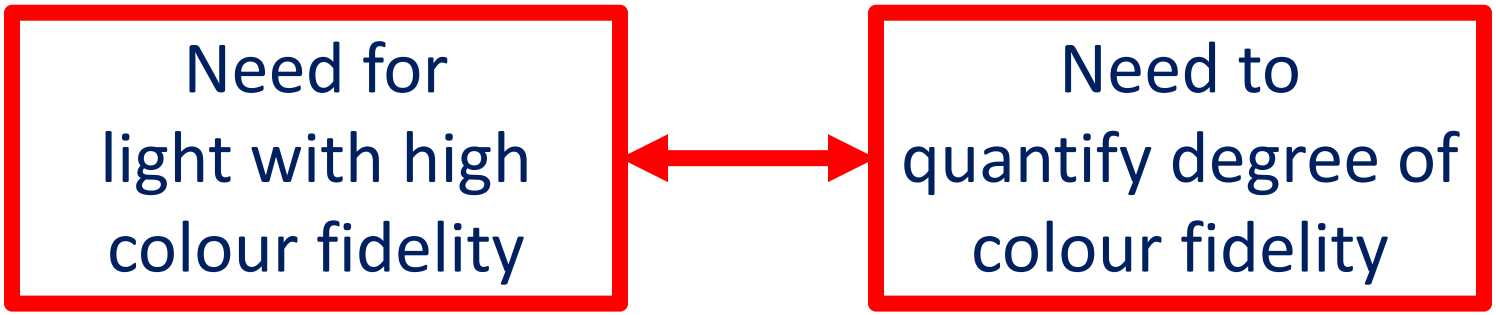
Study Session on
Phosphor-Free White LEDs for Solid State Lighting

Improving the CIE Color Rendering Index – how this can be done and why it matters

