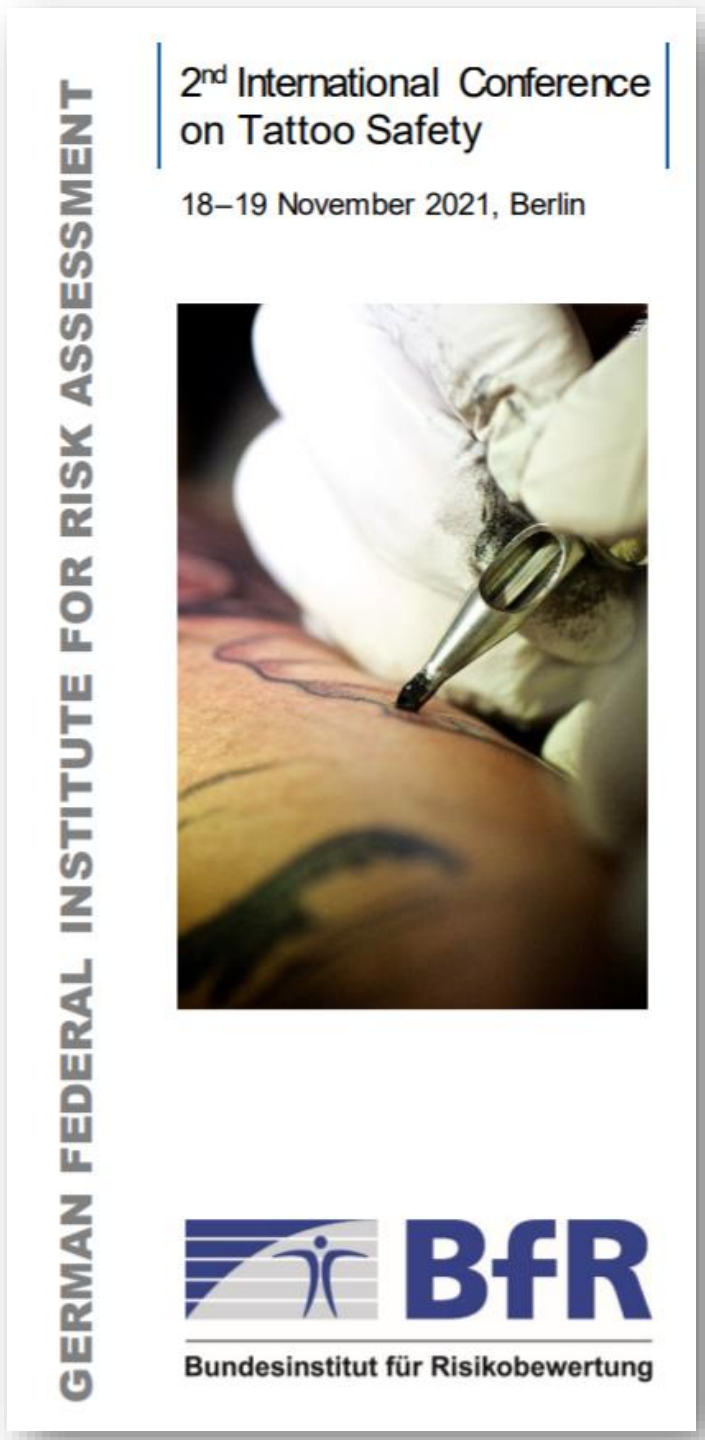


Tattoo pigments in skin and body, transportation processes boosted by laser light and UV radiation

Wolfgang Bäumler
Department of Dermatology
University of Regensburg
Germany

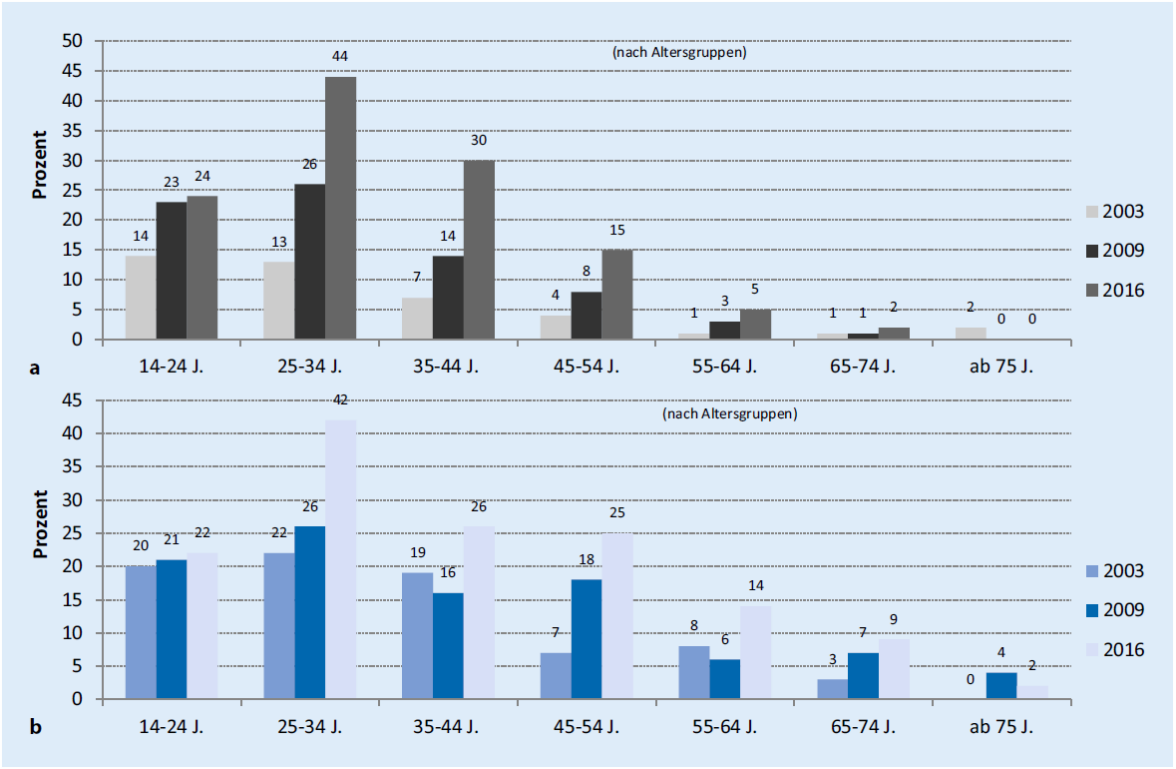
Prevalence of tattoos – meanwhile high numbers

Kluger et al, JEADV 2019, 33, e437–e495

Table 1 Overall characteristics of the respondents (*N* = 11 079)

	Total *N* = 11 079 *n* (%)	Brazil *n* = 2003 *n* (%)	China *n* = 3010 *n* (%)	France *n* = 2048 *n* (%)	Russia *n* = 2010 *n* (%)	United-States *n* = 2008 *n* (%)
Tattooed *n* (%)	2047 (18.4)	446 (22.3)	367 (12.2)	365 (17.8)	236 (11.7)	633 (31.5)

Germany, about 20 % (participants: N=2510)



Borkenhagen et al, Bundesgesundheitsbl 2019, 62:1077–1082

Prevalence of tattoos – meanwhile high numbers

a conservative estimate of percentages and tattooed people

Figures			
area	**population**	**percentage**	**tattooed people**
EU 27	447 Mio	12 %	54 Mio
Brazil	212 Mio	22 %	47 Mio
USA	330 Mio	30 %	99 Mio

https://de.statista.com/statistik/daten/studie/1722/umfrage/bevoelkerungsreichste-laender-der-welt/
https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/safety-tattoos-and-permanent-make-final-report
https://theharrispoll.com/tattoos-can-take-any-number-of-forms-from-animals-to-quotes-to-cryptic-symbols-and-appear-in-all-sorts-of-spots-on-our-bodies-some-visible-in-everyday-life-others-not-so-much-but-one-thi/

Ingredients of tattoo inks

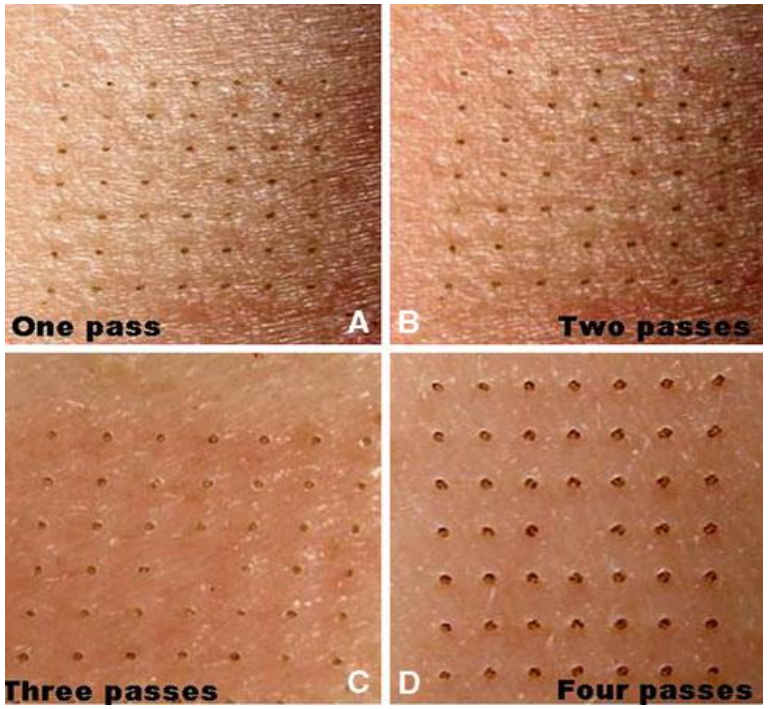
compound	function in the tattoo ink	chemistry
pure pigments	color	organic and inorganic pigments
educts of pigment synthesis	none	
pigment impurities/finishing	none	
solvents	liquid basis of tattoo ink suspension	e.g. water, isopropanol
emulsifier	assist the manufacturing of a suspension	e.g. polyethyleneglycol
binder	optimization of the suspension	e.g. polyvinylpyrrolidone
thixotropic agents	prevent sedimentation of pigments in suspension	silicon dioxide
antifoam agents	prevent generation of foam while shaking a suspension	e.g. polydimethylsiloxane
preservatives	antimicrobial action	e.g. parabens, phenol, methyl-isothiazolinone
metals	none	e.g. nickel, cobalt, chromium
decomposition products	none	different compounds e.g. primary aromatic amines (**PAA**)
other impurities	none	different compounds e.g. polycyclic aromatic hydrocarbons (**PAH**), phthalates, nitrosamines
microorganisms and viruses	none	various species

- W. Bäumler, Handbuch der Umweltmedizin, Ed. Wichmann, Fromme, 2020
- Hauri U. file:///C:/Users/user/Downloads/Tattoo%20Bericht%202019.pdf, 2020
- Piccinini P et al Safety of tattoos and permanent make-up: Final report 2016, Publications Office of the European Union, JRC101601

