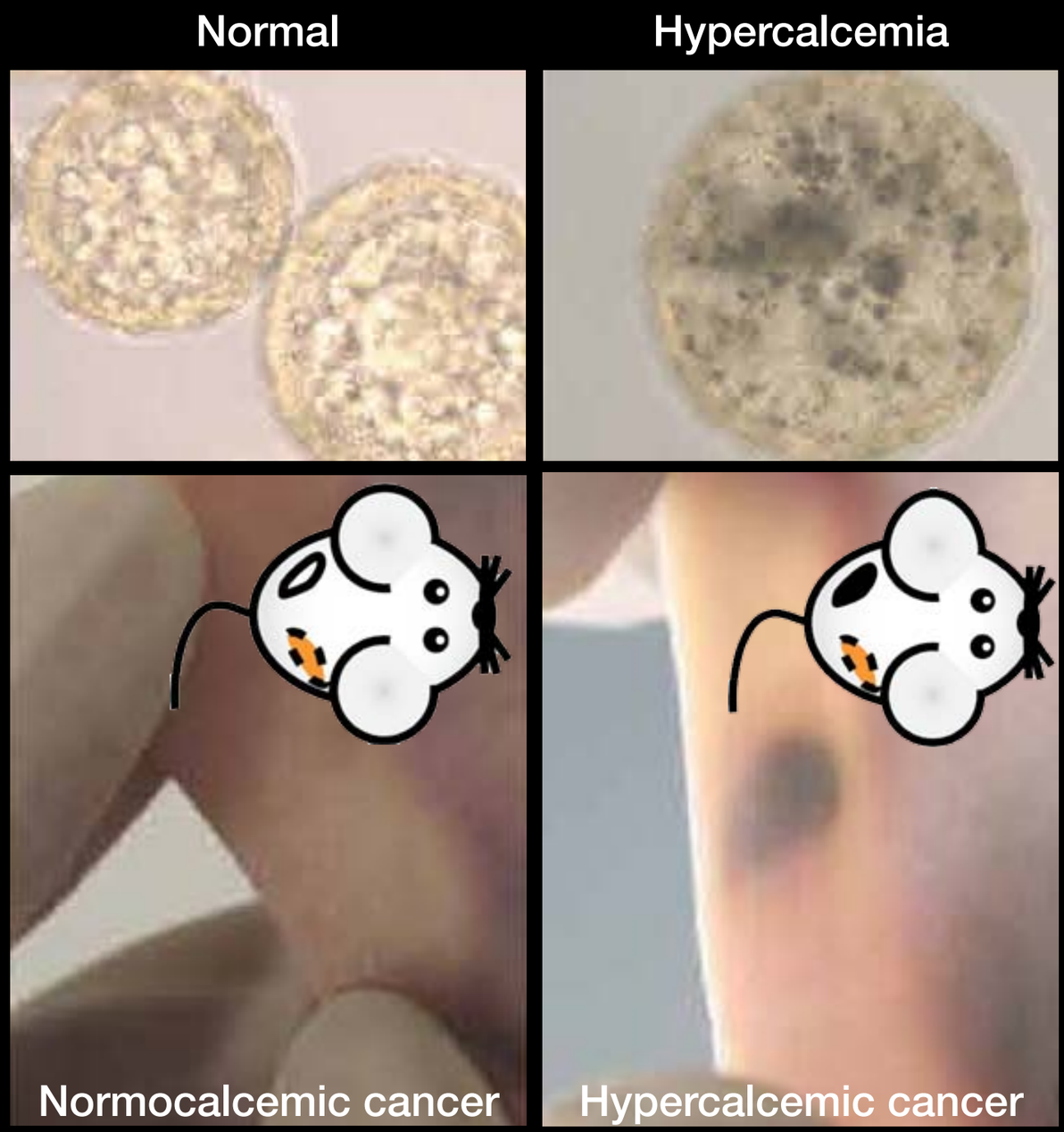

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