January 11, 2013

Lorne Whitehead, University of British Columbia


Need for
light with high
colour fidelity
Need to
quantify degree of
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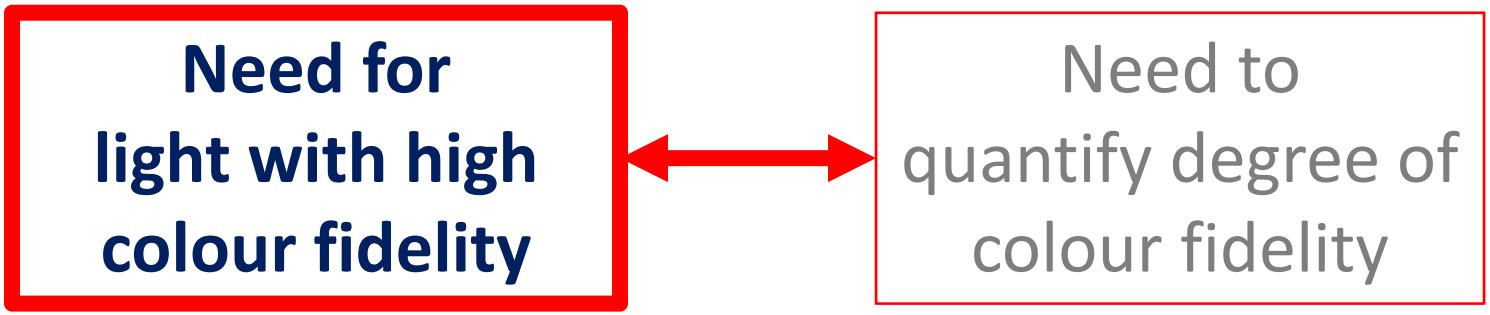
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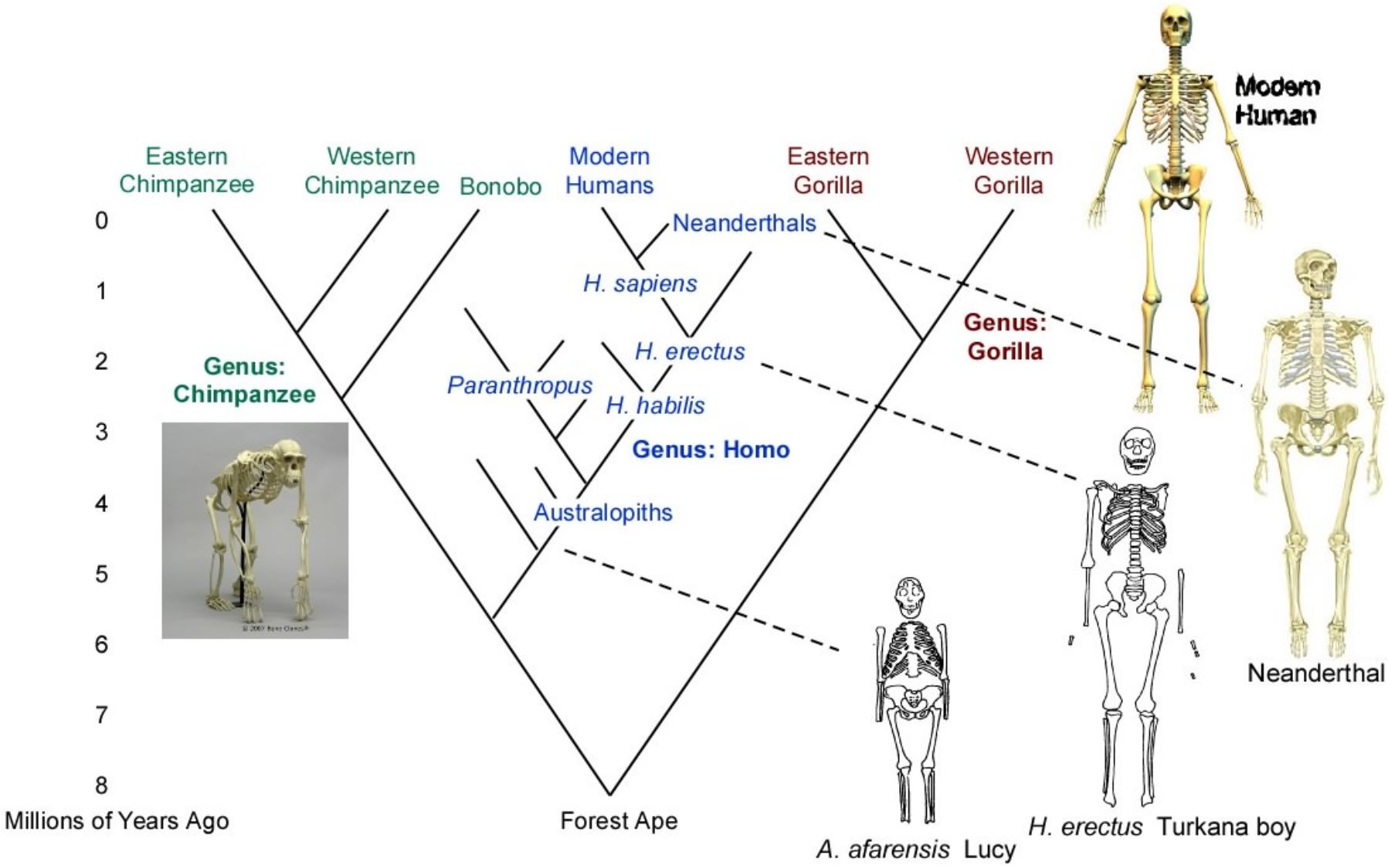
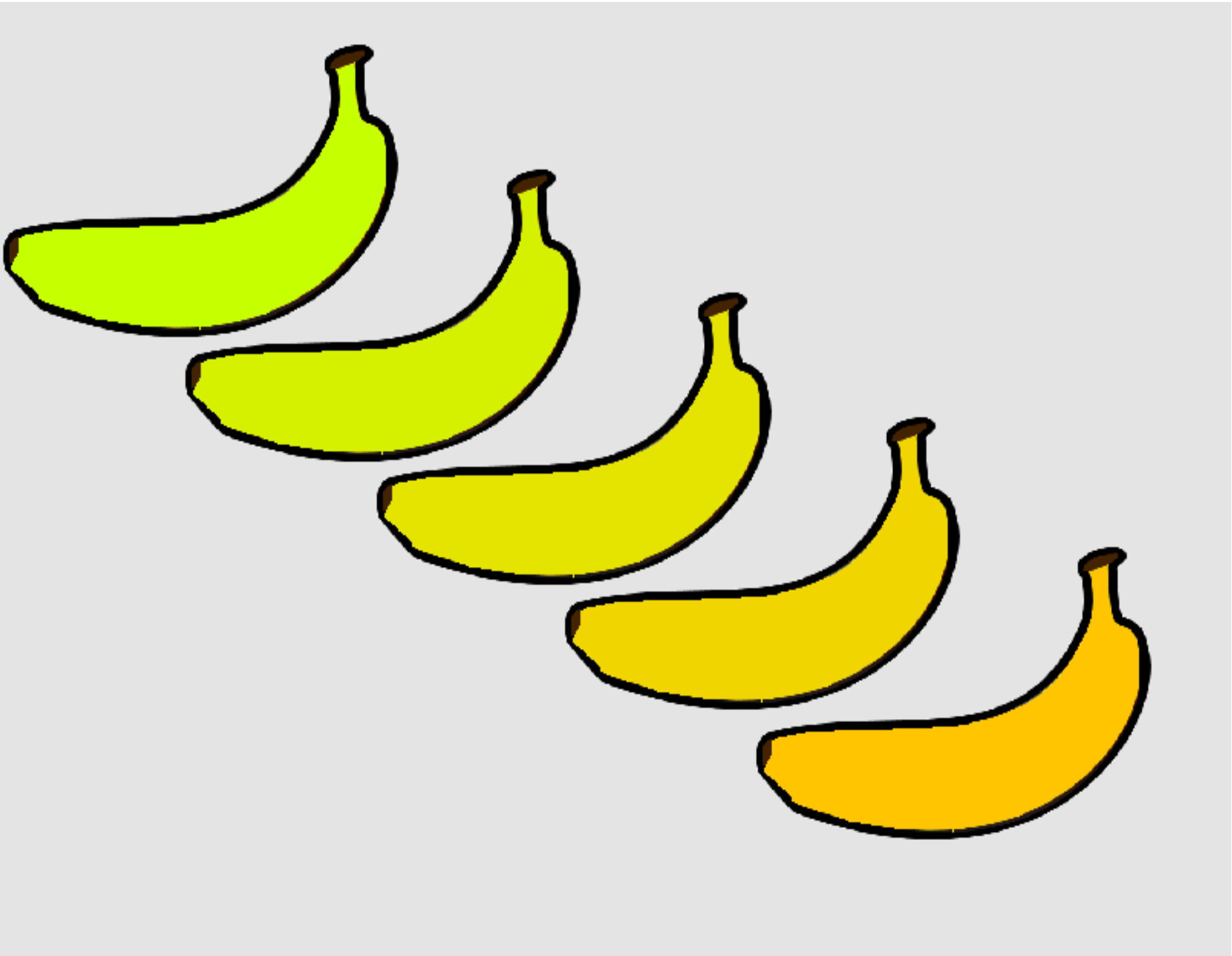
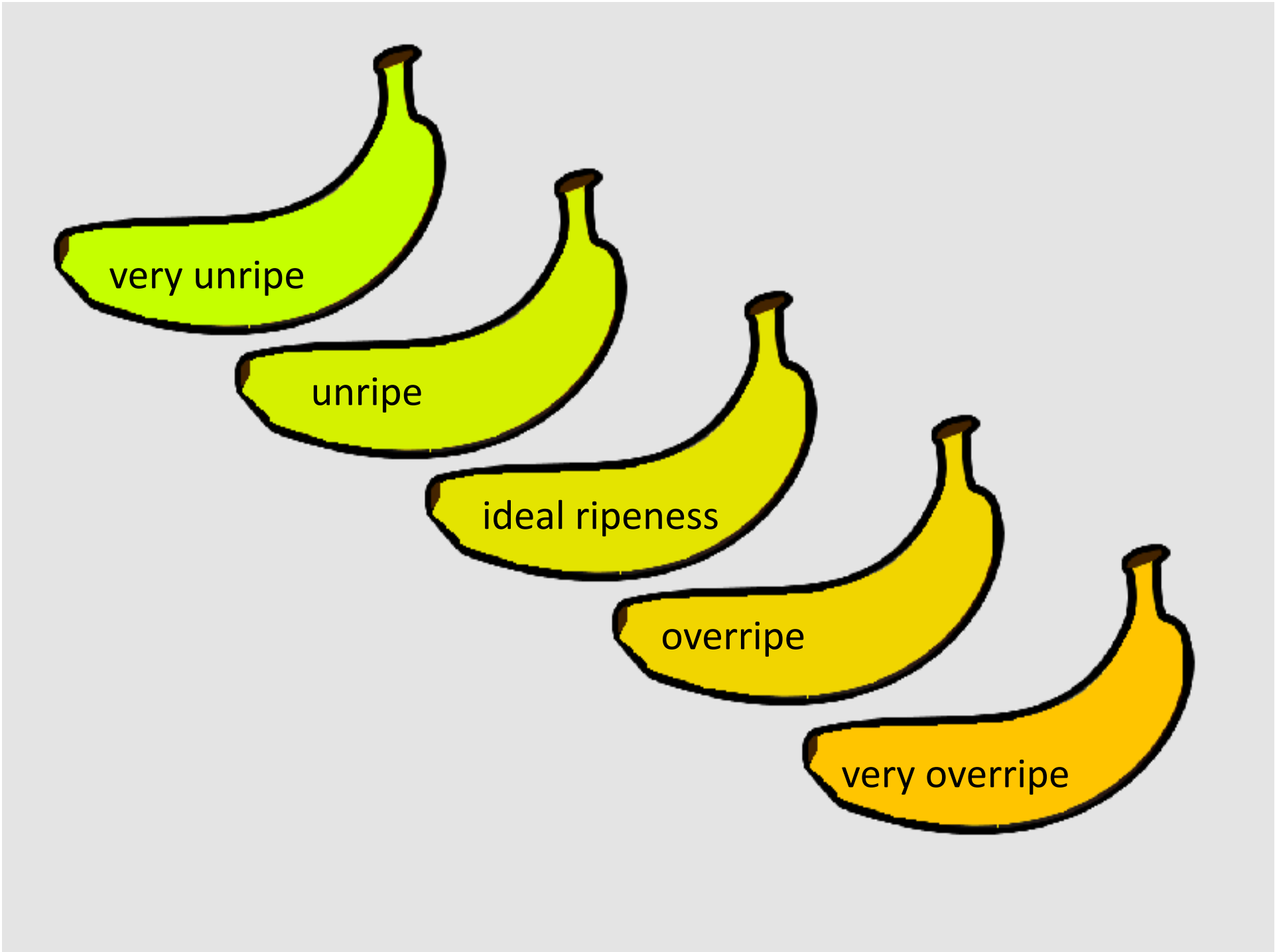
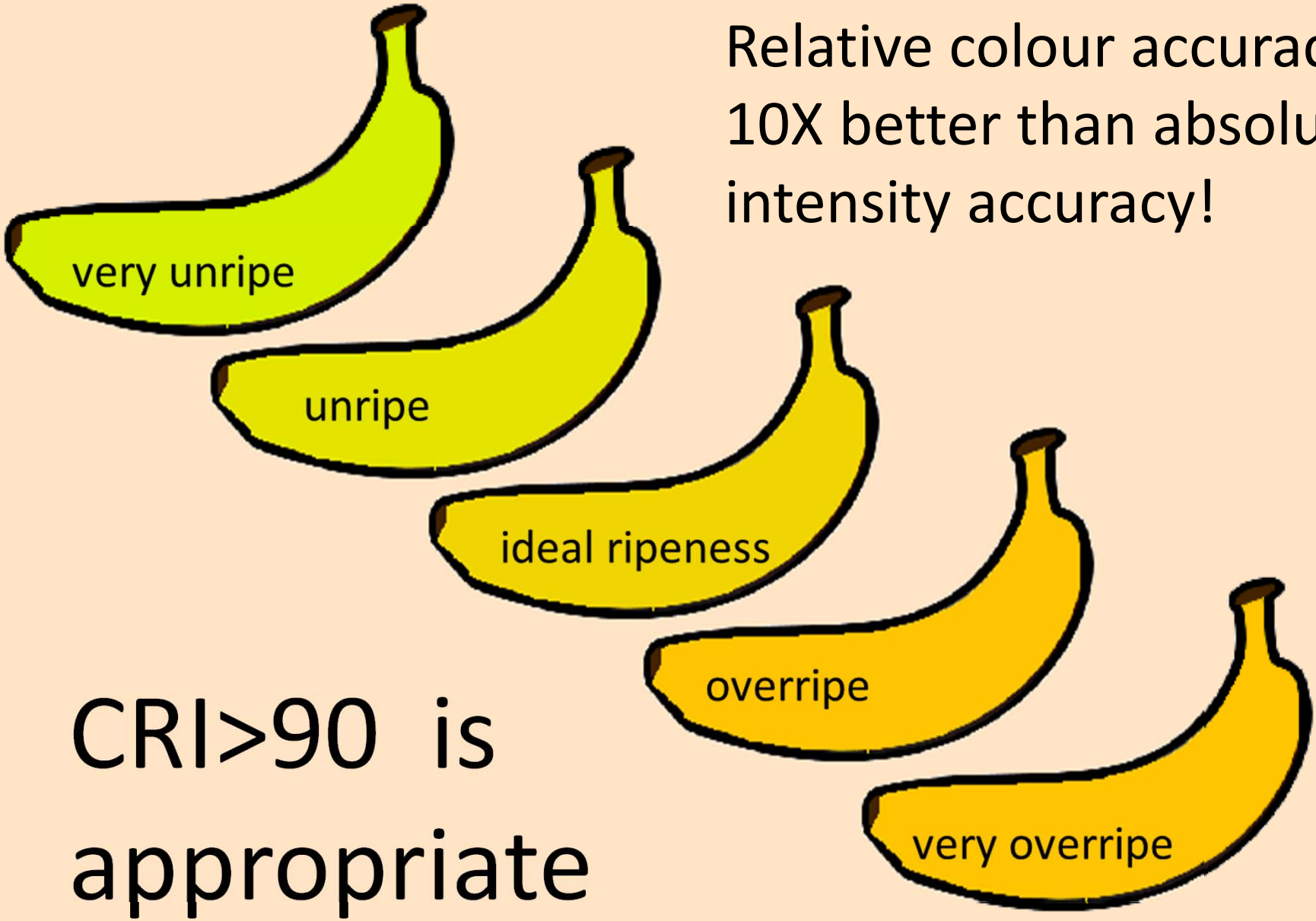

Eastern Chimpanzee
Western Chimpanzee
Bonobo
Modern Humans
Eastern Gorilla
Western Gorilla
Modern Human
Neanderthals
H. sapiens
H. erectus
H. habilis
Paranthropus
Australopiths
Genus: Chimpanzee
Genus: Homo
Genus: Gorilla
0
1
2
3
4
5
6
7
8
Millions of Years Ago
Forest Ape
A. afarensis Lucy
H. erectus Turkana boy
Neanderthal