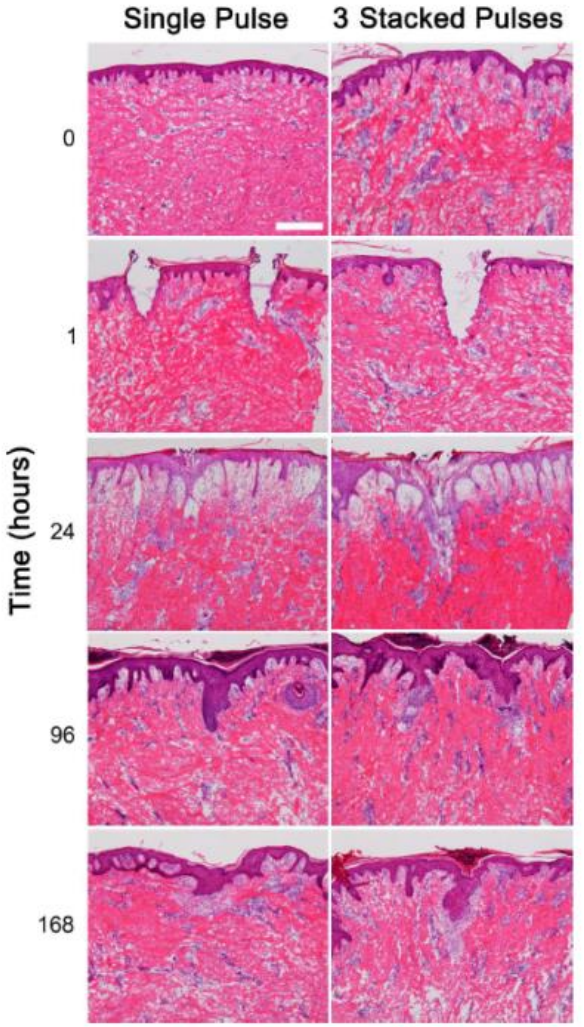
Ingredients of tattoo inks – needle stitch in skin

Example: laser induced holes in skin

Skin-Resurfacing



Trelles MA et al, Safe and effective one-session fractional skin resurfacing using a carbon dioxide laser device in super-pulse mode: a clinical and histologic study. Aesthetic plastic surgery. 2011;35:31-42.



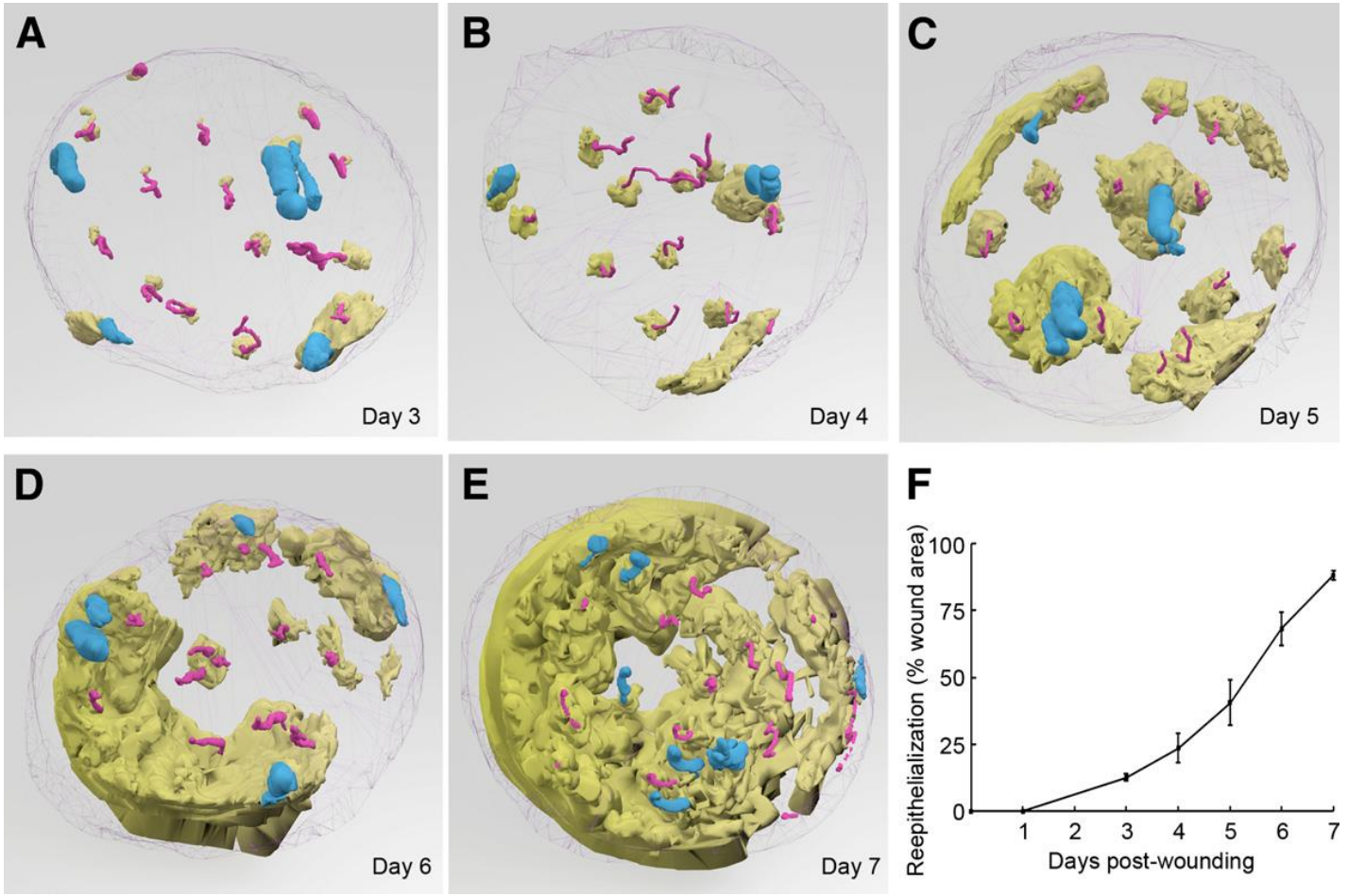
DeBruler DM et al, Inflammatory responses, matrix remodeling, and re-epithelialization after fractional CO2 laser treatment of scars. Lasers in surgery and medicine. 2017, 49:675-85.

Needle stitch in skin – wound healing without tattoo inks

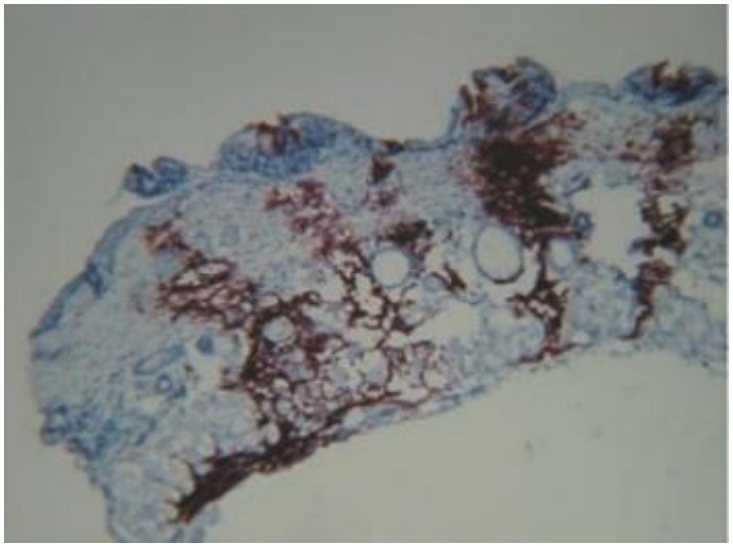
Example: partial-thickness wounds, generated using 2 passes of a CO_2 laser

Rittie et al, Eccrine Sweat Glands are Major Contributors to Re-Epithelialization of Human Wounds, The American Journal of Pathology, Vol. 182, No. 1, January 2013

Keratinocyte outgrowths expand above appendages until they merge with each other, thereby reconstituting the new interfollicular epidermis. 3D reconstruction seen from the underside of epidermis, generated from immunohistochemistry of whole skin biopsy samples obtained at 3, 4, 5, 6, and 7 days after wounding.



Needle stitch in skin – wound healing with tattoo inks



Engel E et al, Exp Dermatol, 2010 Jan;19(1):54-60.

Is the wound healing different for tattooed skin ?

data gaps…

Injection in skin – the amount of pigments

Contact Dermatitis 2008: 58: 228–233
Printed in Singapore. All rights reserved

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Journal compilation © 2008 Blackwell Munksgaard

CONTACT DERMATITIS

Modern tattoos cause high concentrations of hazardous pigments in skin

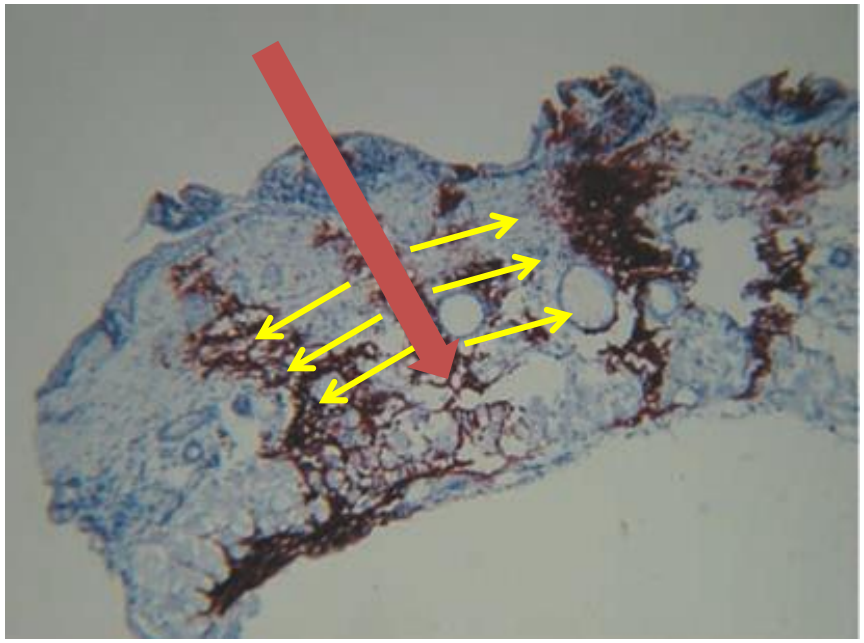
Eva Engel[1], Francesco Santarelli[2], Rudolf Vasold[1], Tim Maisch[2], Heidi Ulrich[2], Lukas Prantl[3], Burkhard König[1], Michael Landthaler[2] and Wolfgang Bäumler[2]

