In Silico Assessment of Tanning Masking Effects on Skin Chromatic Attributes Elicited by Anemia and Hyperbilirubinemia

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Outline

- Introduction
- Investigation Framework
- Results and Discussion
- Conclusion

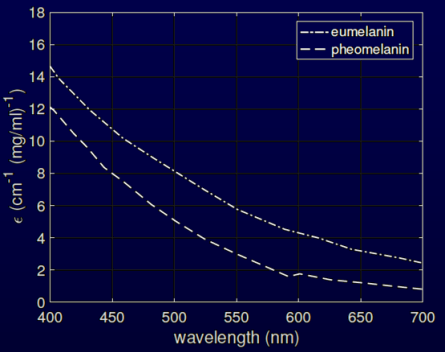
Introduction

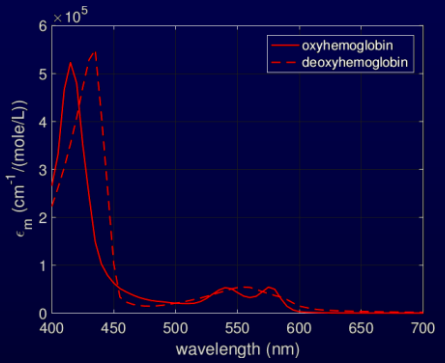
➢ Motivation

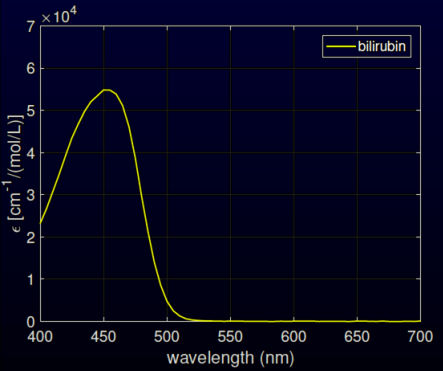
- Anemia and hyperbilirubinemia are pervasive medical conditions that affect the health of individuals of all ages, genders and ethinicities worldwide
- Skin appearance changes are among their most recognizable symptoms
- The correct assessment of these changes plays a pivotal role in the early detection and positive outcome of these conditions
- Investigations on how tanning-elicited variations in skin chromatic attributes can mask these symptoms have not as yet been reported in the literature

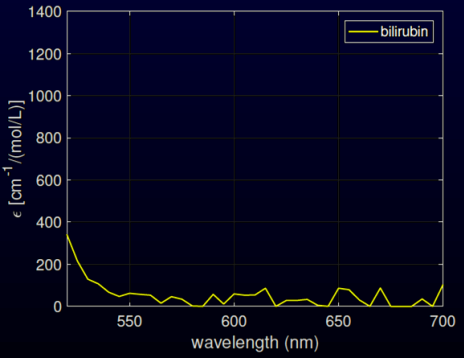
Background

Absorption Spectra of Pigments found in the Cutaneous Tissues







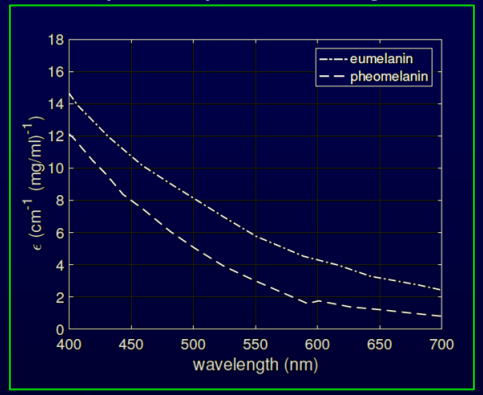


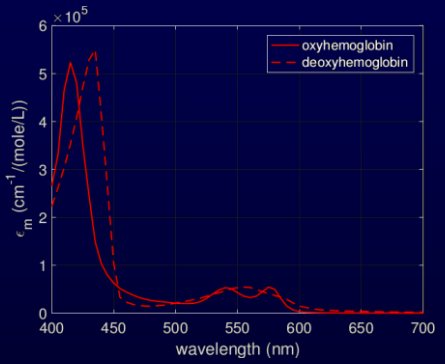
Cutaneous Tissues

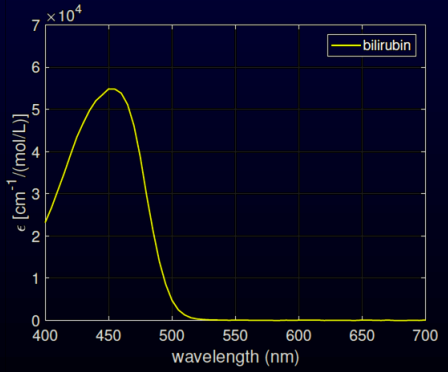
	Stratum corneum
Epidermis	Stratum granulosum
	Stratum spinosum
	Stratum basale
Dermis	Papillary dermis
	Reticular dermis