Cave of Altamira, Spain, painted approximately 30,000 years ago

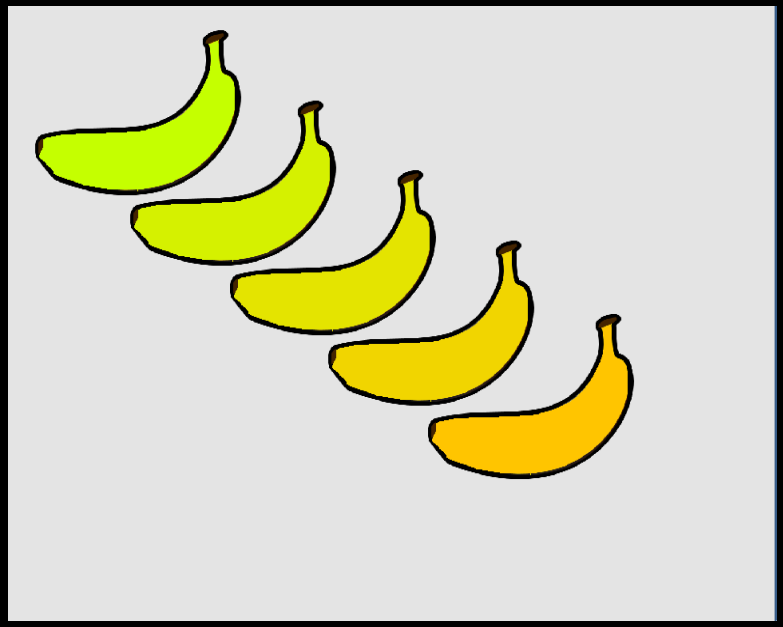


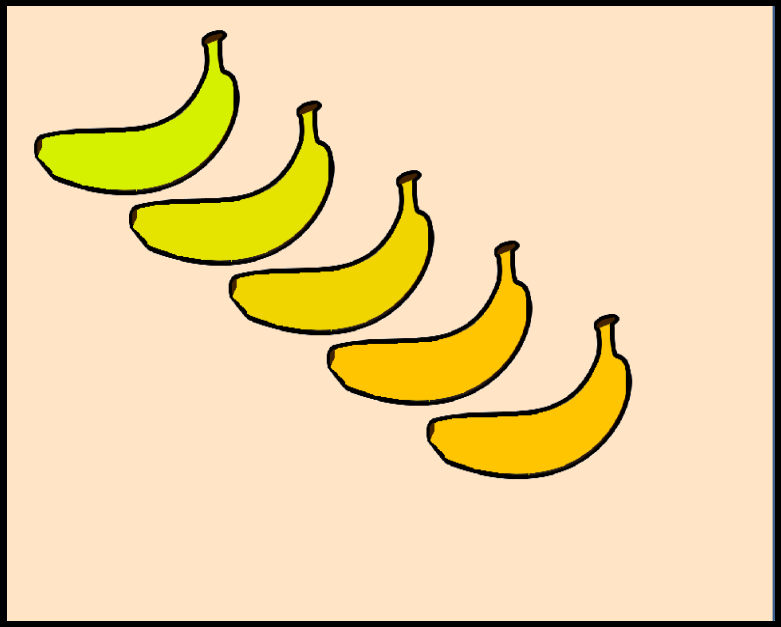

very unripe
unripe
ideal ripeness
overripe
very overripe

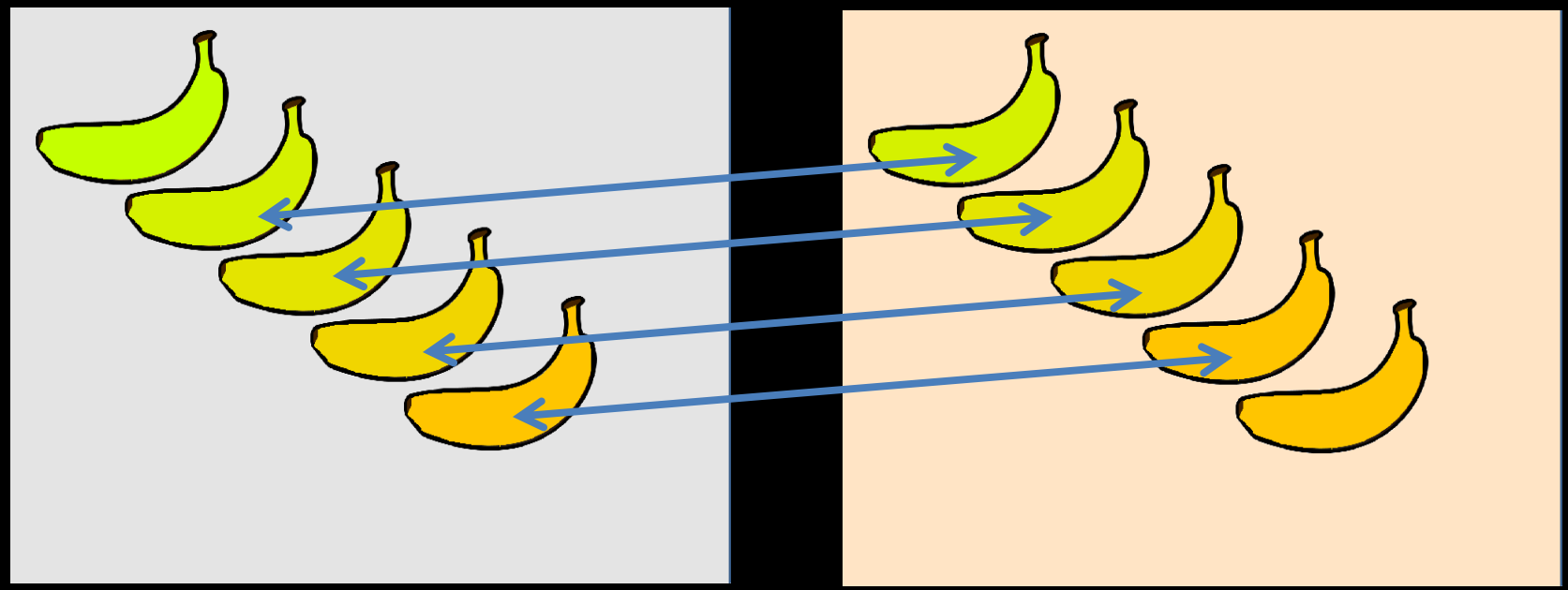
Relative colour accuracy
10X better than absolute
intensity accuracy!



CRI>90 is
appropriate







Challenge:
Colour rendering is difficult to explain

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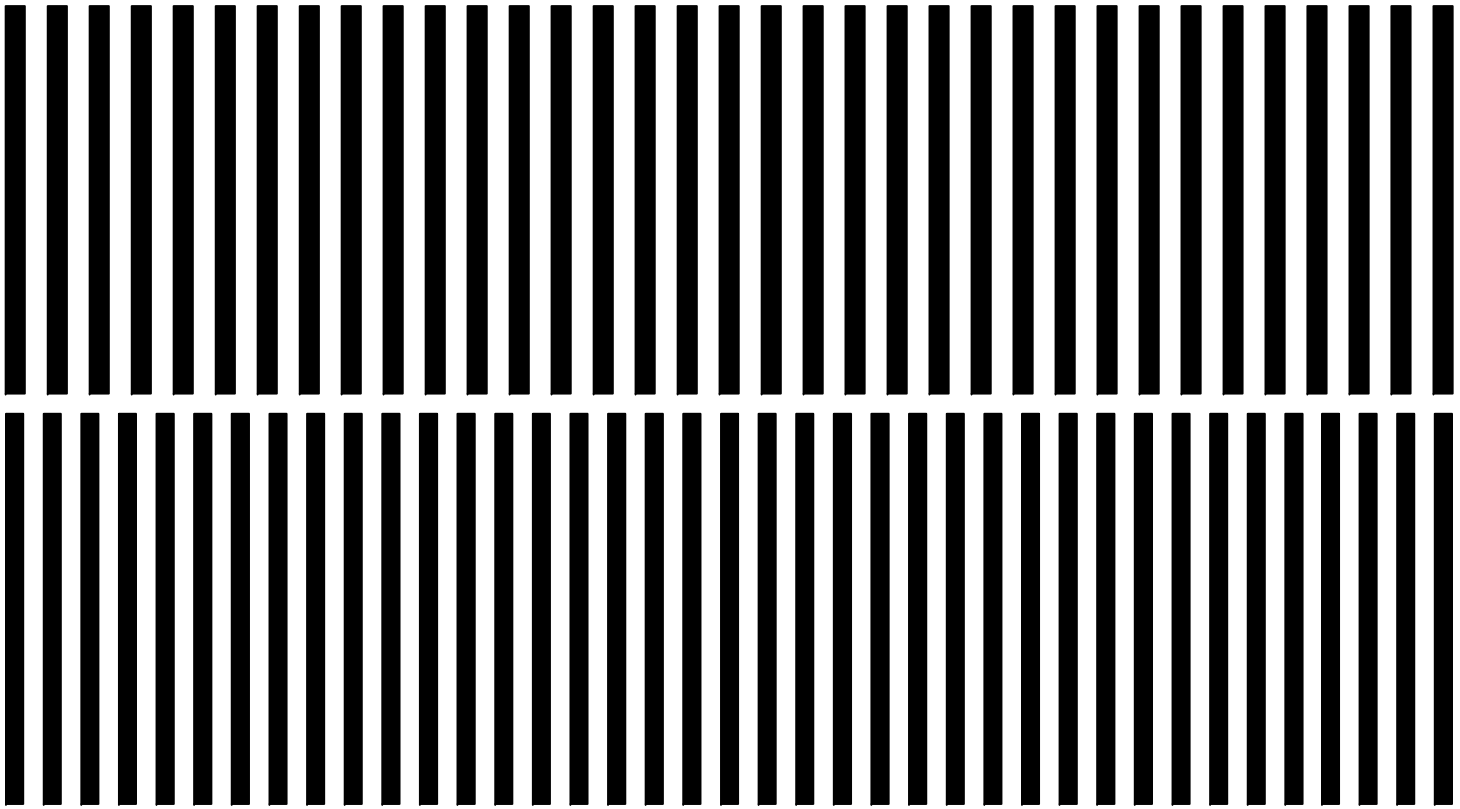