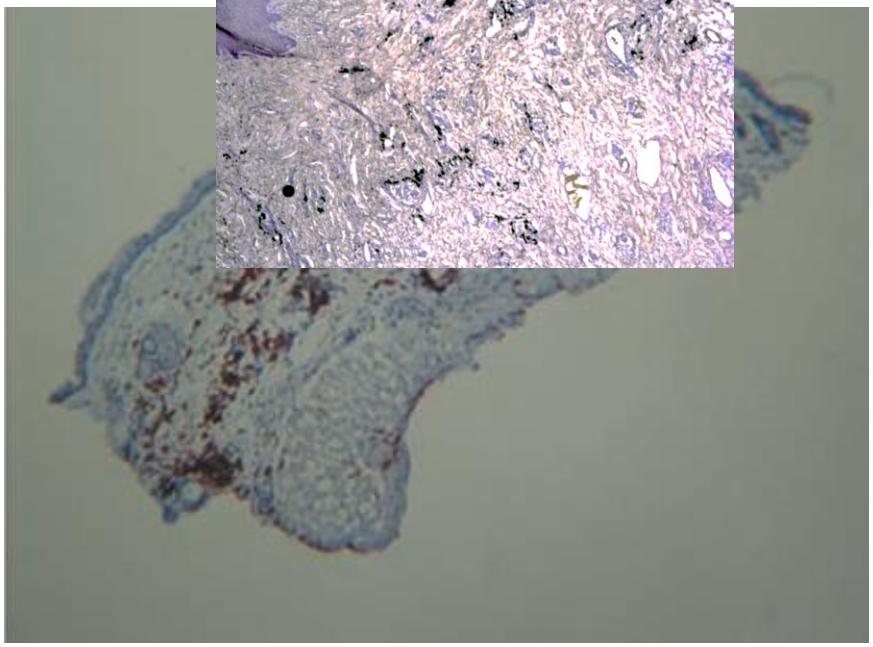
[1]Department of Organic Chemistry, [2]Department of Dermatology, and [3]Department of Trauma Surgery, University of Regensburg, 93042 Regensburg, Germany

- mean value 2.5 mg/cm^2
- animal model
- single pigment (P.R. 22)
- Data gaps regarding human skin and other pigments

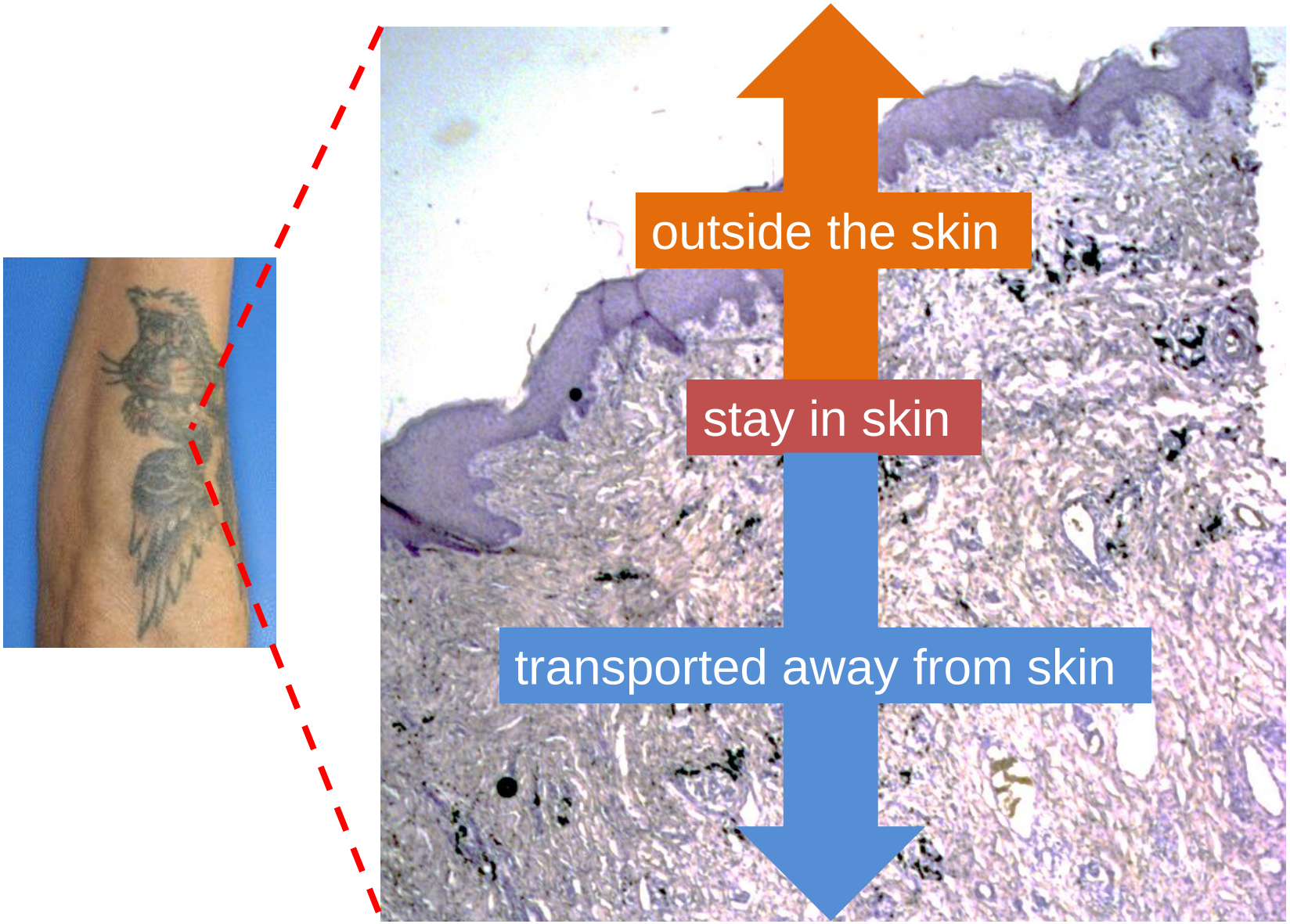
Human skin

1 day after

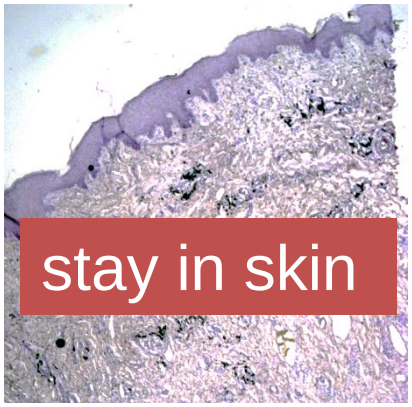




Transportation processes



Transportation processes



Transportation processes

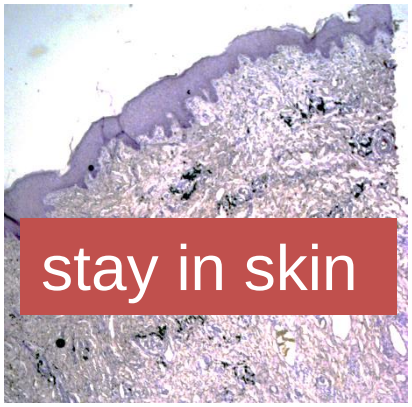
possible modes of action in skin

data gaps…

compounds in ink suspension	mechanism	cell type
solid pigment particle (> 500 nm) other insoluble compounds (> 500 nm) microorganisms	phagocytosis	macrophages dendritic cells neutrophilic granulocytes
solvents and dissolved compounds maybe nano-particles	macro-pinocytosis	different cell types
small pigment particles (< 120 nm) other, insoluble compounds (< 120 nm) organic compounds bio-molecules	clathrin- and caveolae-endocytosis (potentially assisted by protein marking)	different cell types

W. Bäumler, Handbuch der Umweltmedizin, Ed. Wichmann, Fromme, 2020

Transportation processes



2018, 215(4):1115-1133.

JEM Journal of Experimental Medicine

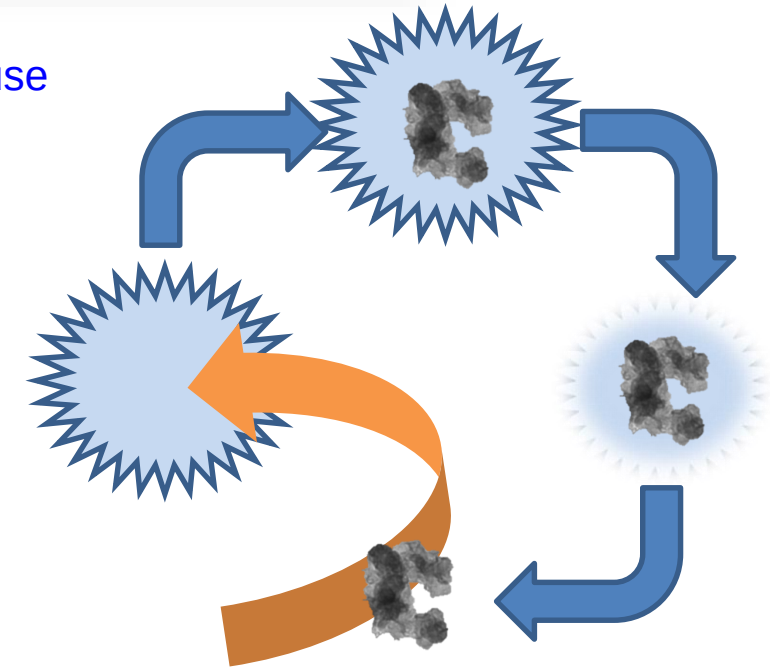
ARTICLE

Unveiling skin macrophage dynamics explains both tattoo persistence and strenuous removal

Anna Baranska[1], Alaa Shawket[1*], Mabel Jouve[3*], Myriam Baratin[1*], Camille Malosse[1], Odessa Voluzan[1], Thien-Phong Vu Manh[1], Frédéric Fiore[2], Marc Bajénoff[1], Philippe Benaroch[4], Marc Dalod[1], Marie Malissen[1,2], Sandrine Henri[1**], and Bernard Malissen[1,2**]

A model for long-term tattoo persistence is proposed (mouse model)

- pigment capture–release–recapture model
- such dermal macrophages do not have the capacity to migrate to draining lymph nodes
- that ensures the macroscopic stability and long-term persistence of tattoos
- however, whether the pigment capture–release–recapture model of tattoo persistence applies to humans remains to be determined



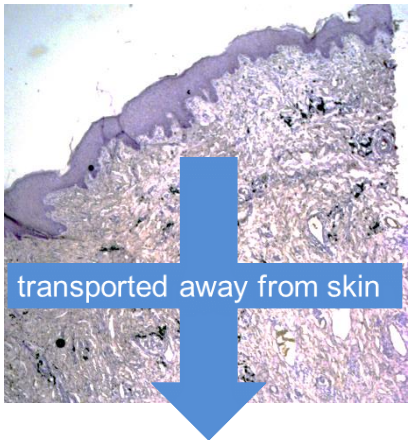
Transportation processes

Foreign material: after deposition in skin

- transportation to lymph nodes, liver, kidney, …
- possibly excretion
- large data gaps

Pubmed data search, November 2021:

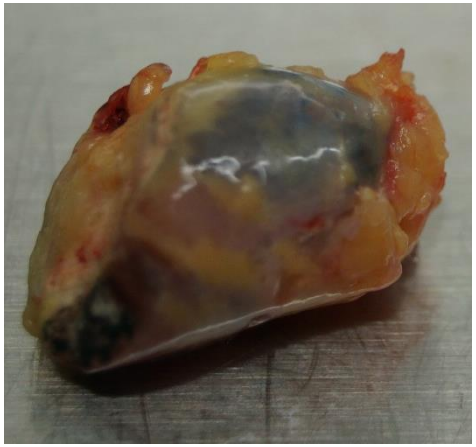
search expression	papers found
1. tattoo skin	2010
2. tattoo lymph node	183 (mostly clinical presentation of pigments in lymph nodes)
3. tattoo liver	197 (mostly surveys/studies to find association of tattooing with hepatitis)
4. tattoo ink liver	4
5. tattoo ink kidney	2
6. other organs	?