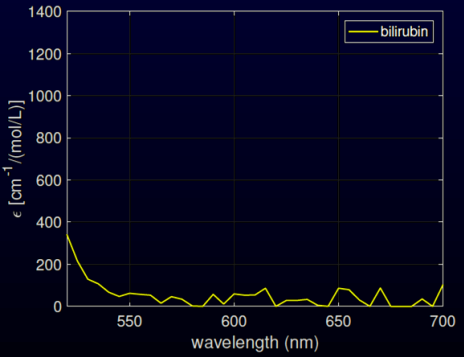
➢ Background

Absorption Spectra of Pigments found in the Cutaneous Tissues









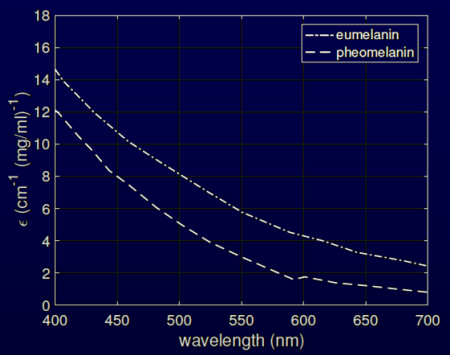
Tanning ➔ increased melanin presence

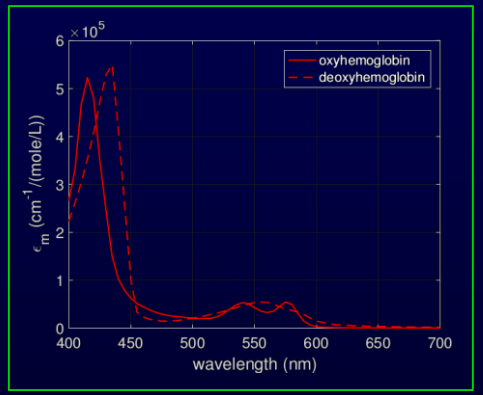
constitutive pigmentation

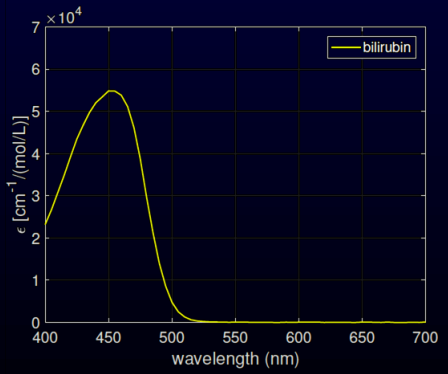
facultative pigmentation

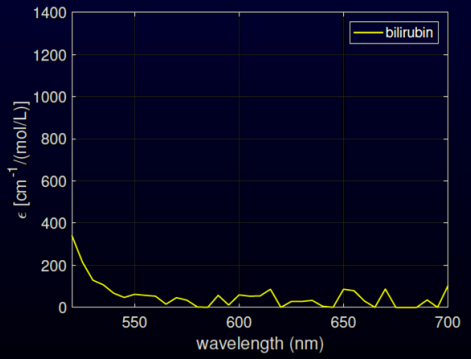
➢ Background

Absorption Spectra of Pigments found in the Cutaneous Tissues

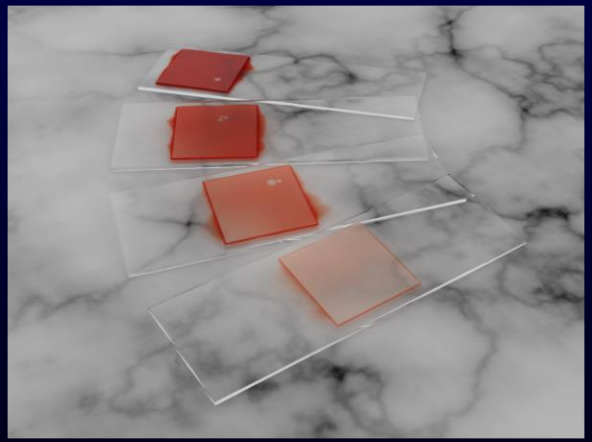








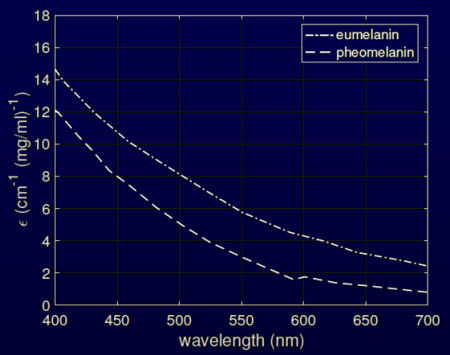
Anemia ➔ reduced red blood cell count

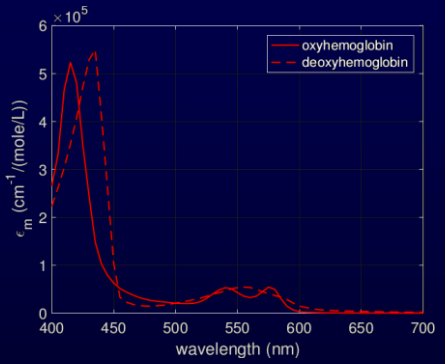


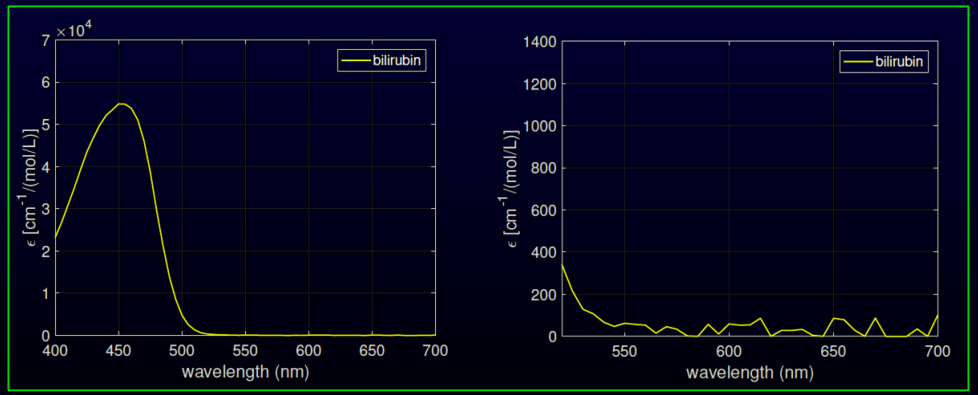
lower hemoglobin contents ➔ paleness

➢ Background

Absorption Spectra of Pigments found in the Cutaneous Tissues







Hyperbilirubinemia ➔ excessive bilirubin presence

yellow-tinted appearance (janudice)