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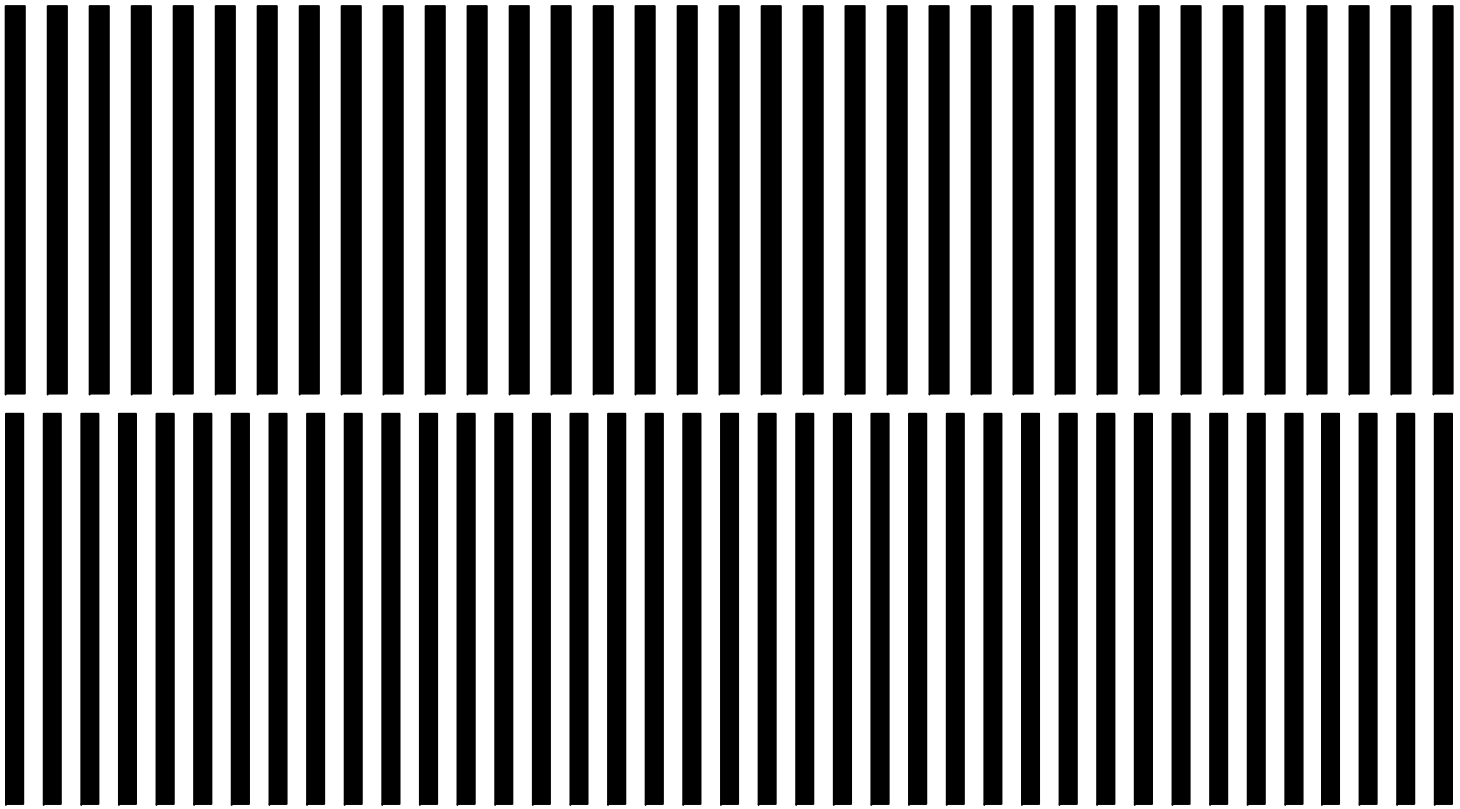

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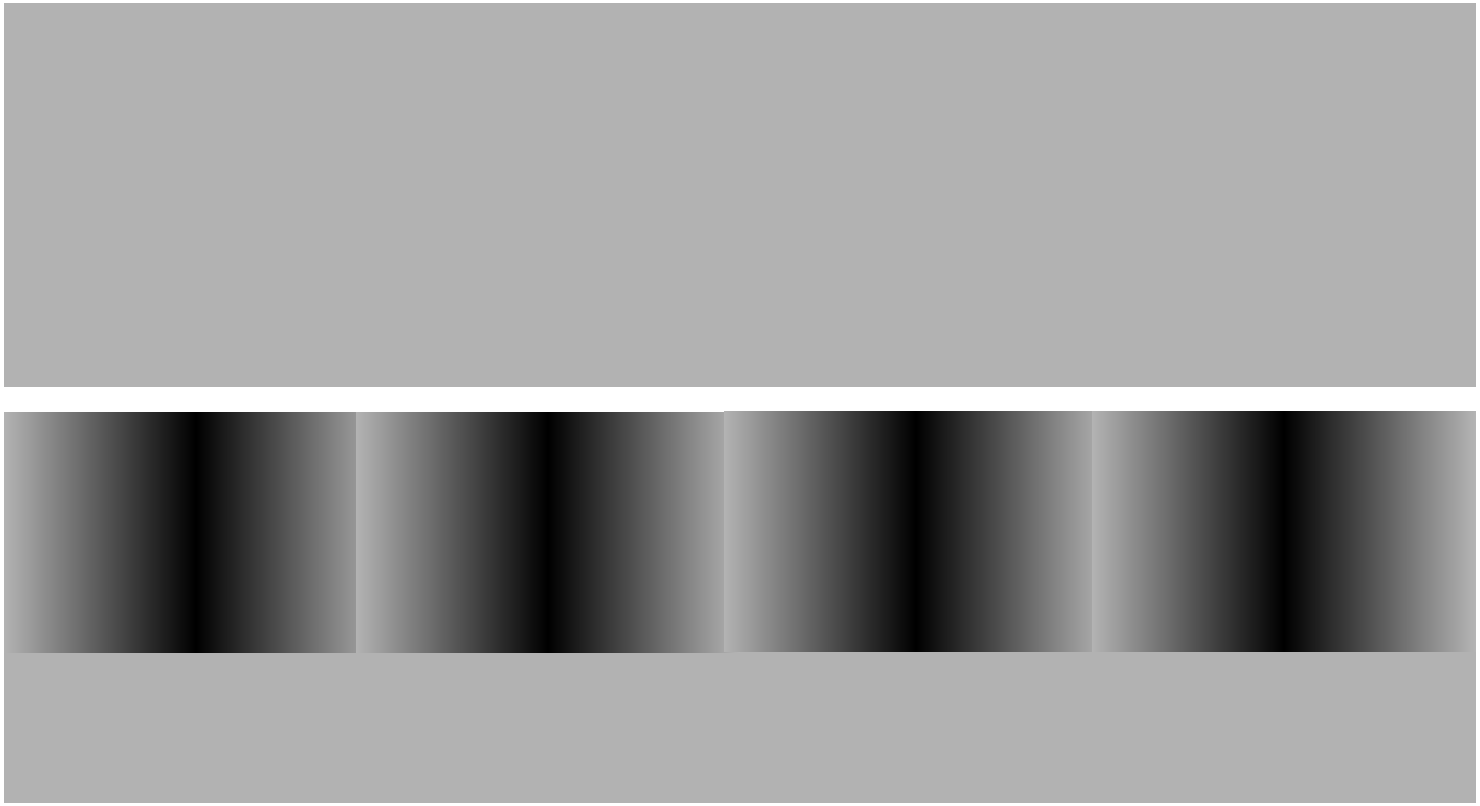
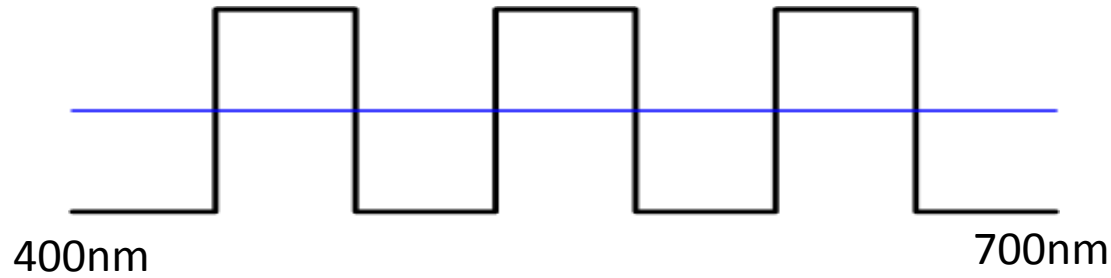
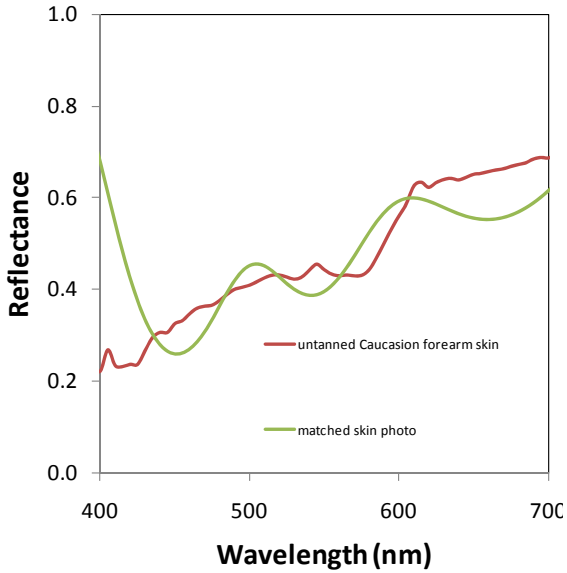


Challenge:
Colour rendering is difficult to explain

$I(\lambda)$



An important case: “Flesh Tone”



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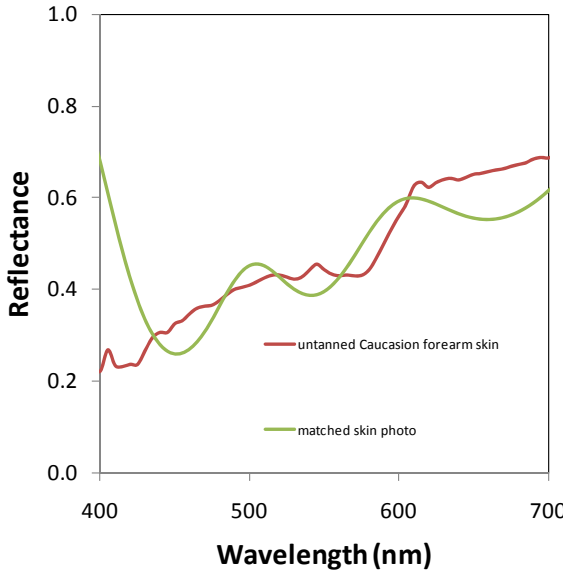