Transportation processes

skin and lymph node samples from Institute of Forensic Medicine, LMU Munich, Germany

green tattooed skin sample



Transportation processes

lymph node samples from Institute of Forensic Medicine, LMU Munich, Germany

OPEN ACCESS Freely available online

PLOS ONE

Black Tattoos Entail Substantial Uptake of Genotoxicpolycyclic Aromatic Hydrocarbons (PAH) in Human Skin and Regional Lymph Nodes

Karin Lehner[1], Francesco Santarelli[1], Rudolf Vasold[2], Randolph Penning[3], Alexis Sidoroff[4], Burkhard König[2], Michael Landthaler[1], Wolfgang Bäumler[1]*

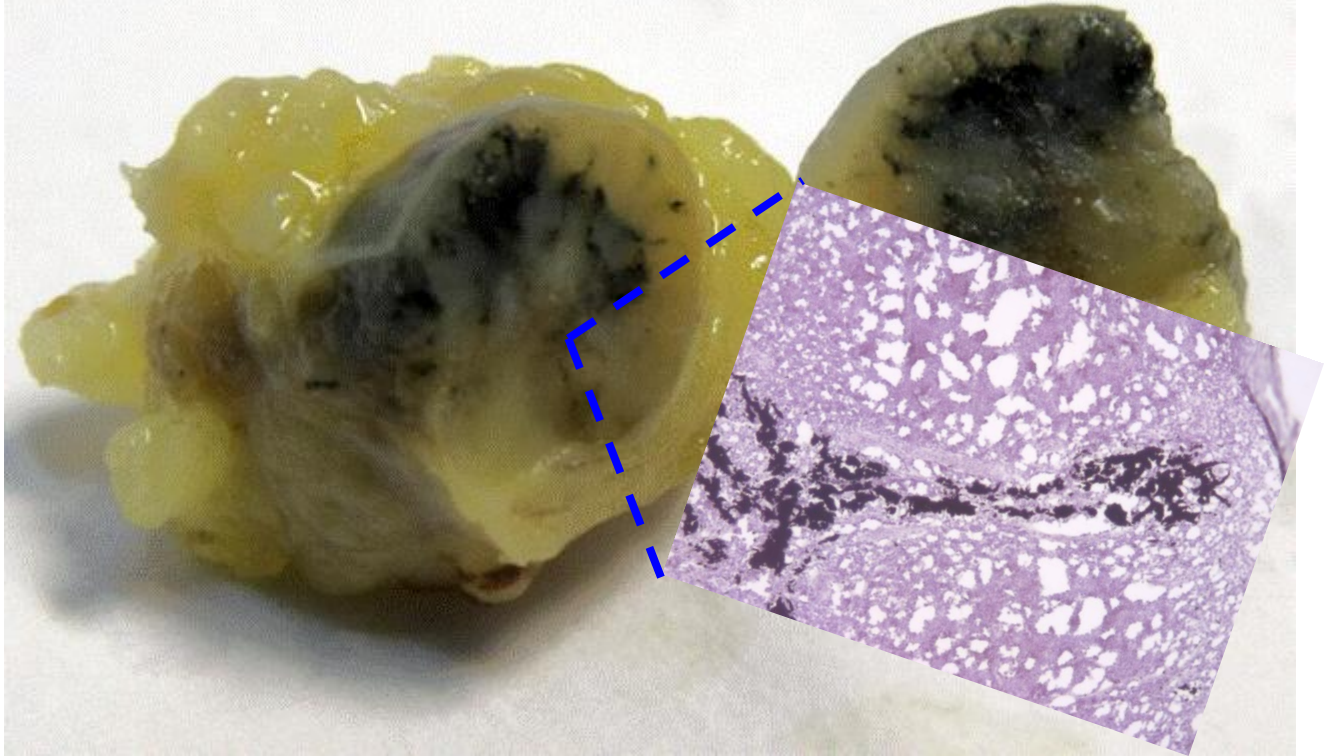
1 Department of Dermatology, University of Regensburg, Regensburg, Germany, 2 Department of Organic Chemistry, University of Regensburg, Regensburg, Germany, 3 Department of Forensic Medicine, Ludwig Maximilian University, Munich, Germany, 4 Department of Dermatology and Venereology, University of Innsbruck, Innsbruck, Austria

function of lymph nodes handicapped ?

data gaps…

loco-regional lymph nodes

- Carbon Black: up to 17 mg/g
- PAH: up to 12 µg/g



Transportation processes

Tattoo and Body Art / Original Paper

Dermatology

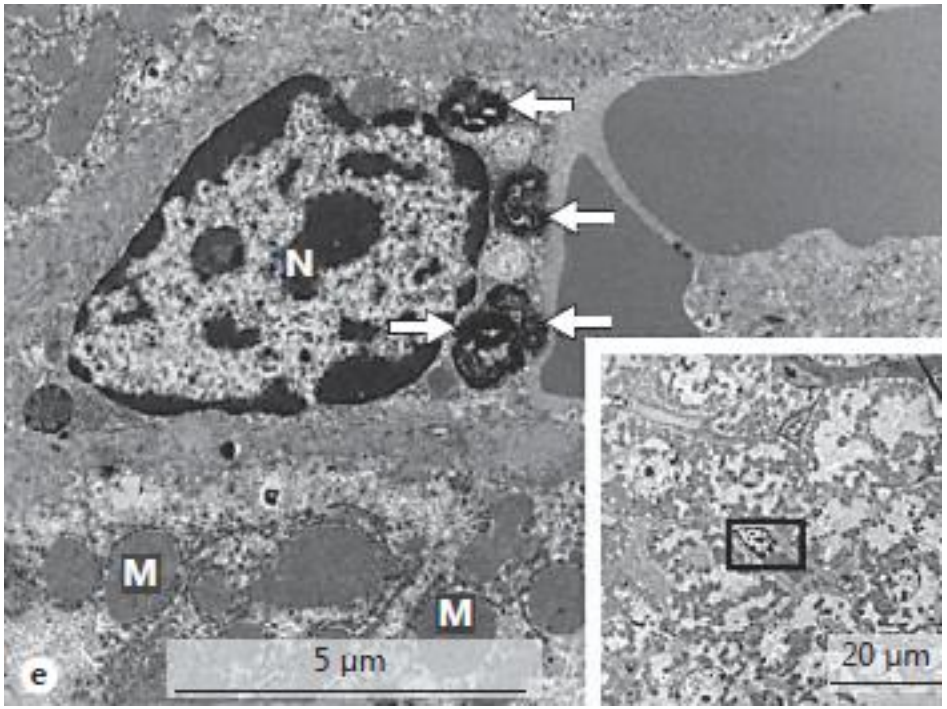
Dermatology 2017;233:86–93
DOI: 10.1159/000468149

Tattoo Pigments Are Observed in the Kupffer Cells of the Liver Indicating Blood-Borne Distribution of Tattoo Ink

Mitra Sepehri[a, b] Tobias Sejersen[c] Klaus Qvortrup[c] Catharina M. Lerche[b] Jørgen Serup[b]

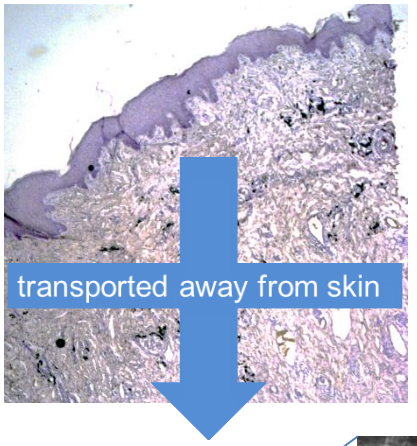
function of liver handicapped ?

data gaps…

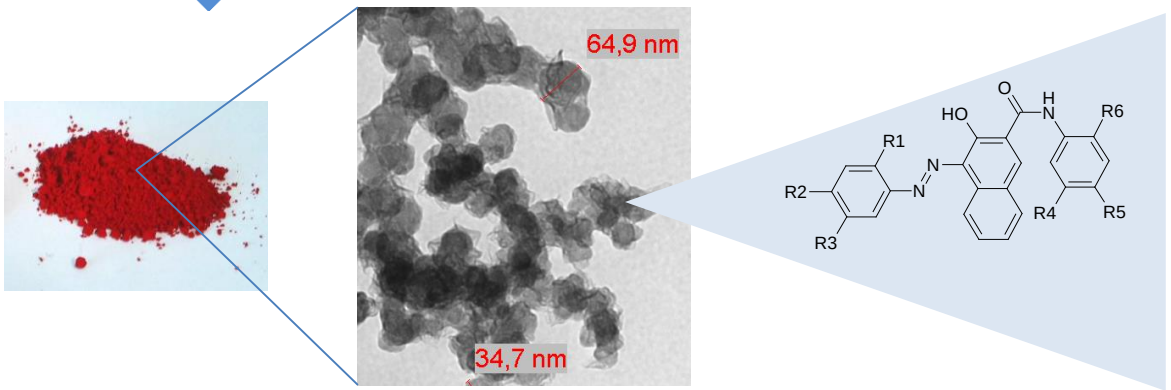


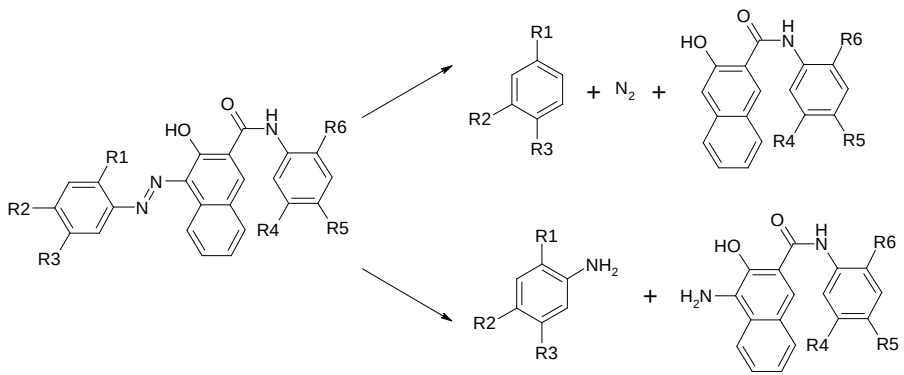
e) Red tattoo, Kupffer cell in the liver. White arrows, pigment deposits; N, nucleus; M, mitochondrium.