➢ Challenges

- Intrinsic limitations of traditional “wet” laboratory procedures
  - simultaneous reduction in hemoglobin concentration and increase in bilirubin concentration may be problematic to be achieved/controlled
  - synchronization of those variations with a tanning process may be even more difficult to be achieved/controlled
- Possible risks to a subject’s health, which can be further exacerbated by overexposure to ultraviolet radiation triggering a tanning process

➢ Objectives

- Systematically assess the masking effects of tanning on skin chromatic changes caused by anemia and hyperbilirubiemia, occurring separately or simultaneously

- Contribute to the mitigation of the knowledge gap in this area

➢ Approach

- Controlled *in silico* experiments conducted using a first-principles hyperspectral model of light interactions with human skin: HyLIoS (Chen & Baranoski, 2015)

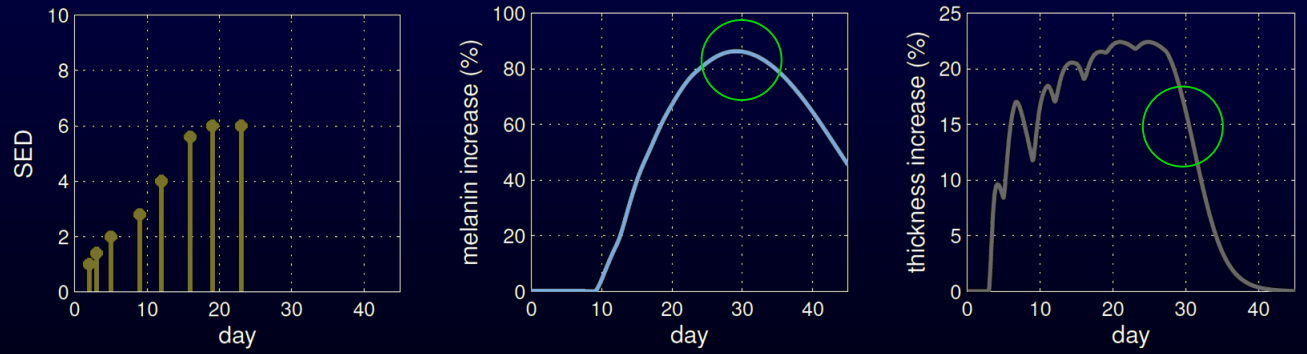
http://www.npsg.uwaterloo.ca/resources/videos/hylios.mp4

Investigation Framework

➢ Materials

- We considered the untanned (baseline) and tanned states of a lightly-pigmented specimen with a moderate tanning ability
  - for the tanning data, we sampled the variables at their peak (day 30)

1 SED = 100 J/m^2 at 298 *nm*



http://www.npsg.uwaterloo.ca/resources/videos/tanning.mp4

- To characterize distinct anemia severity levels, we employed dermal hemoglobin concentration values reported in the literature

Level	Severity	Hemoglobin Concentration (g/L)
A0	baseline	147.0
A1	mild	117.6
A2	moderate	88.2
A3	severe	58.8

- Similarly, to characterize distinct hyperbilirubinemia toxicity stages, we employed cutaneous bilirubin concentration values also reported in the literature

Stage	Toxicity	Bilirubin Concentration (g/L)
H0	baseline	0.003
H1	significant	0.071
H2	excessive	0.161
H3	extreme	0.233

➢ Methodology

- We computed directional-hemispherical reflectance curves for the specimens using HyLIoS and considering an angle of incidence of 15 degrees

- We generated skin swatches through the convolution involving:
  - the CIE D50 illuminant's spectral power distribution
  - the modeled reflectance data
  - the human photoreceptors' spectral responses

- To enable the reproduction of our *in silico* experimental results, we provide the employed biophysical data and made HyLIoS available for online use

HyLIoS

Hyperspectral Light Impingement on Skin

(Extended Spectrometric Mode*)

The HyLIoS model uses a Monte Carlo formulation to simulate light interaction with human skin. Melanosomes are created and discarded on the fly as the light propagates through the skin tissue. The light rays can be scattered or absorbed by these organelles as well as other skin constituents. For more details about this model, please read our related publication (2015).

Note that HyLIoS provides bidirectional readings. However, one can obtain directional-hemispherical quantities (provided by our online system) by integrating the outgoing light (rays) with respect to the collection hemisphere. Similarly, bihemispherical quantities can be calculated by integrating the BSDF (Bidirectional Scattering Distribution Function) values with respect to incident and collection hemispheres.

Run HyLIoS Online

Enter your email address:
(used to send the results)

Model Parameter	Value
Number of samples	100000
Angle of incidence	8 degrees
Wavelength range	400-700 nm
Output Reflectance Data	☑
Output UV Absorptance Data	☐

Morphological Parameters

Aspect ratio of skin surface folds	0.1
Stratum corneum thickness	0.0004 cm
Stratum granulosum thickness	0.0033 cm

- We also computed CIELAB differences between pairs of swatches

$$\Delta E^*_{ab} = \sqrt{(L^*_1 - L^*_2)^2 + (a^*_1 - a^*_2)^2 + (b^*_1 - b^*_2)^2},$$

where:

L^*, a^* and b^* correspond to the CIE color space dimensions, and the subscripts 1 and 2 represent the compared swatches.