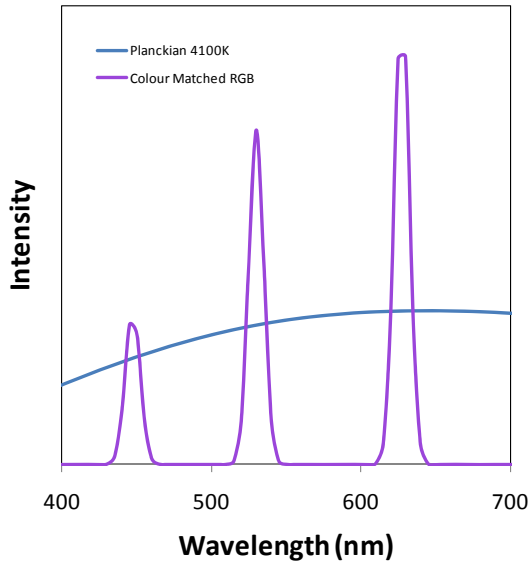

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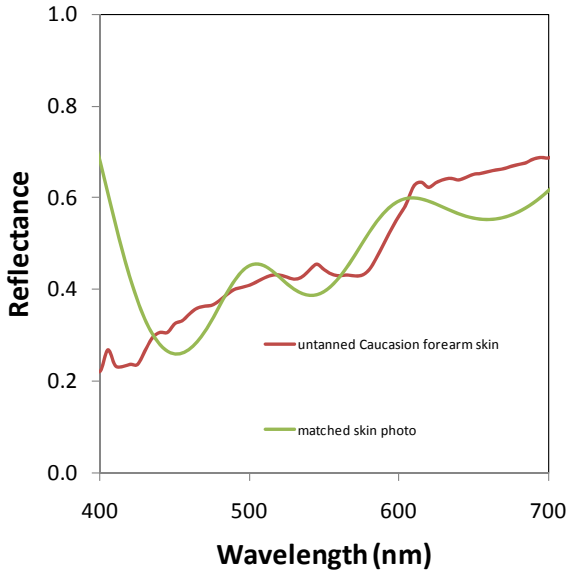

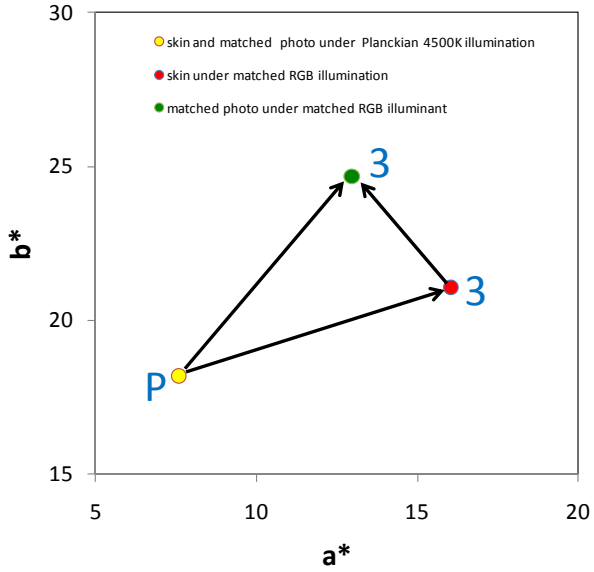

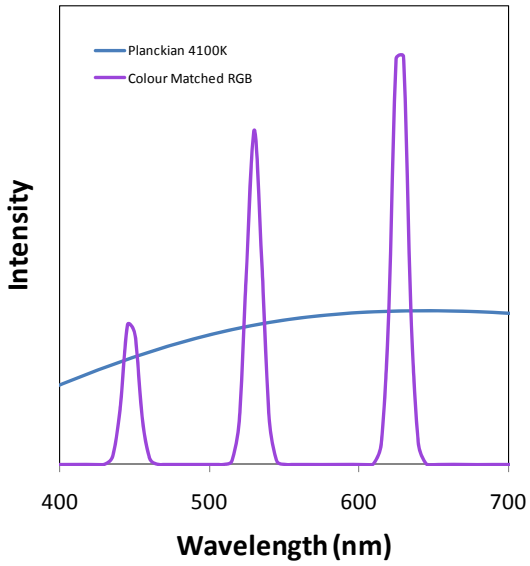

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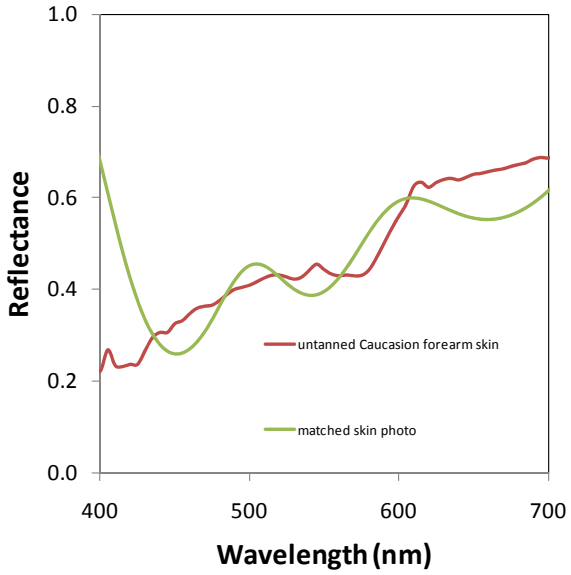
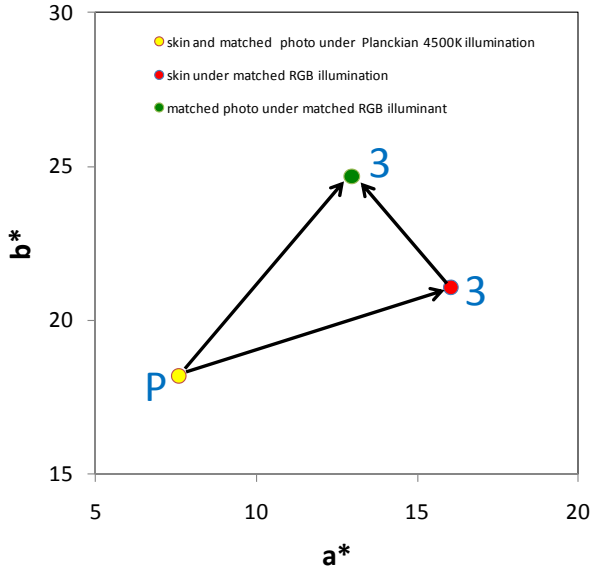
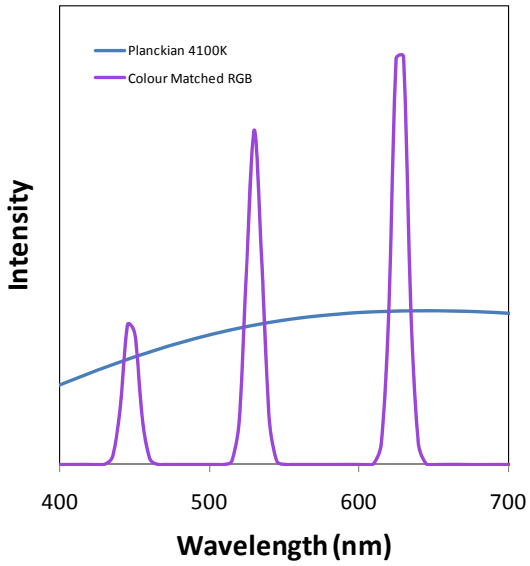
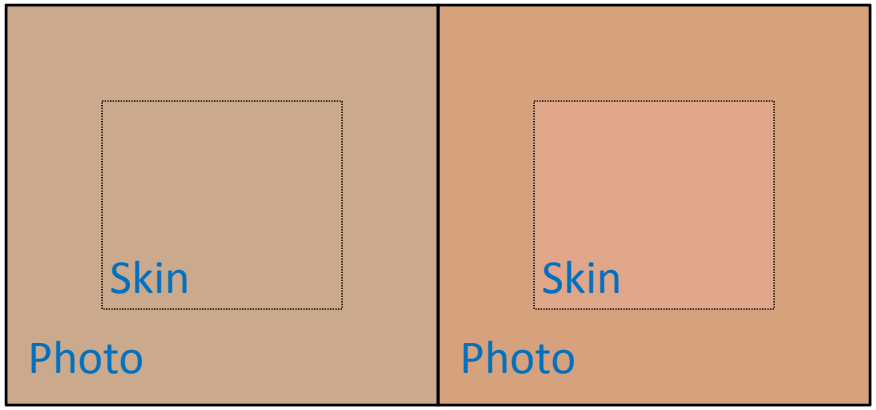