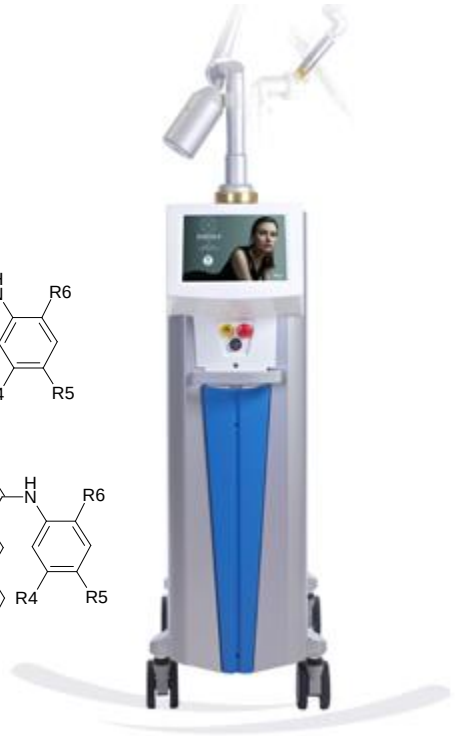
Transportation processes – UV and laser

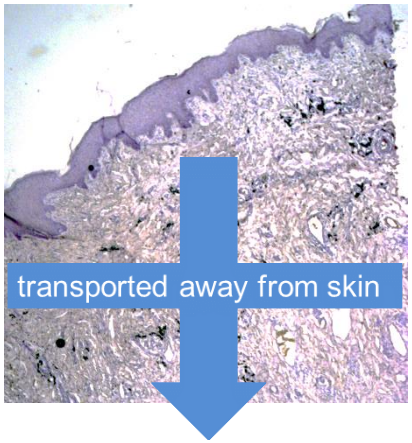


- UV radiation — decomposition of pigment molecules
- laser light — pigment particle fragmentation and decomposition of pigment molecules



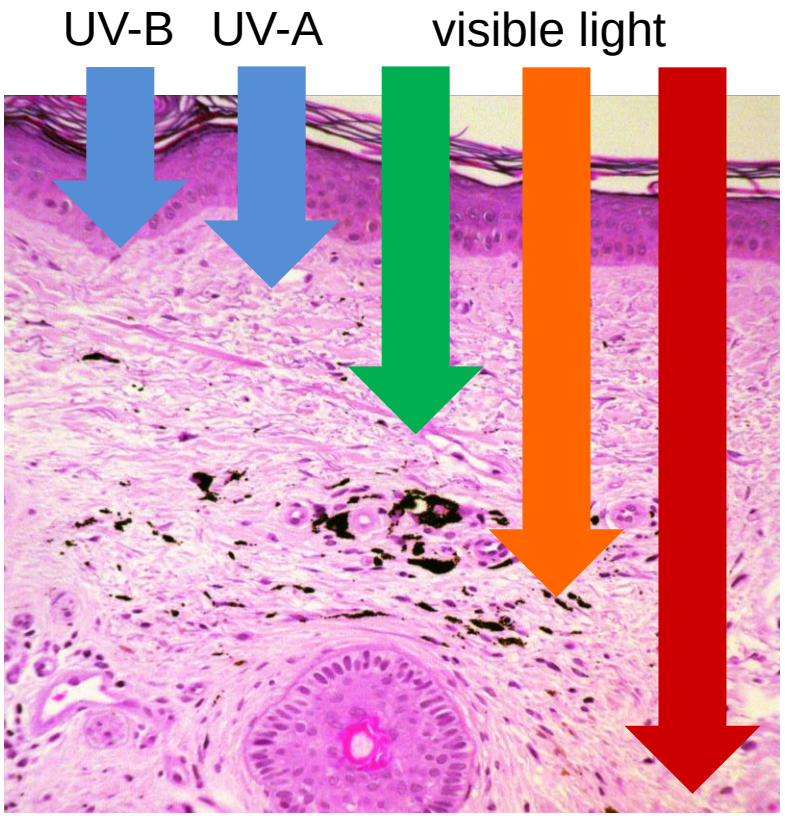






Transportation processes – UV and laser

- after a few weeks of tattooing, only tattoo pigments should be left behind in the skin
- to allow interaction with pigments, UV radiation or laser light, must **reach** the pigments inside skin



scattering and **absorption** of light in skin

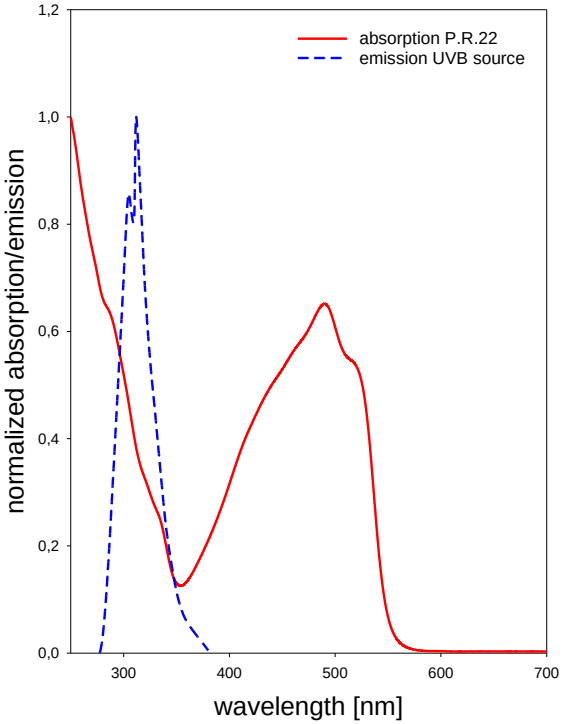
- limit the penetration depth
- light **absorption** depends on the wavelength
- light **scattering** strongly depends on the wavelength

UV radiation and tattooed skin

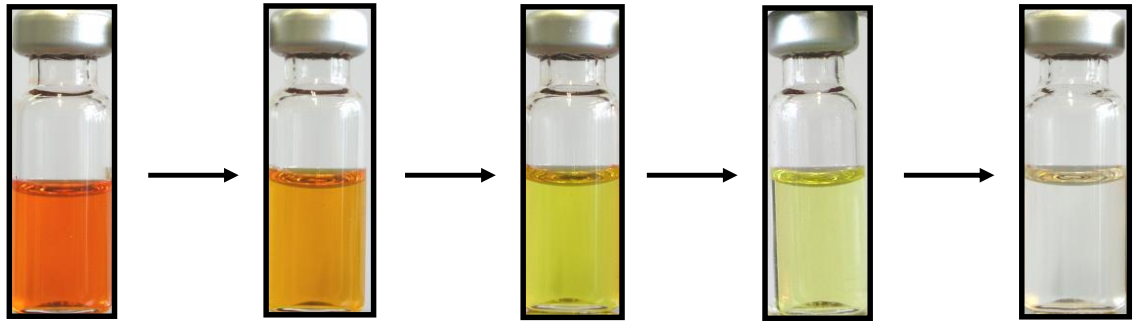
Photochemical cleavage of a tattoo pigment by UVB radiation or natural sunlight

Eva Engel[2], Andrea Spannberger[2], Rudolf Vasold[2], Burkhard König[2], Michael Landthaler[1], Wolfgang Bäumler[1]
(1) Department of Dermatology, University of Regensburg, Germany
(2) Institute of Organic Chemistry, University of Regensburg, Germany

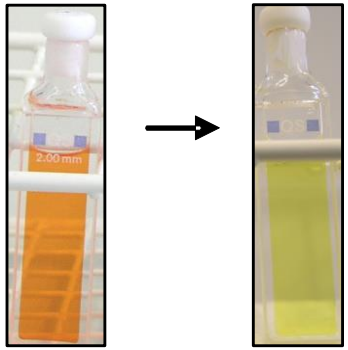
JDDG; 2007 · 5:583–589 Submitted: 6.12.2006 | Accepted: 30.1.2007



solar radiation for 110 days



UV-B radiation (308 nm), 150 min



UV radiation and tattooed skin

Photodynamic effects of tattoo inks

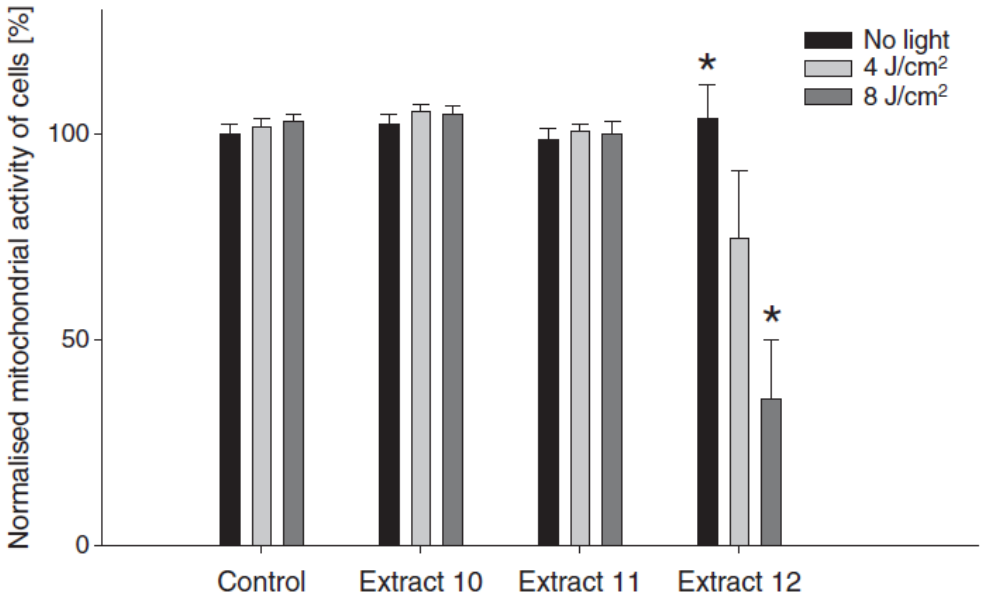
DOI:10.1111/j.1600-0625.2010.01068.x
www.blackwellpublishing.com/EXD

Original Article

Tattoo inks contain polycyclic aromatic hydrocarbons that additionally generate deleterious singlet oxygen

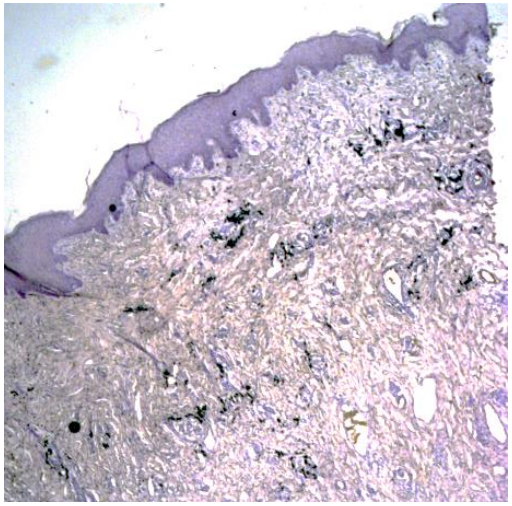
Johannes Regensburger[1*], Karin Lehner[1*], Tim Maisch[1], Rudolf Vasold[2], Francesco Santarelli[1], Eva Engel[2], Anita Gollmer[1], Burkhard König[2], Michael Landthaler[1] and Wolfgang Bäumler[1]

PAH: singlet oxygen quantum yield 18 to 85 %



Tattoo Removal – laser radiation and tattooed skin

Laser treatment can be described by selective photothermolysis using appropriate laser parameters: wavelength, energy and pulse duration