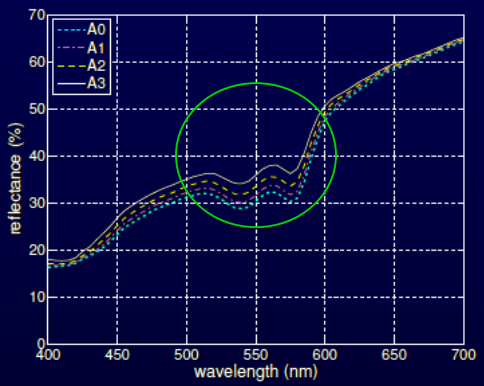
Perceptibility threshold: $\Delta E^*_{ab} < 2.3$

(Source: Mahy et al., 1994)

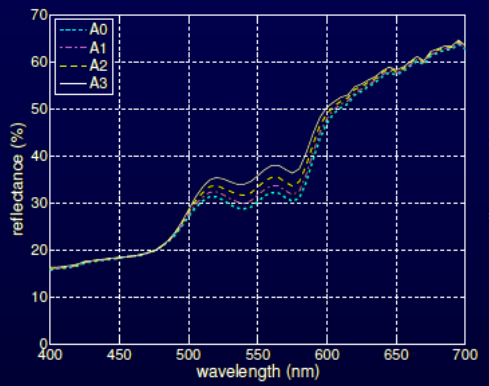
Results and Discussion

➢ Reflectance curves

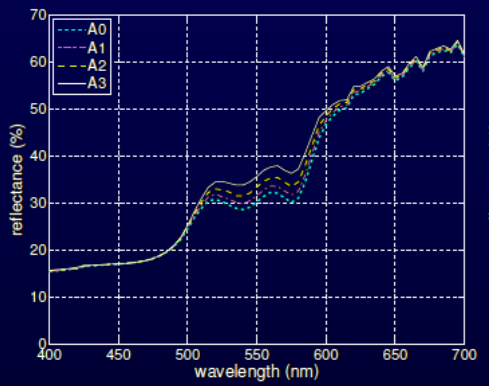
Specimen in its **Untanned** State



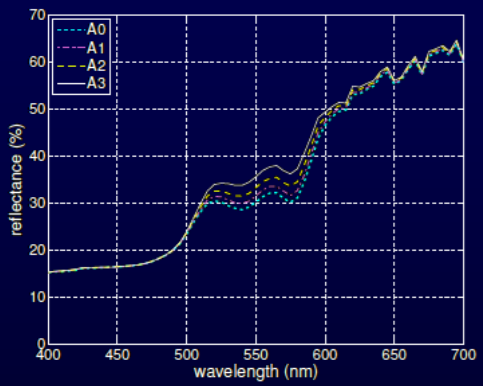
H0



H1



H3

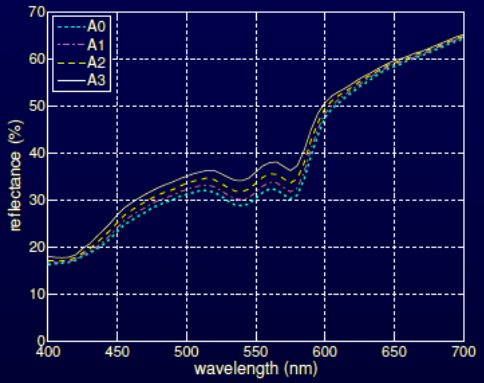


H4

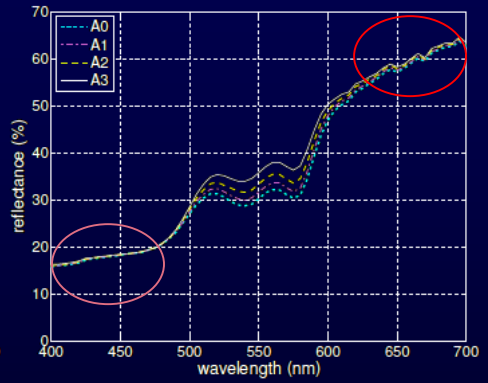
- For a normal bilirubin level (H0), the increase in anemia severity is accompanied by an overall reflectance increase, notably between 500-600 *nm*

➢ Reflectance curves

Specimen in its Untanned State



H0



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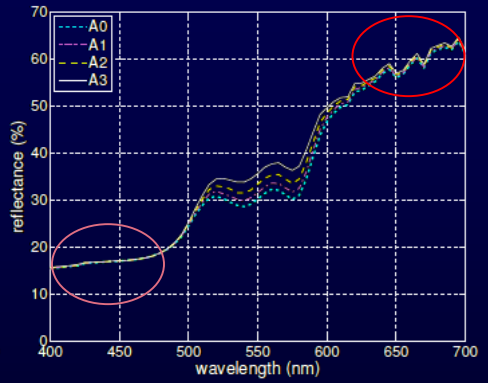
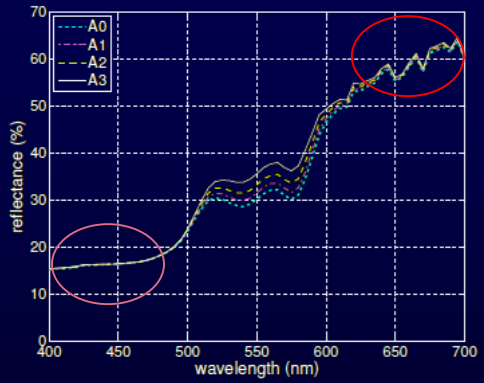