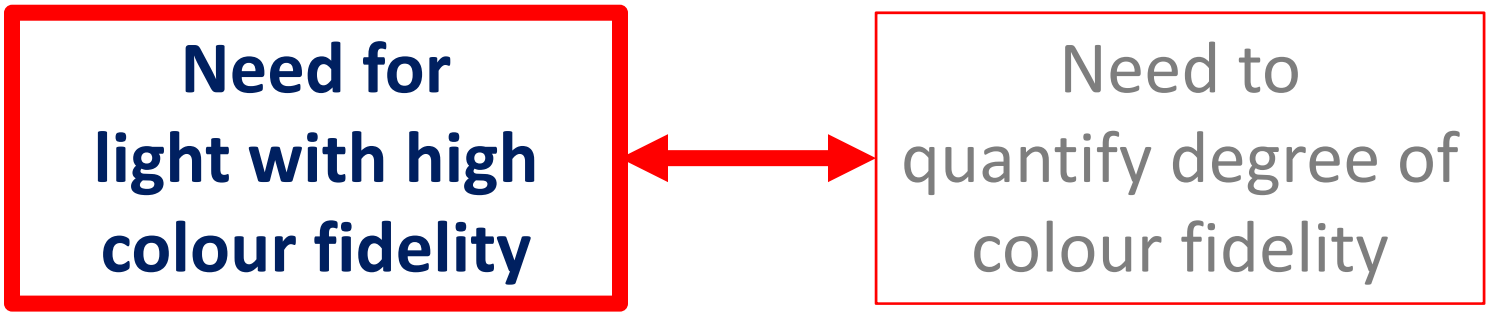






Key Ideas

- Different spectra can appear the same color
- But may ***render*** colors of surfaces differently
- We don’t adapt to poor color rendering
- This causes some people ***discomfort***
- Critical issue: ***efficacy/rendering trade-off***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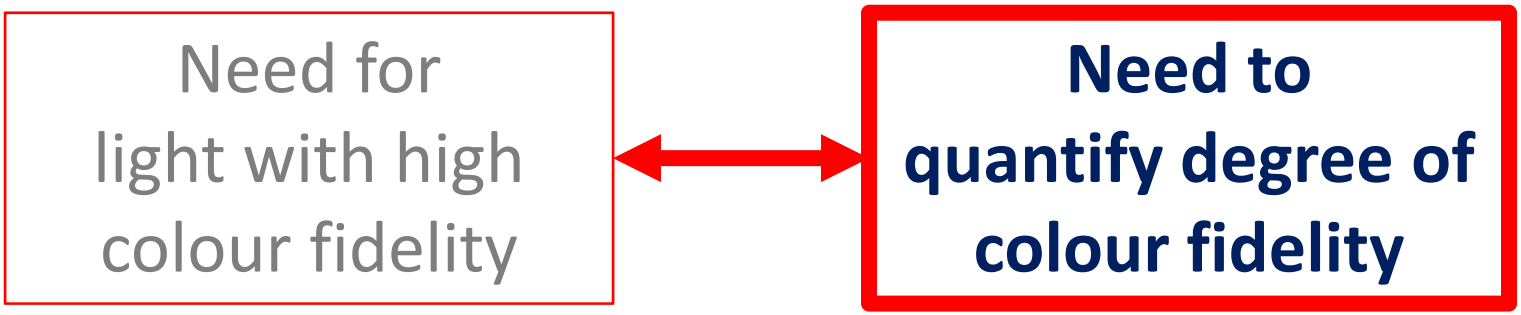
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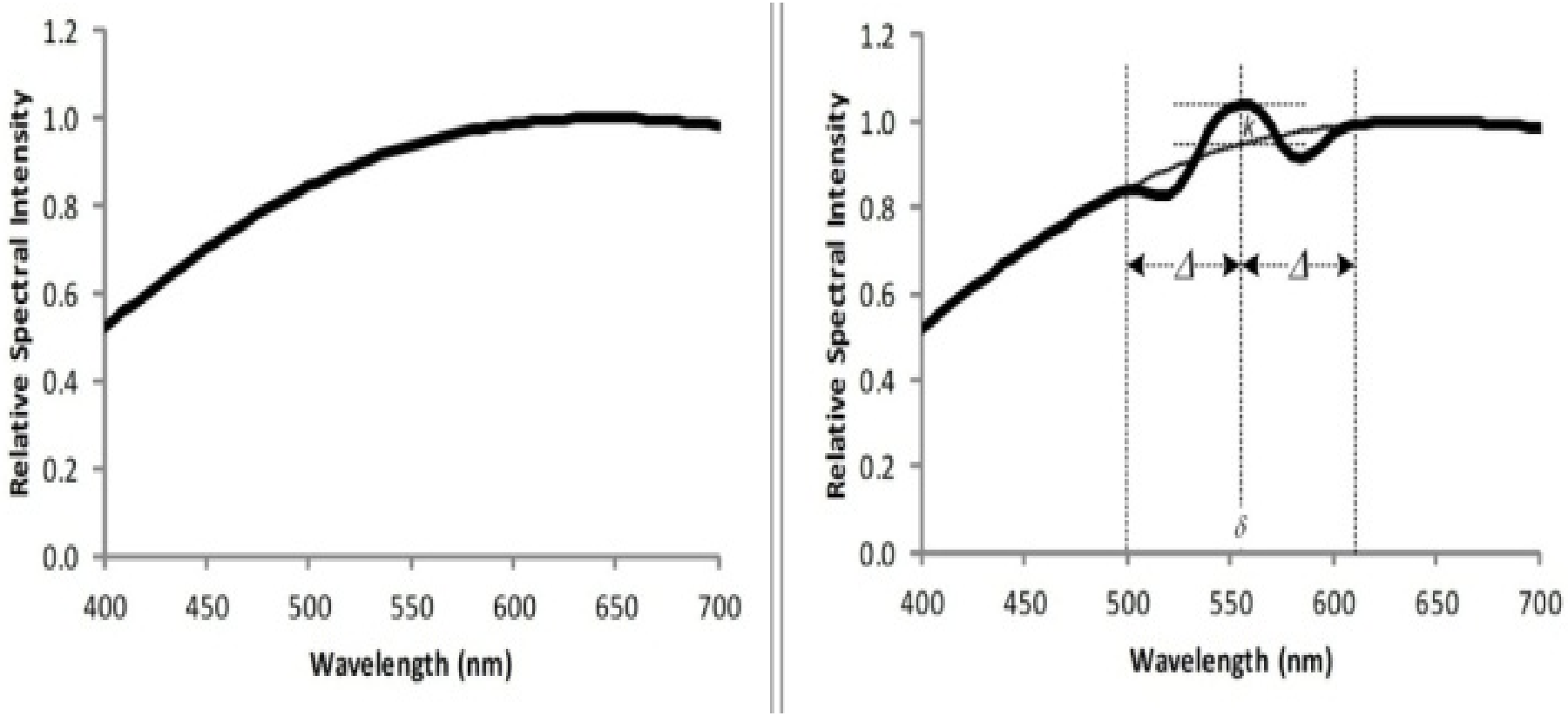
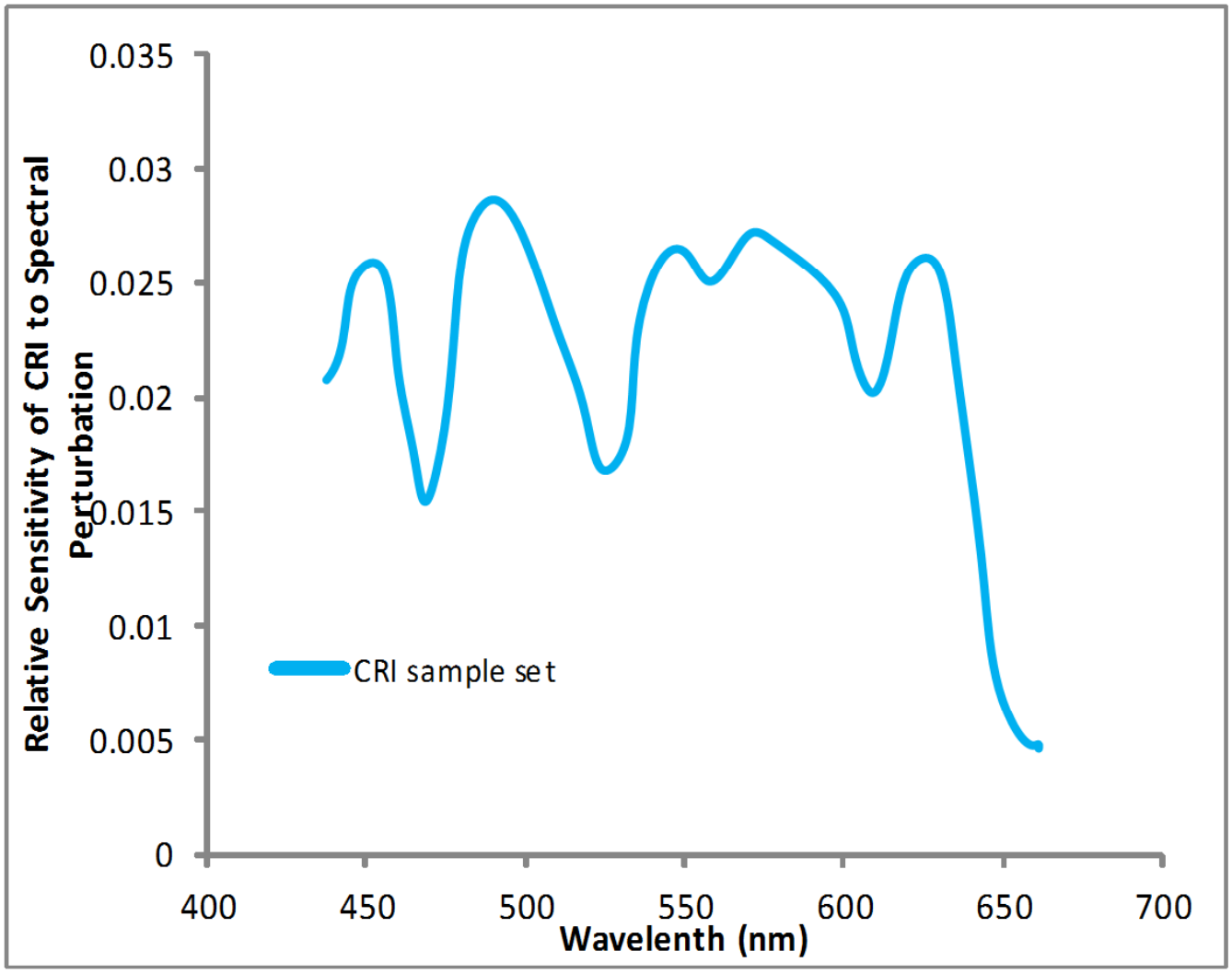
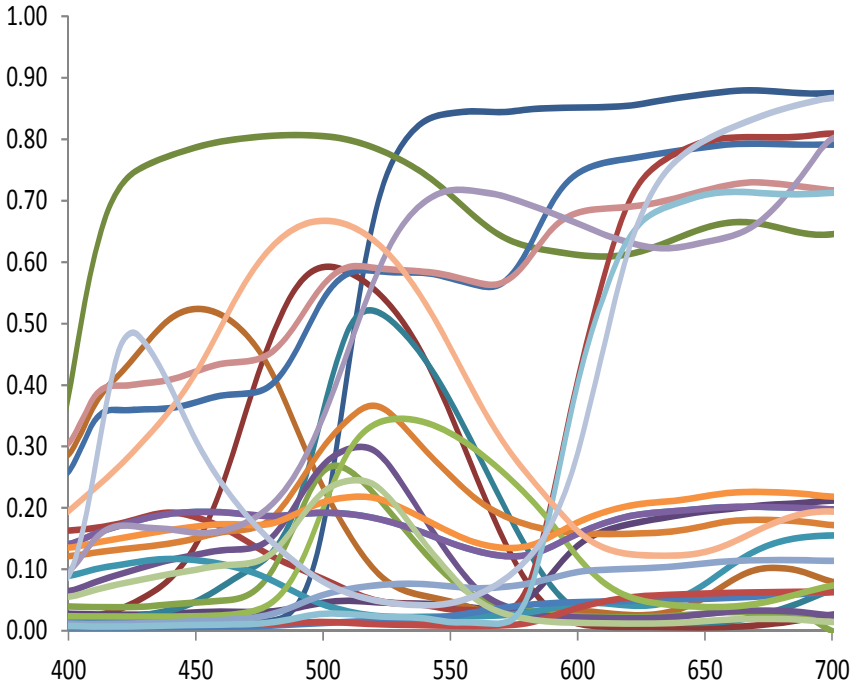