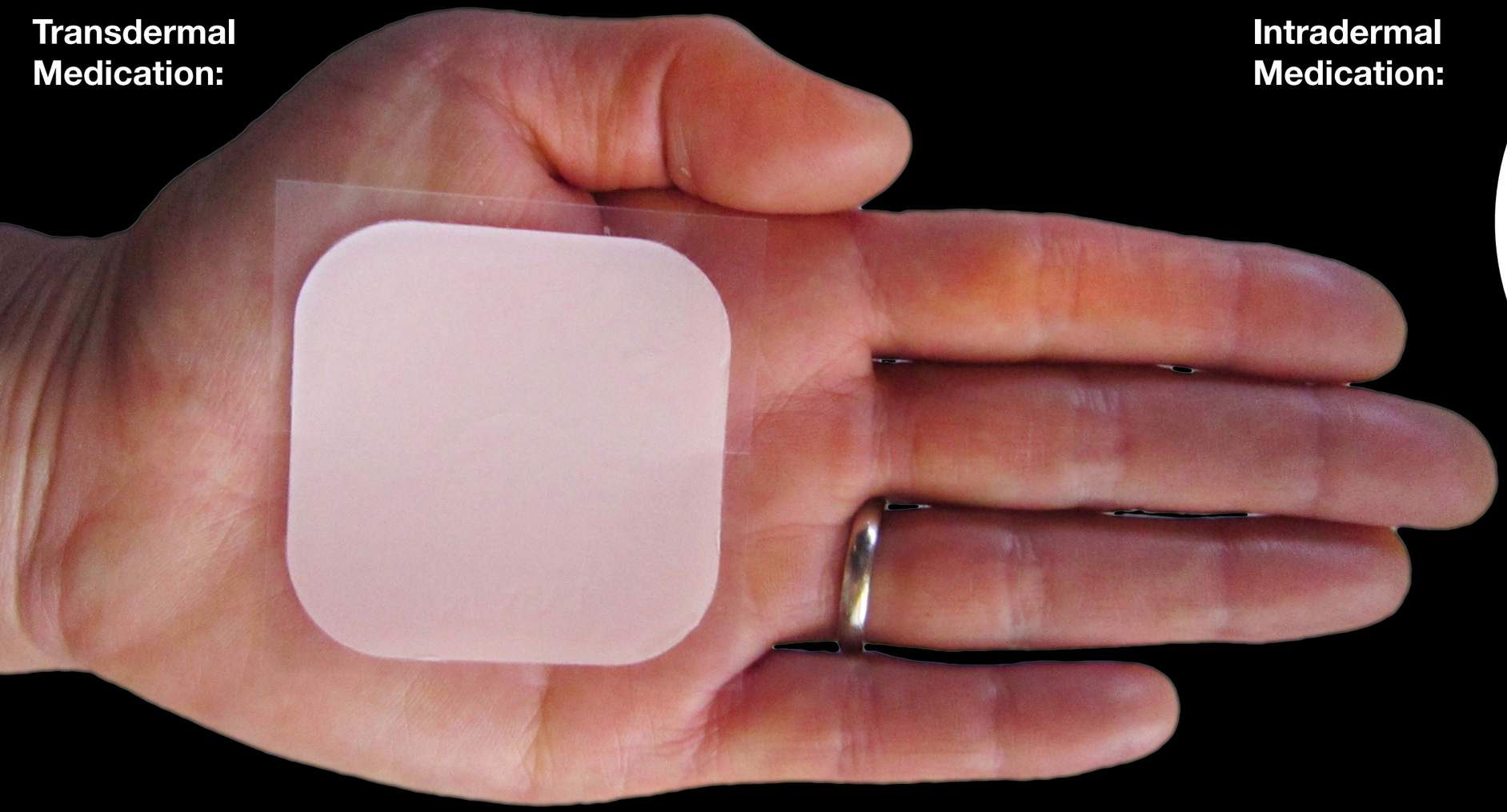
Transdermal Medication:



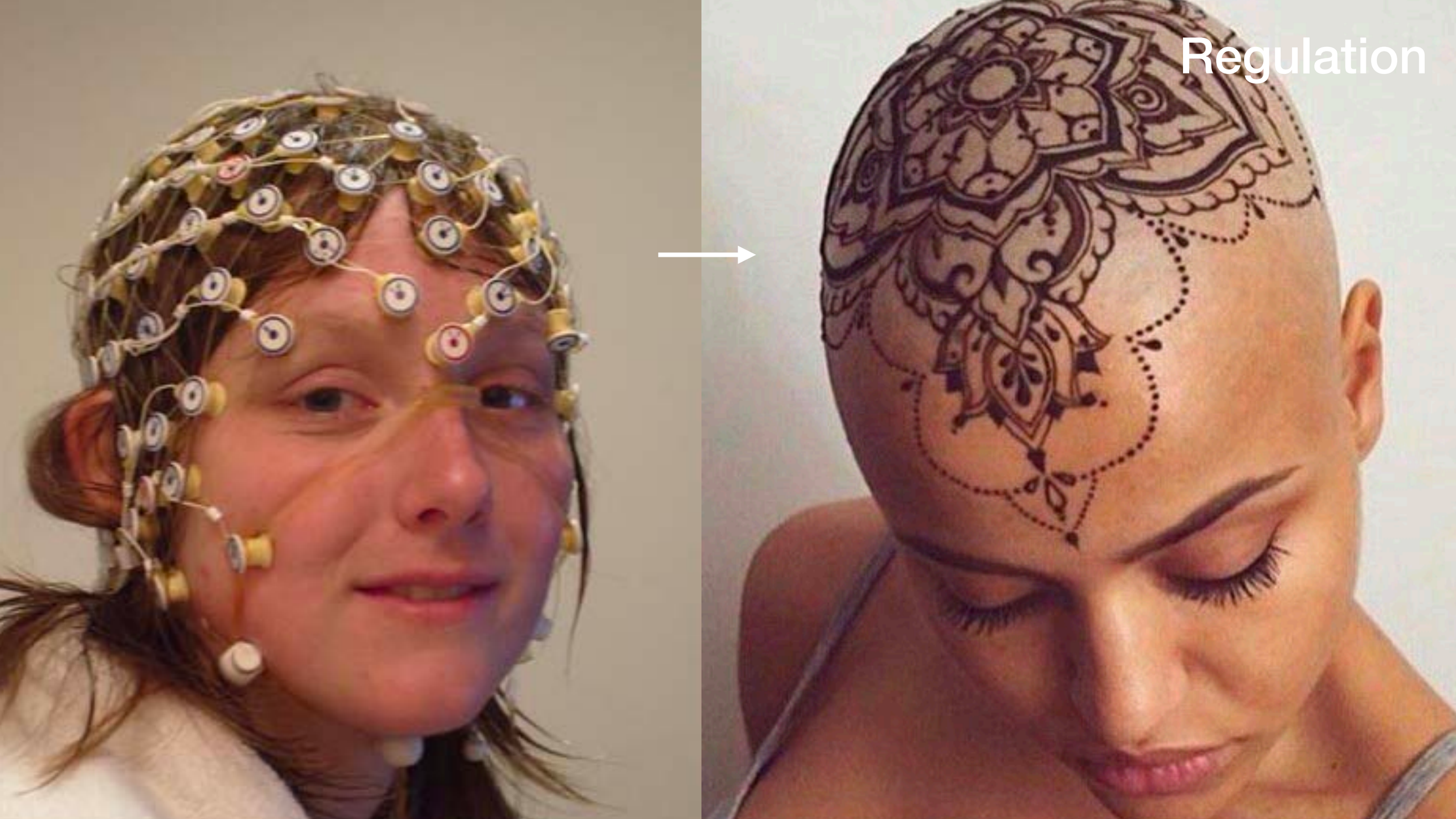
Intradermal Medication:

Controlled-Release Biodegradable Microcapsules

- Contraception
- Hormonal therapy
- Addiction management
- Antidepressants

Regulation

A Conducting Tattoo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CHROMAPRAXIS

HELP US REVOLUTIONIZE TATTOOS

We want to talk to tattooers, supply shops, and ink makers

carson.bruns@colorado.edu

Thank you!