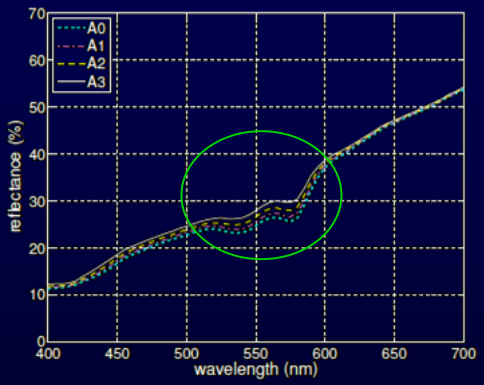
H3



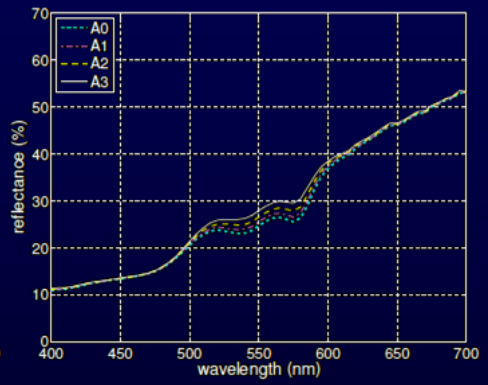
H4

- For a normal bilirubin level (H0), the increase in anemia severity is accompanied by an overall reflectance increase, notably between 500-600 *nm*
- Increase in hyperbilirubinema toxicity makes the reflectance increase negligible between 400-475 *nm*, and bilirubin-related dips in the 620-700 *nm* noticeable

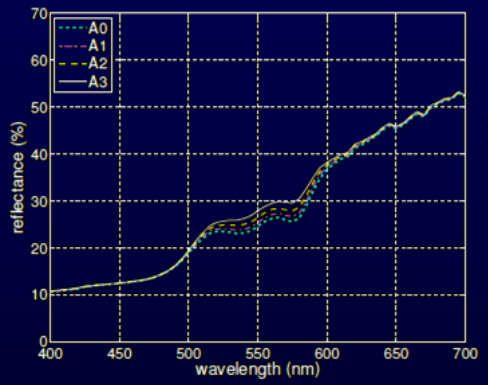
Specimen in its Tanned State



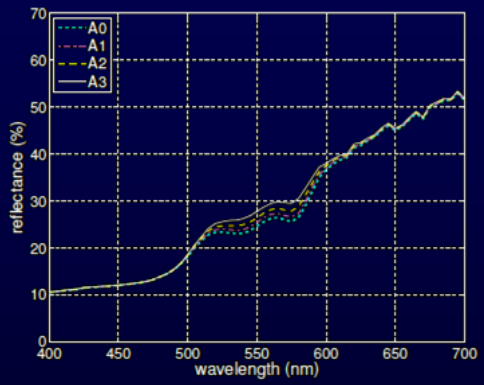
H0



H1



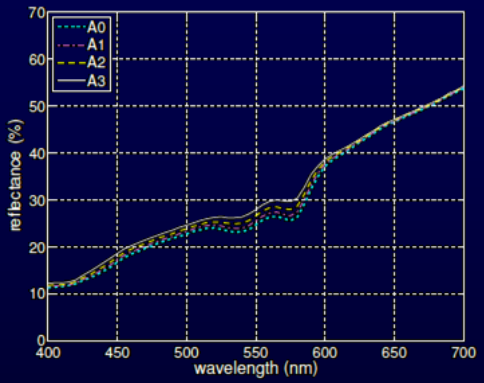
H3



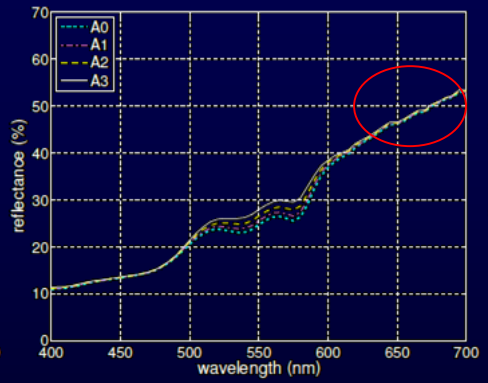
H4

- Reflectance curves are lower than those obtained by the untanned specimen
- Reflectance curves for distinct anemia severities are closer to each other

Specimen in its Tanned State



H0



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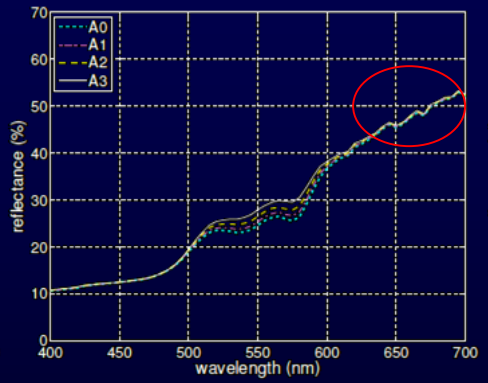
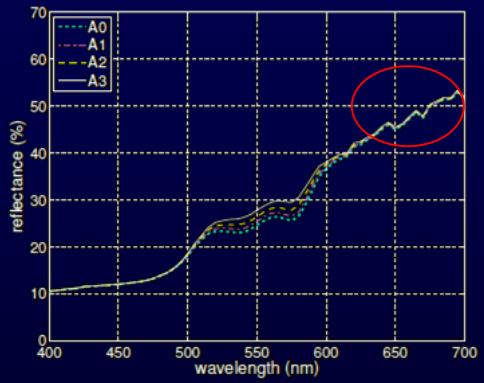