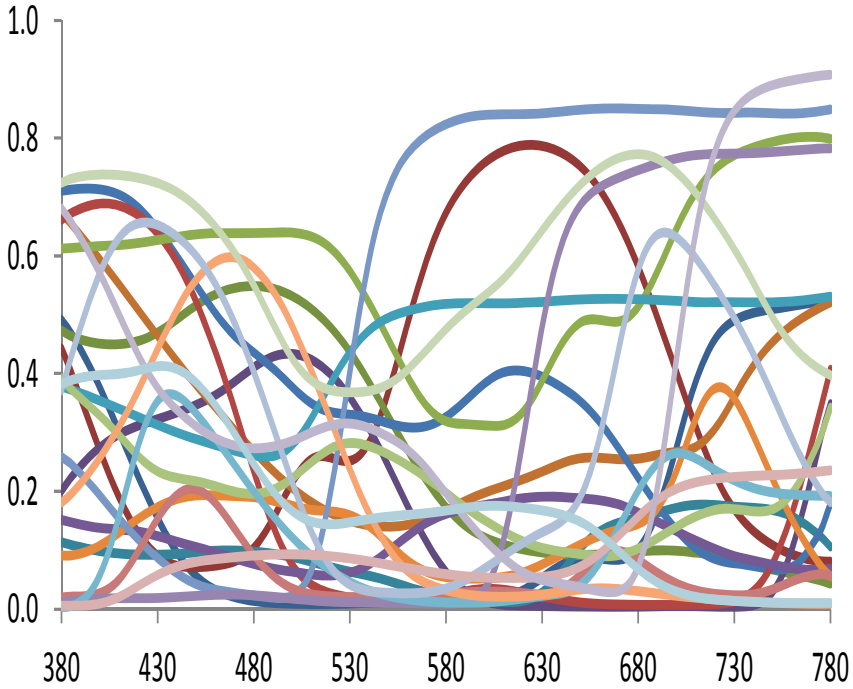
Color-Neutral Perturbation of Planckian



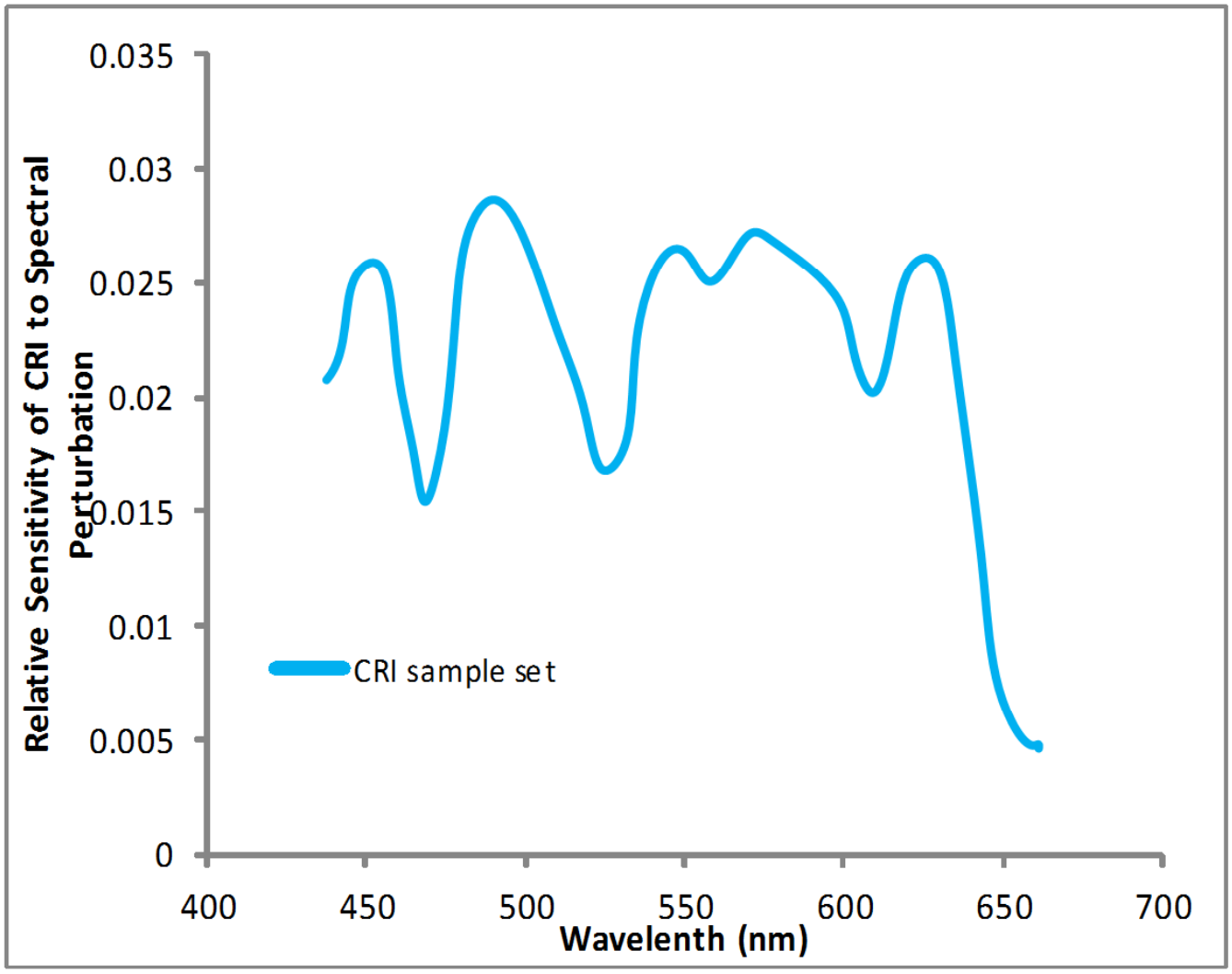
Sensitivity of CRI to Perturbations vs. Wavelength



Raw Spectra



Hybrid Spectra



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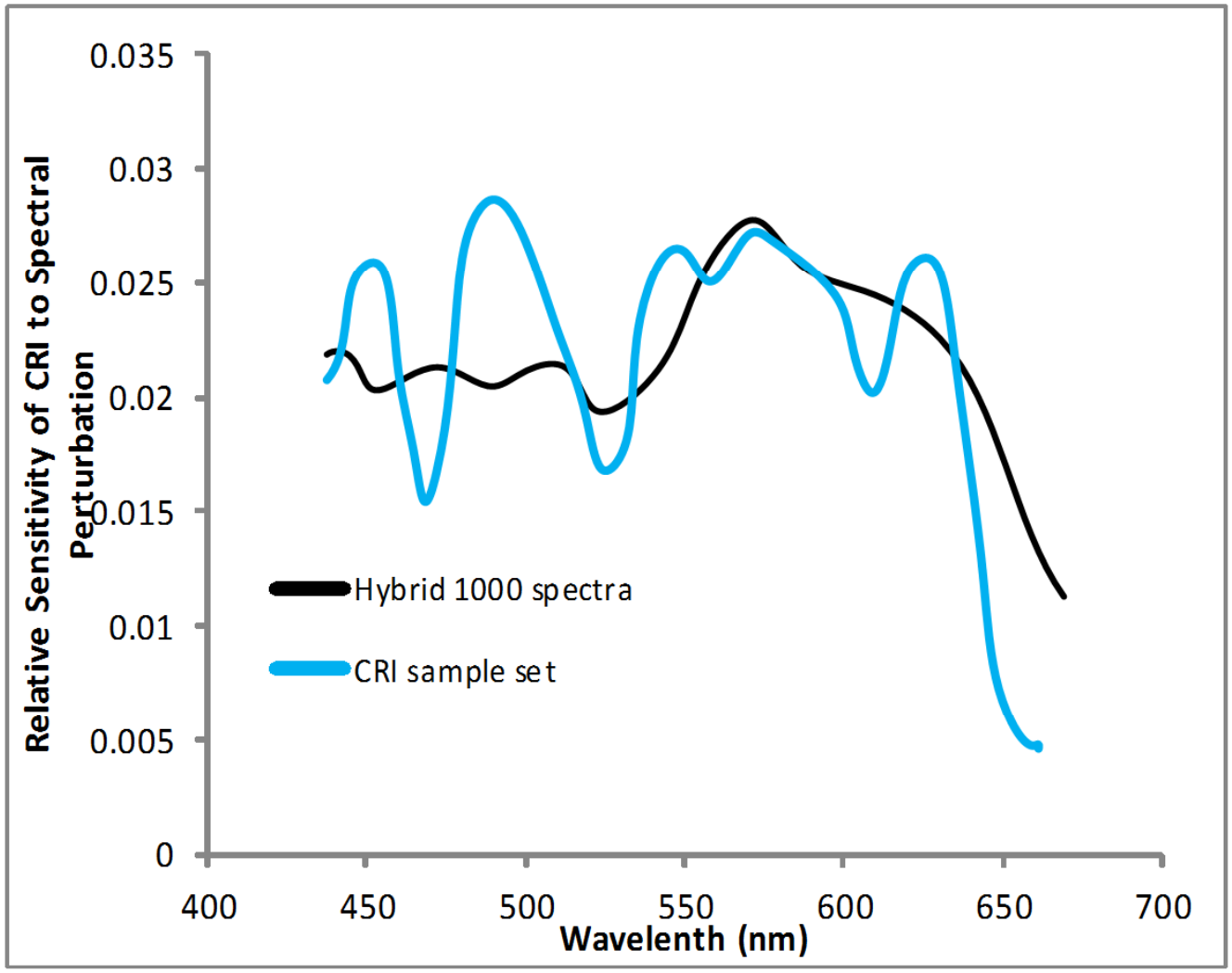