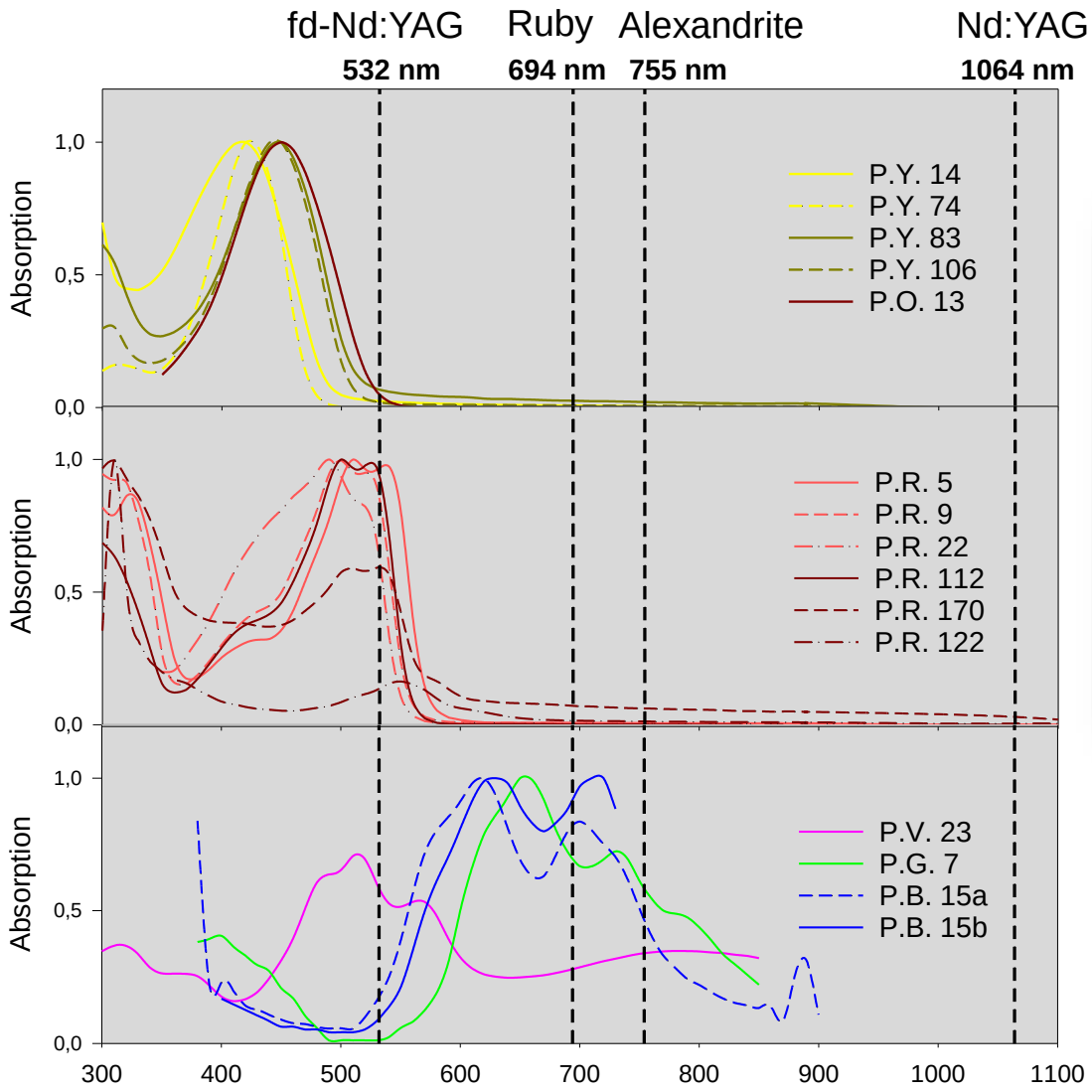


Basic model

- the laser light should be absorbed in the pigment molecule
- the applied energy is sufficient to fragment the pigment particles
- the pulse duration is short and the thermal effect is limited to the pigment particles (minimized collateral damage)

Tattoo Removal – laser radiation and tattooed skin

Laser treatment can be described by selective photothermolysis using appropriate laser parameters: wavelength, energy and pulse duration



Bäumler W et al, Lasers Surg Med. 2000;26(1):13-21.

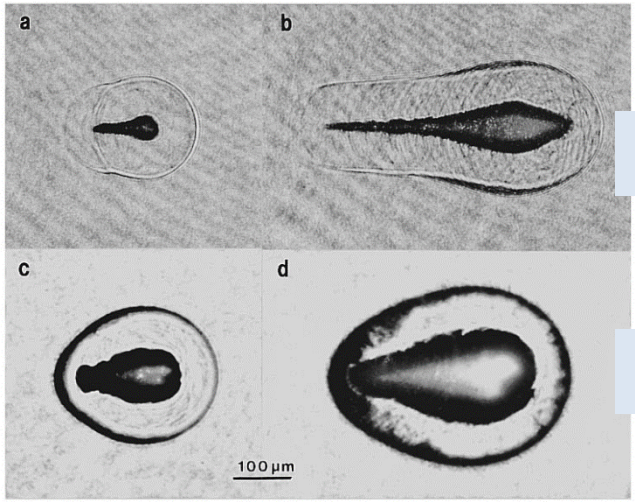
Tattoo Removal – laser radiation and tattooed skin

Laser treatment can be described by selective photothermolysis using appropriate laser parameters: wavelength, energy and pulse duration

Extended model

Nano- and Picoseconds and high light intensities provoke optical and thermal, non-linear effects

- plasma formation (optical breakdown)
- strong heating up of the plasma (up to 20000 °C, up to 60 bar) generating a shock wave (up to 2500 m/s)
- shock waves in fluid/tissue generates cavitation bubbles
- cavitation spots in skin and/or fragmentation of pigment particles in immediate vicinity of shock waves

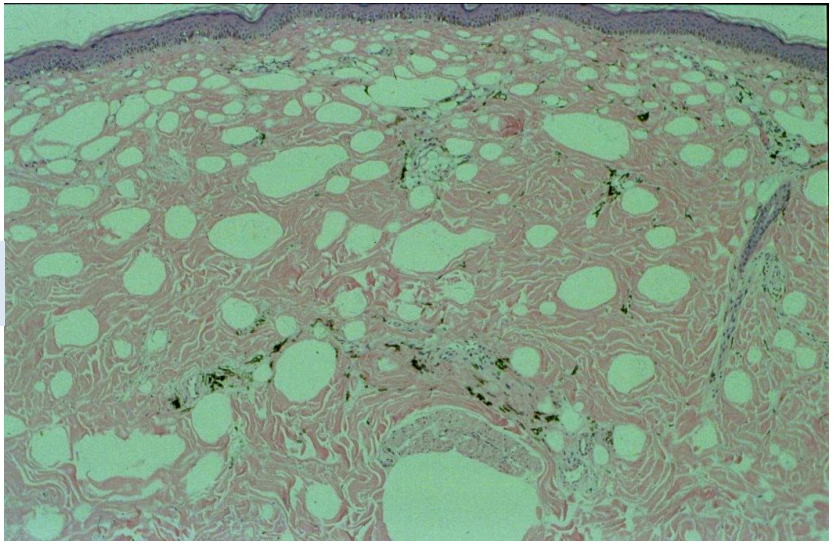


Picoseconds

Nanoseconds

ophthalmology

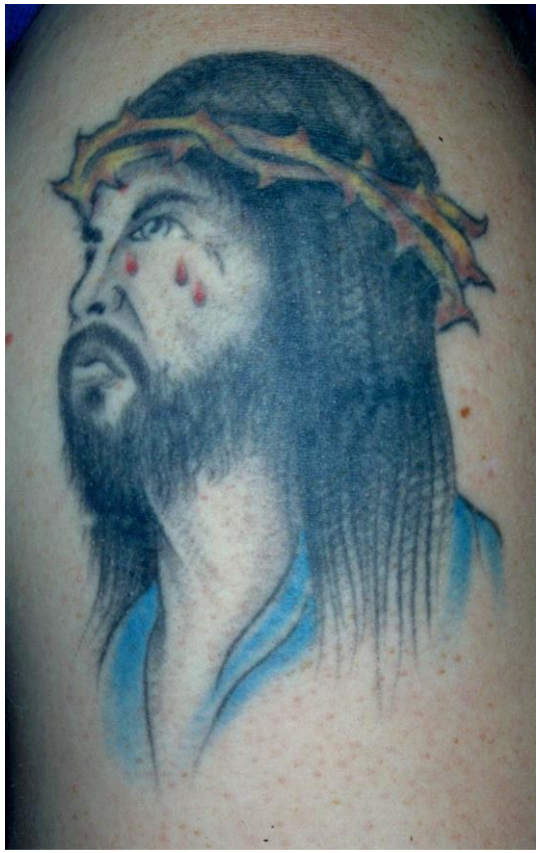
Histology of tattooed skin
5 minutes after laser impact



Vogel et al, The Journal of the Acoustical Society of America 100, 148 (1996);

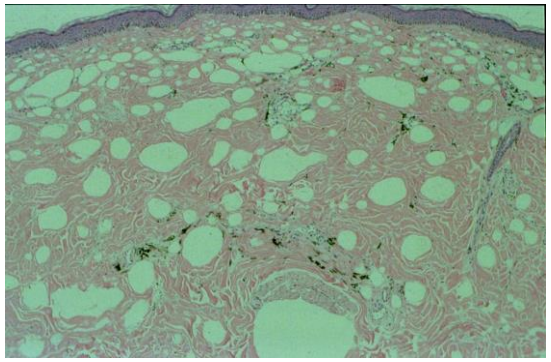
Tattoo Removal – laser radiation and tattooed skin