H3

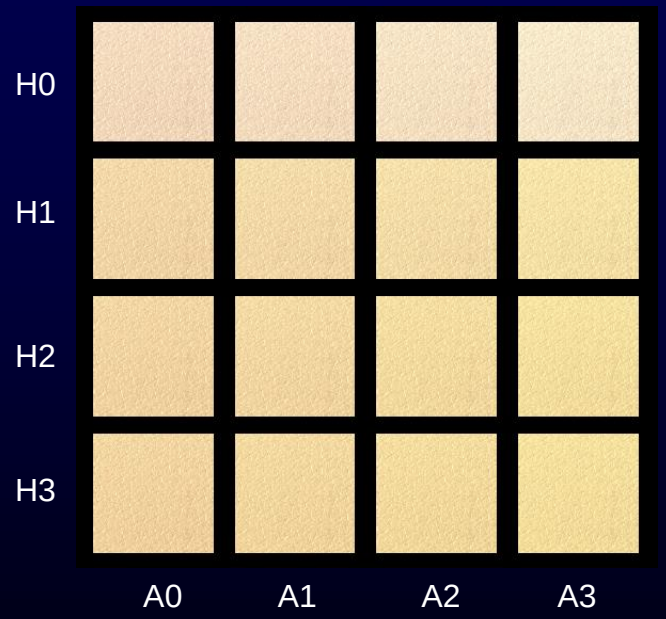


H4

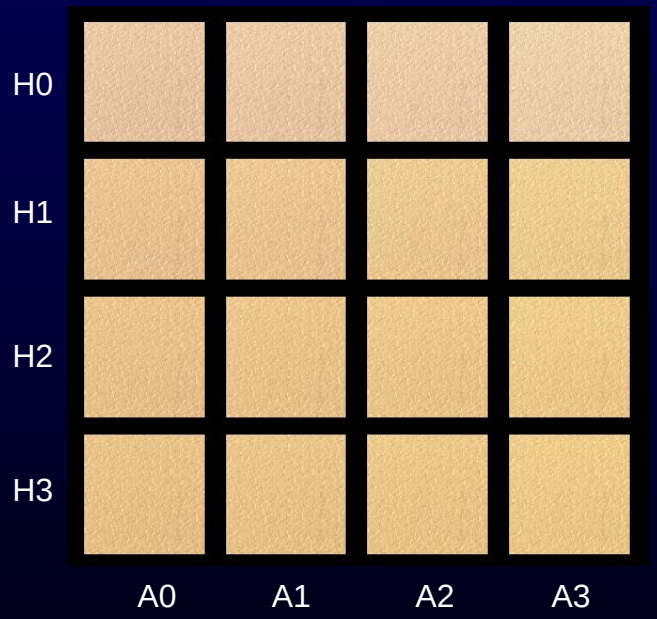
- Reflectance curves are lower than those obtained by the untanned specimen
- Reflectance curves for distinct anemia severities are closer to each other
- Bilirubin-related reflectance dips in the 620-700 *nm* region are less noticeable

Skin swatches

Untanned State

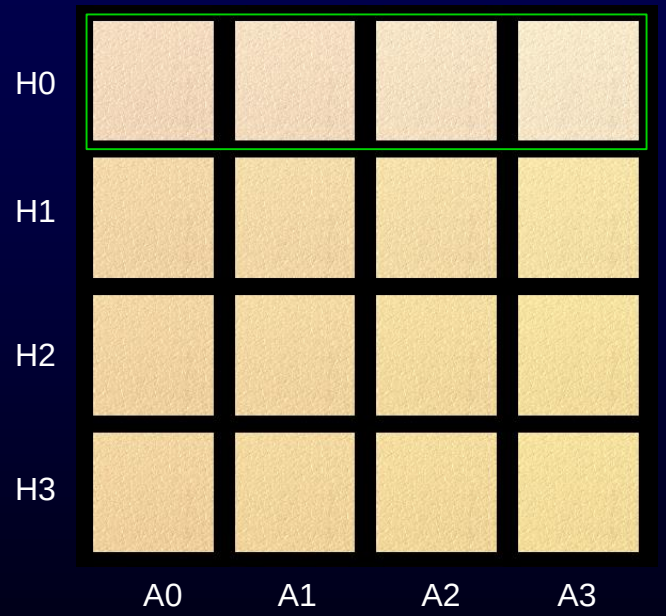


Tanned State

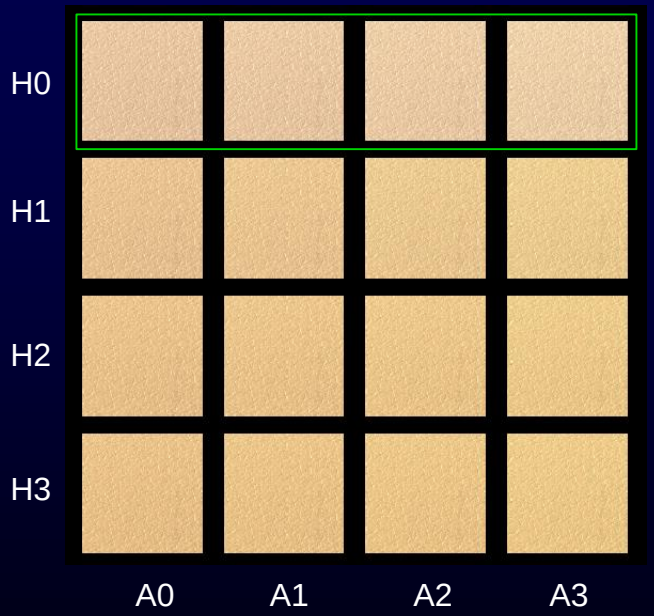


Skin swatches

Untanned State

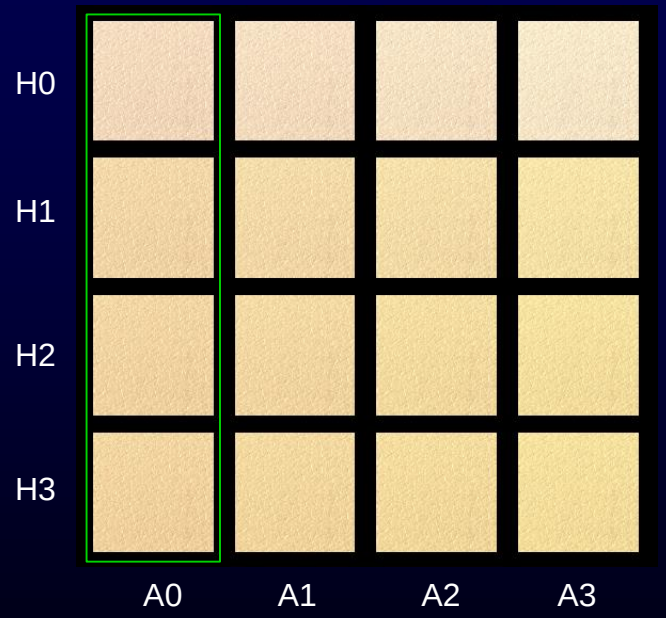


Tanned State



Skin swatches

Untanned State



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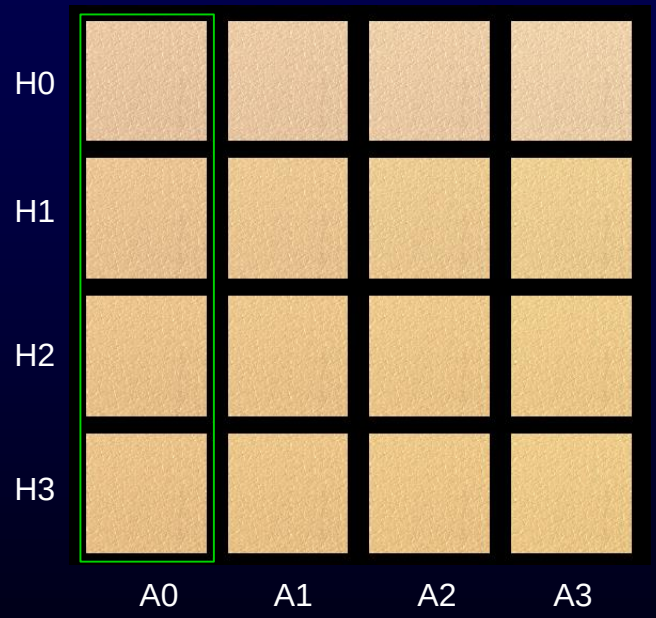


➢ Row-wise CIELAB differences (for anemia transitions)

Specimen in its Untanned State

Hyperbilirubinemia Toxicity Stages	Anemia Severity Transitions		
	A0 & A1	A1 & A2	A2 & A3
H0	**1.4941**	2.4602	2.9653
H1	**1.8897**	3.4710	3.1428
H2	**1.8841**	2.8347	4.0730
H3	**1.8811**	2.8282	4.0646

> 2.3

Specimen in its Tanned State

Hyperbilirubinemia Toxicity Stages	Anemia Severity Transitions		
	A0 & A1	A1 & A2	A2 & A3
H0	**1.2739**	**1.1314**	**1.7449**
H1	**1.1385**	**2.1030**	**1.7358**
H2	**1.1694**	**2.1032**	**2.2464**
H3	**1.5921**	**1.1242**	2.6211

> 2.3

- Column-wise CIELAB differences (for hyperbilirubinemia transitions)

Specimen in its Untanned State

Hyperbilirubinemia Toxicity Transitions	Anemia Severity Levels			
	A0	A1	A2	A3
H0 & H1	9.2849	10.2381	12.6477	14.2340
H1 & H2	2.4813	2.4693	2.3954	2.8839
H2 & H3	**1.2427**	**1.2364**	**1.2275**	**1.2141**

> 2.3

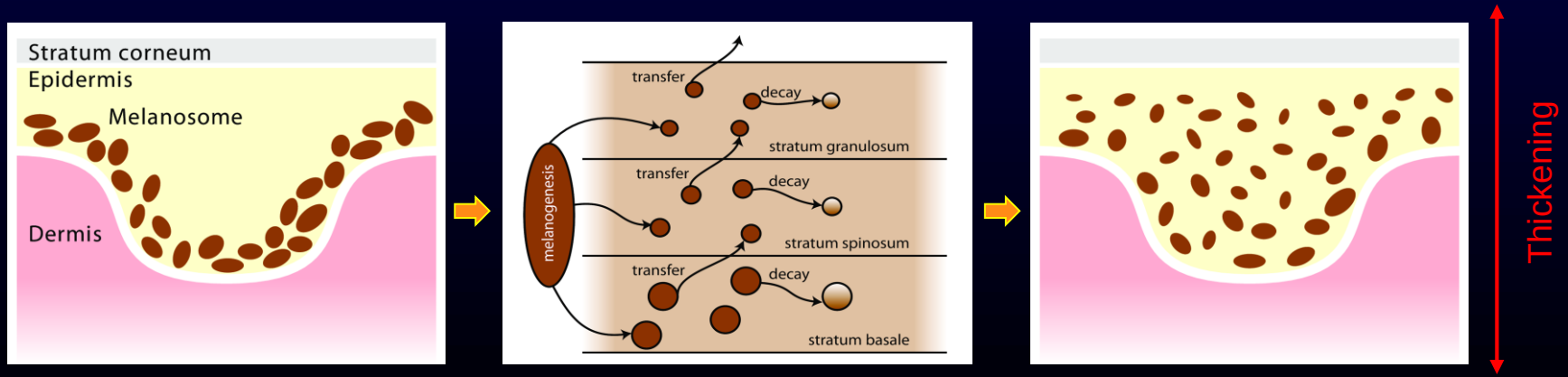
Specimen in its Tanned State

Hyperbilirubinemia Toxicity Transitions	Anemia Severity Levels			
	A0	A1	A2	A3
H0 & H1	7.8167	8.5305	9.9711	11.1466
H1 & H2	2.5341	2.7732	2.5116	2.8683
H2 & H3	**1.0098**	**1.5076**	**0.8269**	**1.2464**