pigment particle fragmentation and decomposition of pigment molecules



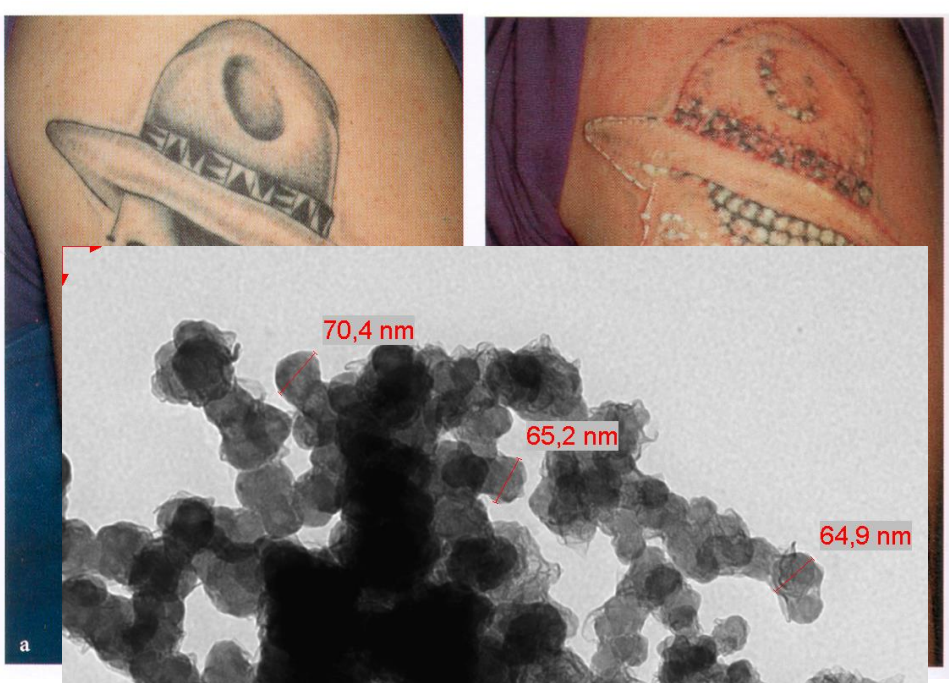
before laser therapy

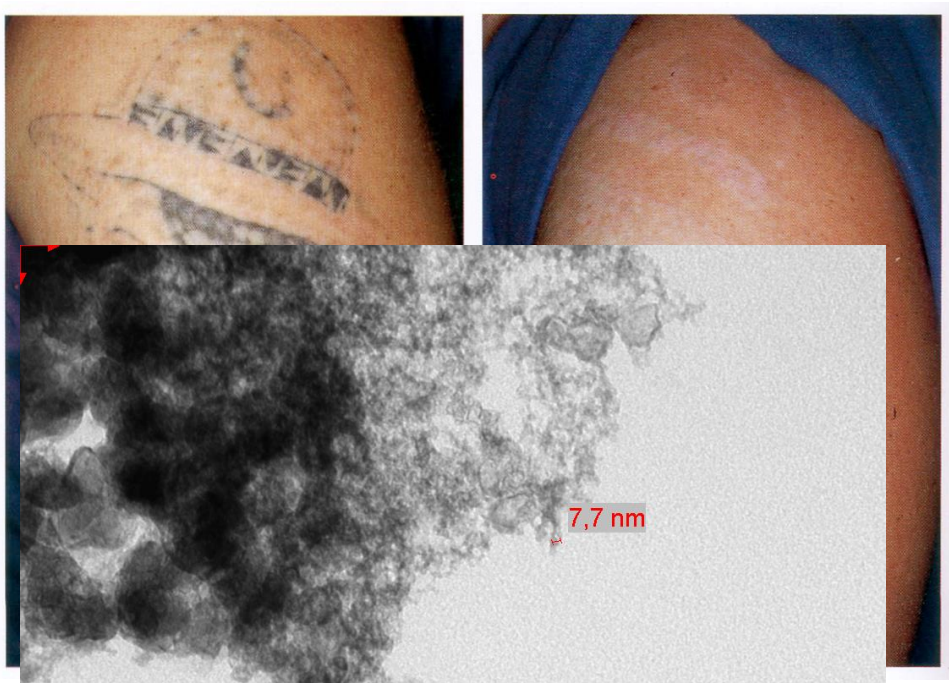
5 min
after laser therapy



Tattoo Removal – laser radiation and tattooed skin

pigment particle fragmentation and decomposition of pigment molecules





QS-Nd:YAG, 532 nm, 10 ns

Tattoo Removal – laser radiation and tattooed skin

pigment particle fragmentation and decomposition of pigment molecules

… a lot of energy to initiate changes of the pigment molecules

DOI: 10.1111/jdv.17674 JEADV

2021

ORIGINAL ARTICLE

The efficacy and the adverse reactions of laser-assisted tattoo removal – a prospective split study using nanosecond and picosecond lasers

W. Bäumler, C. Breu, B. Philipp, B. Haslböck, M. Berneburg, K.T. Weiß

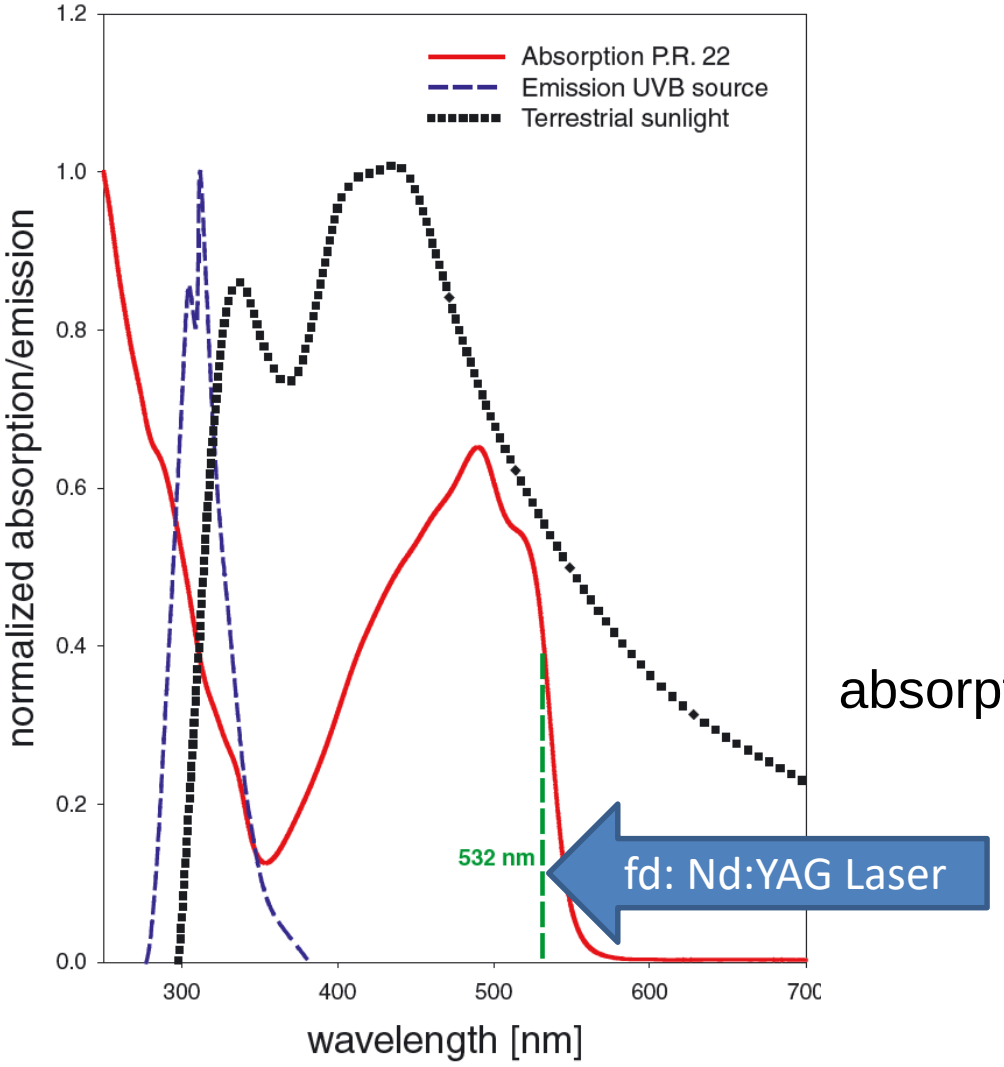
Department of Dermatology, University of Regensburg, Regensburg, Germany

*Correspondence: W. Bäumler. E-mail: wolfgang.baeumler@ukr.de

before laser treatment | 2 days after laser treatment | after final laser treatment

Tattoo Removal – laser radiation and tattooed skin

pigment particle fragmentation and decomposition of pigment molecules



absorption of laser light

Tattoo Removal – laser radiation and tattooed skin

… a lot of energy to decompose pigment molecules

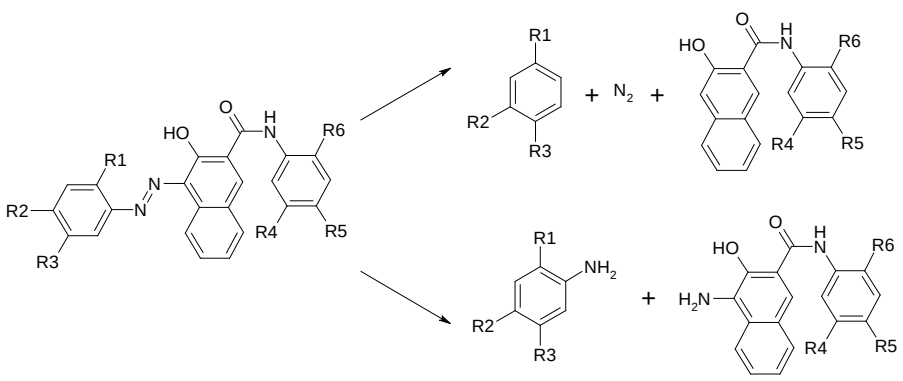
Photochemistry and Photobiology, 2004, 80: 185–190

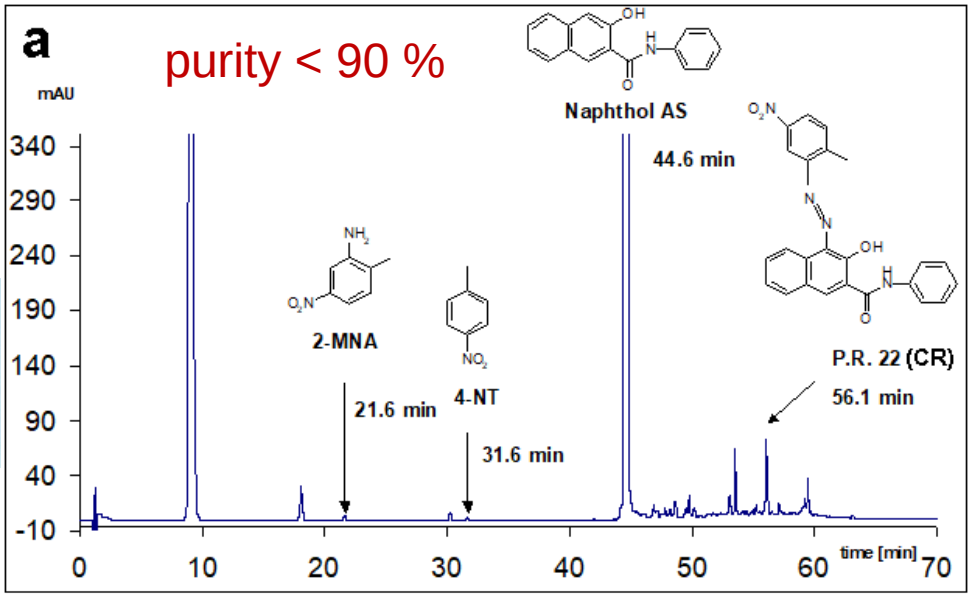
Tattoo Pigments are Cleaved by Laser Light—The Chemical Analysis *In Vitro* Provide Evidence for Hazardous Compounds[¶]

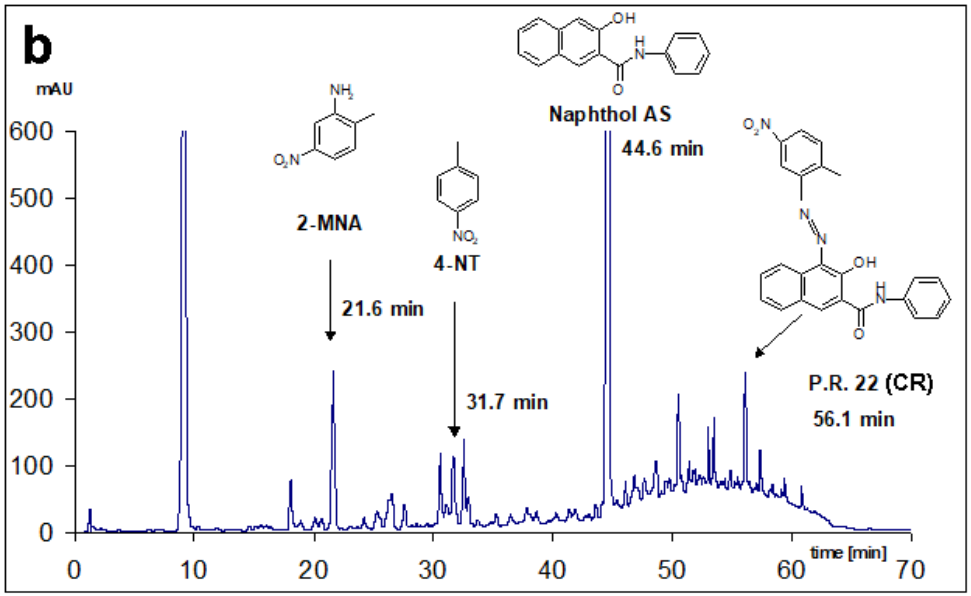
Rudolf Vasold[1], Natascha Naarmann[1], Heidi Ulrich[2], Daniela Fischer[1], Burkhard König*[1], Michael Landthaler[2] and Wolfgang Bäumler*[2]