> 2.3

➢ Biomedical ramifications

- Low cost approaches for the detection and treatment of anemia and hyperbilirubinemia rely on the correct assessment of their visual symptoms
- It is necessary to take into account possible changes in a patient's physiological status during the monitoring of these medical conditions over a period of time
- During tanning, a number of physiological changes take place



- Tanning-elicited masking effects can affect the perception of paleness and yellowness following the onset of anemia and hyperbilirubinemia, respectively
    - the degree of difficulty in the differentiation of skin color variations tends to be higher for anemia than for hyperbilirubinemia
    - in the case of hyperbilirubinemia, these effects are more likely to become a hindrance when transitions to extreme stages of this disorder are involved

Conclusion

➢ Status quo

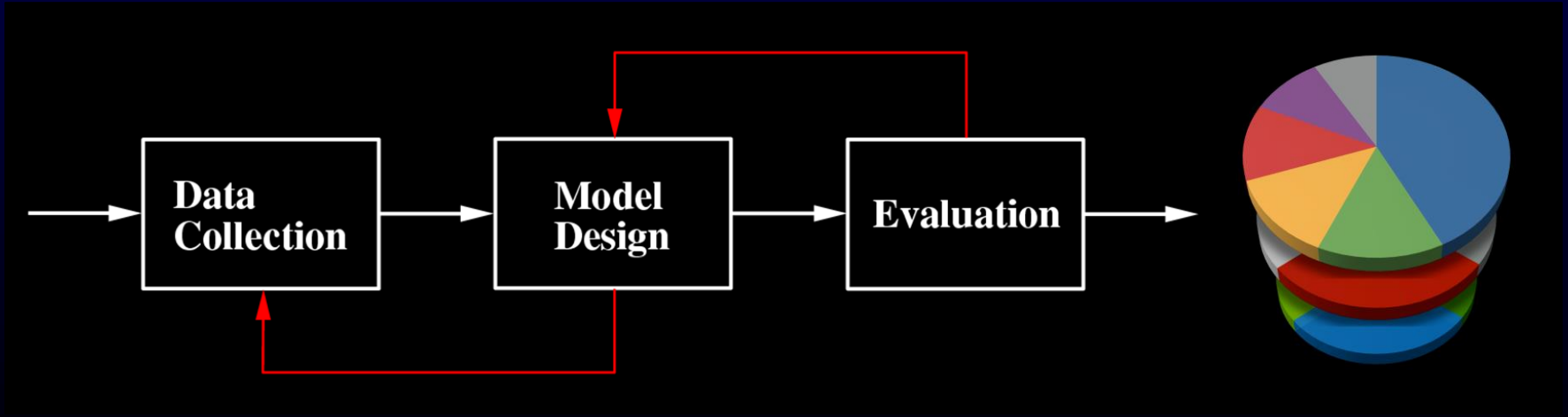
- Our findings, albeit still subject to *in vivo* confirmation, provided insights about:
  - the interations between anemia and hyperbilirubinemia's visual symptoms
  - how they can be affected by tanning-induced processes

- The precise magnitude of tanning masking effects varies from one invidual to another, and its quantification under *in vivo* conditions would incur health risks
- Alternatively, comprehensive databases, containing spectral responses, images and the specimens' characterization information could be compiled *in silico*

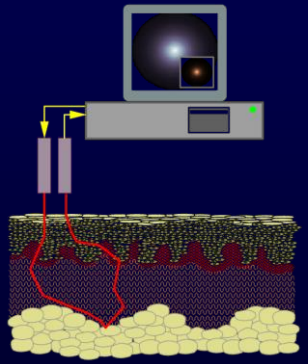
➢ Outlook

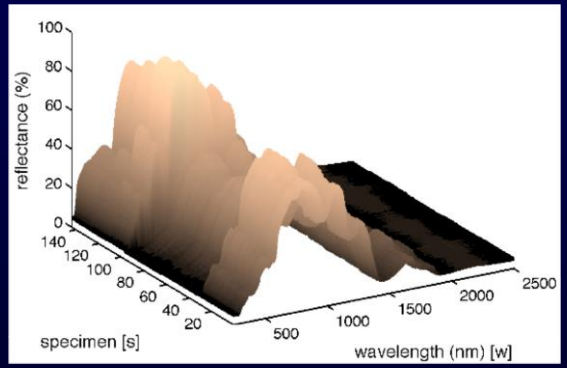
- The compilation of such *in silico* databases, however, would not diminish the value of measured skin spectral datasets obtained from live skin specimens

- These measured datasets are essential for the proper evaluation of computer models to be used to obtain comprehensive *in silico* databases



- Moreover, many devices used in the screening, monitoring and treatment of diseases employ models in the interpretation of skin spectral responses





- The efficacy of these medical applications depends on the proper evaluation of these models' predictive capabilities through comparisons with measured data

- Hence, we believe that the biomedical community should promote and provide effective support to iniatives aiming at increasing the availability of such data

Thank you!