[1]Department of Organic Chemistry, University of Regensburg, Germany
[2]Department of Dermatology, University of Regensburg, Germany

red pigments (PR 9, PR 22)
decomposed by laser light







Tattoo Removal – laser radiation and tattooed skin

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toxic or carcinogenic substances

	PR 22	**PR 22**	PR 9	**PR 9**
	before irradiation	**after irradiation**	before irradiation	**after irradiation**
		µg/ml		
2-methyl-5-nitroaniline	1.6 ± 0.3	**53.1 ± 10.1**		
4-nitrotoluene	1.0 ± 0.2	**44.7 ± 8.2**		
2-5-dichloroaniline			11.8 ± 0.3	**79,6 ± 1,4**
1-4-dichlorobenzene			< 0.5	**32.6 ± 0.4**

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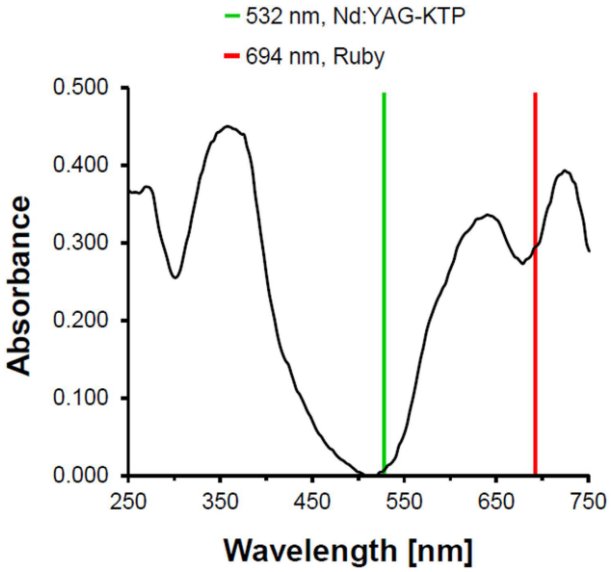
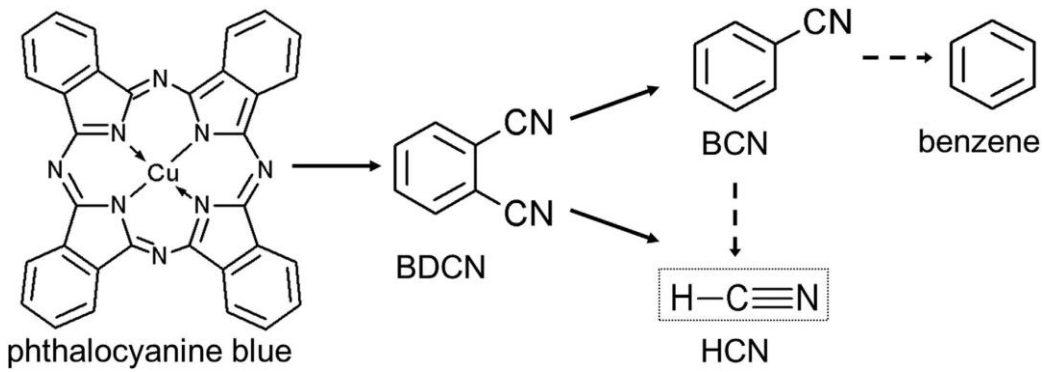
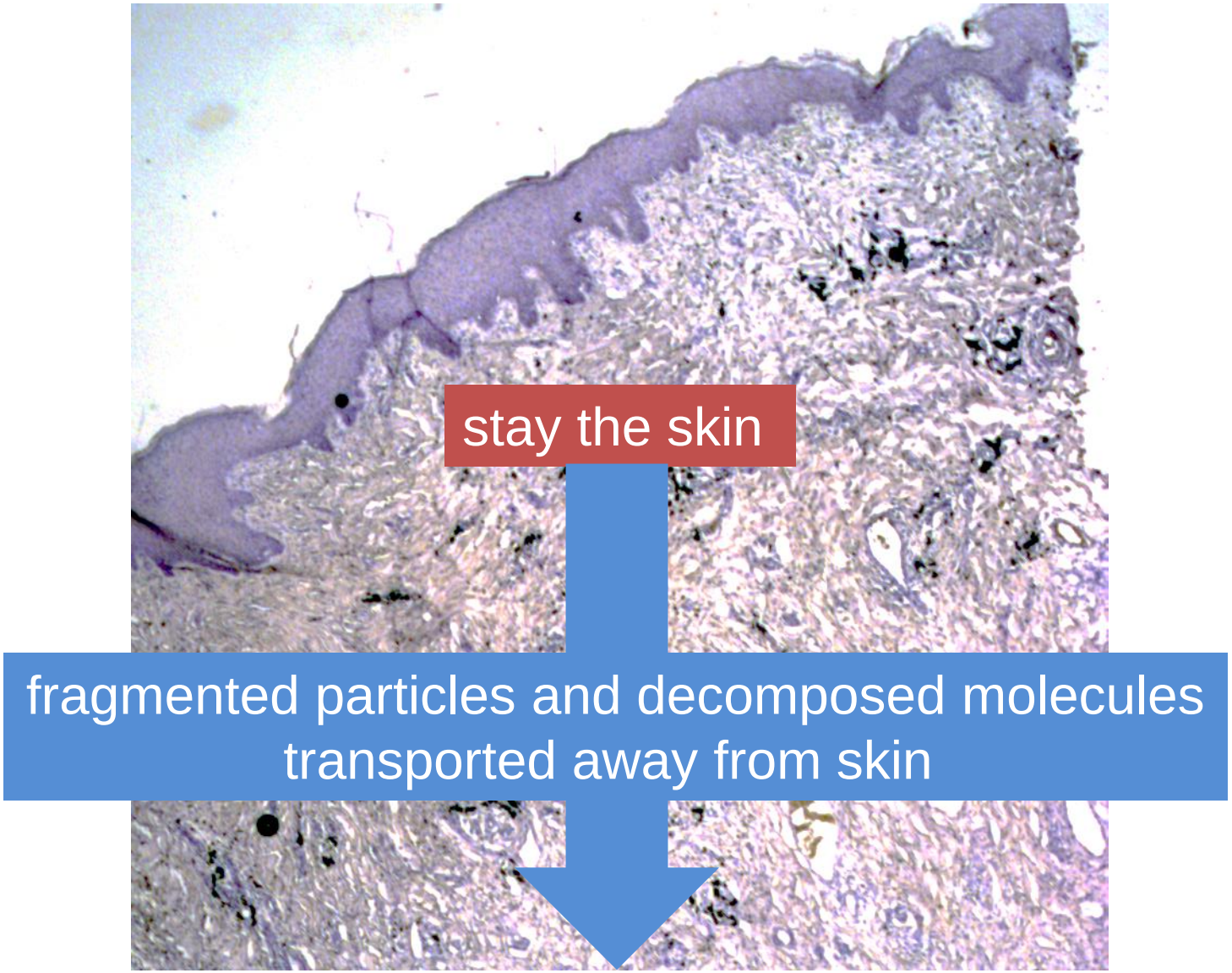
Formation of highly toxic hydrogen cyanide upon ruby laser irradiation of the tattoo pigment phthalocyanine blue

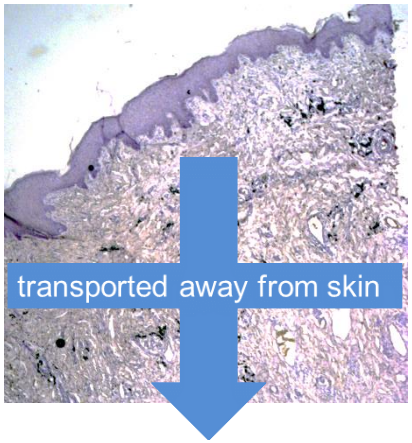
Ines Schreiver[1], Christoph Hutzler[1], Peter Laux[1], Hans-Peter Berlien[2] & Andreas Luch[1]





Transportation processes – UV and laser





Transportation processes – UV and laser

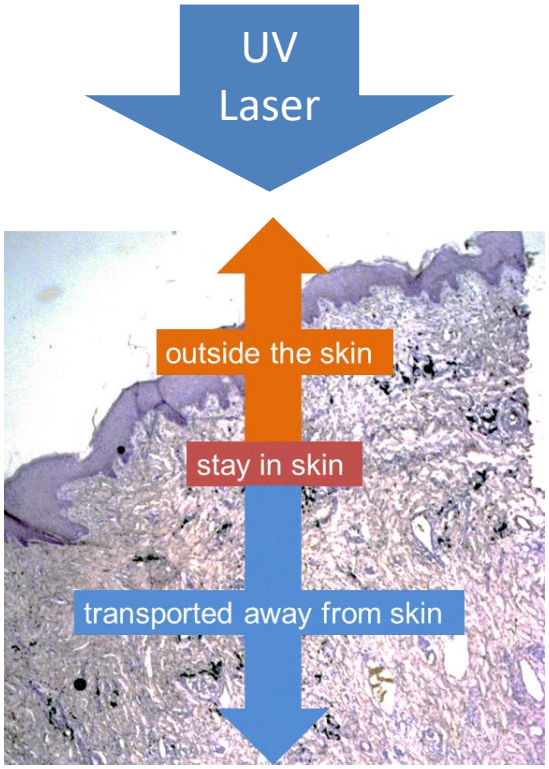
After deposition in skin and fragmentation/decomposition

- transportation to lymph nodes, liver, kidney, …
- excretion
- large data gaps…

Pubmed data search, November 2021:

search expression	papers found
1. tattoo skin	2010
2. tattoo lymph node	183
3. tattoo liver	197
4. tattoo ink liver	4
5. tattoo ink kidney	2
6. tattoo inks transportation	**?**
7. decomposition products (laser, UV)	**?**

Conclusions



large data gaps, need for scientific investigations

- concentration of different tattoo inks in human skin
- amount of secreted inks directly after tattooing
- wound healing after tattooing
- UV and Laser: fragmentation and decomposition
- transportation of tattoo inks
- transportation of fragmented and decomposed substances
- tattoo ink in other organs
- role of ink in other organs
- risk calculations for potential systemic adverse effects
- **epidemiological studies on possible health effects**

Conclusions

More data allows a better risk evaluation

- human skin
- other organs

Stand alone regulation for tattoos

(not only a simple ban of more than 4000 chemical compounds, REACH)

that includes*

- non-substitutable pigments
- effective and safe preservatives
- a selection of auxiliary compounds
- avoidance of other impurities (e.g. from industrial pigments)
- sterility and correct labeling of ink products

* Giulbudagian et al, Archives of Toxicology (2020) 94:357–369