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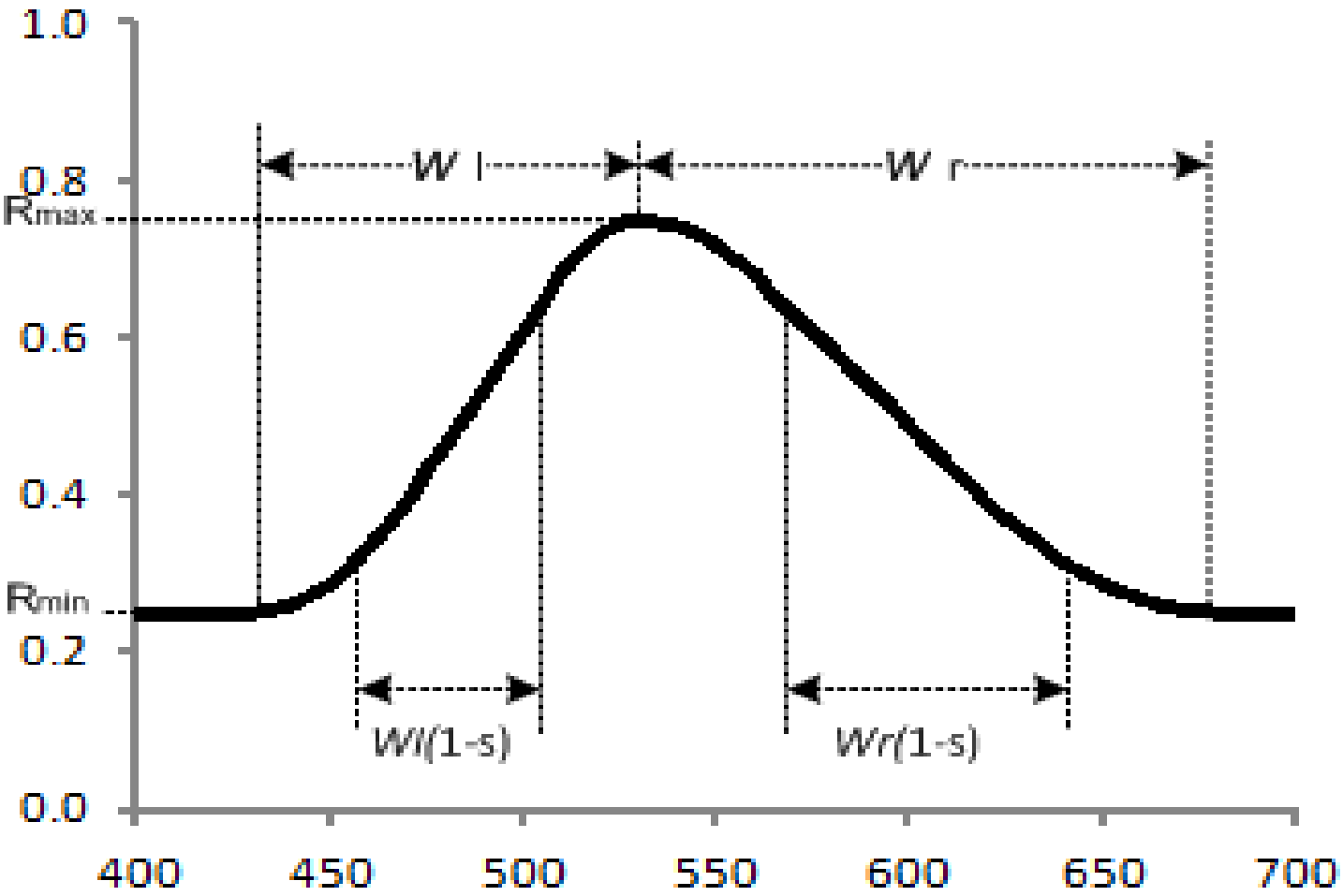


Form of Representative Spectrum

i =1 to 17 $\quad l_{ci}$ = 550nm + 25nm * (i -9)

M_i = 0.5 + 0.001nm^{-1} * (l_{ci} – 550nm)

A) If ABS($l - l_{ci}$) ≥ [125nm] :

$R(l)$=[0.01]

B) If [125nm]>ABS($l - l_{ci}$)≥[75nm] :

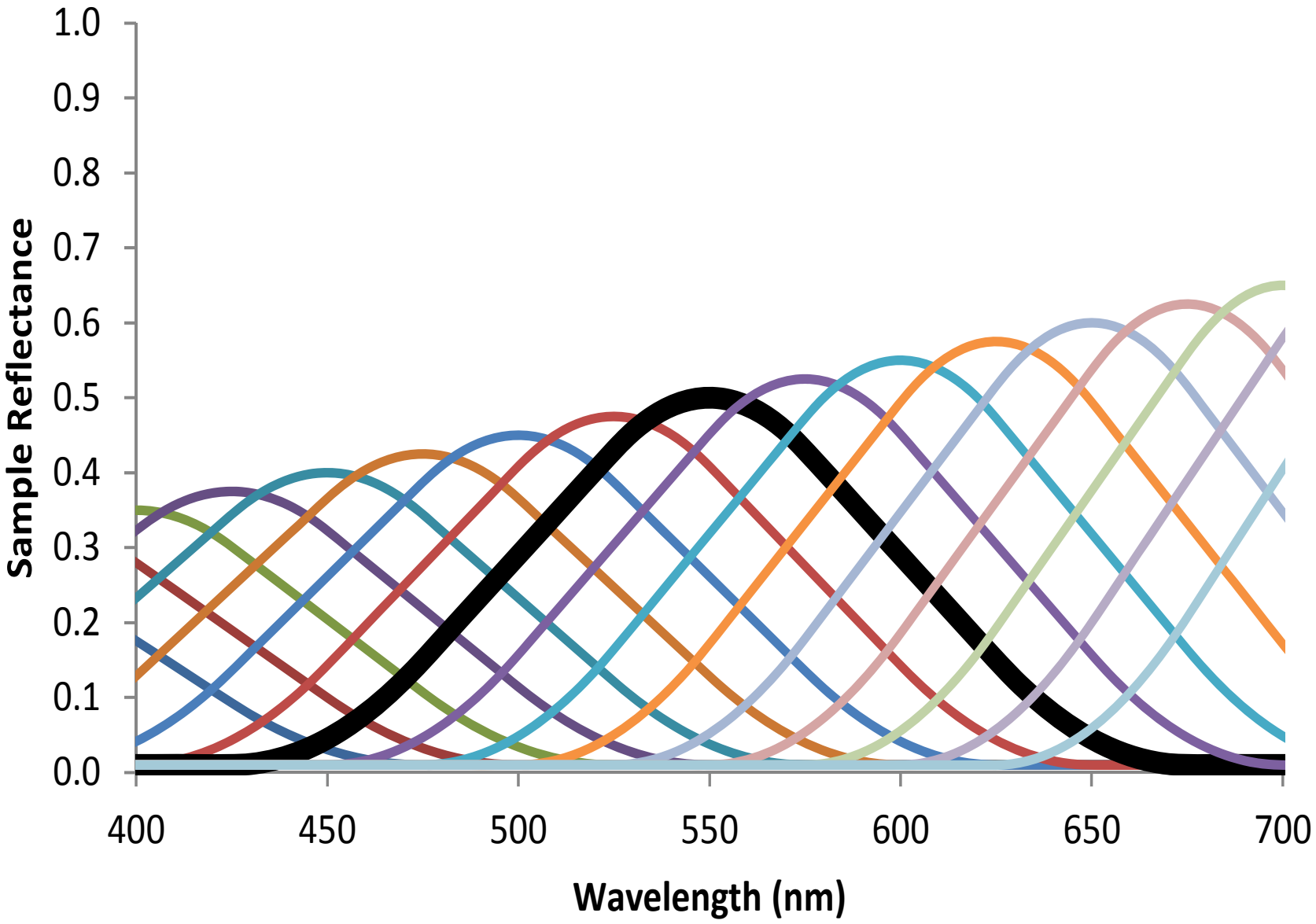
$$R(l)=[0.01]+(Mi-[0.01])*\left[\frac{1}{8750nm^2}\right]*\left([125nm]-ABS(\lambda-\lambda_{ci})\right)^2$$

C) If [75nm]>ABS($l - l_{ci}$)≥[25nm] :

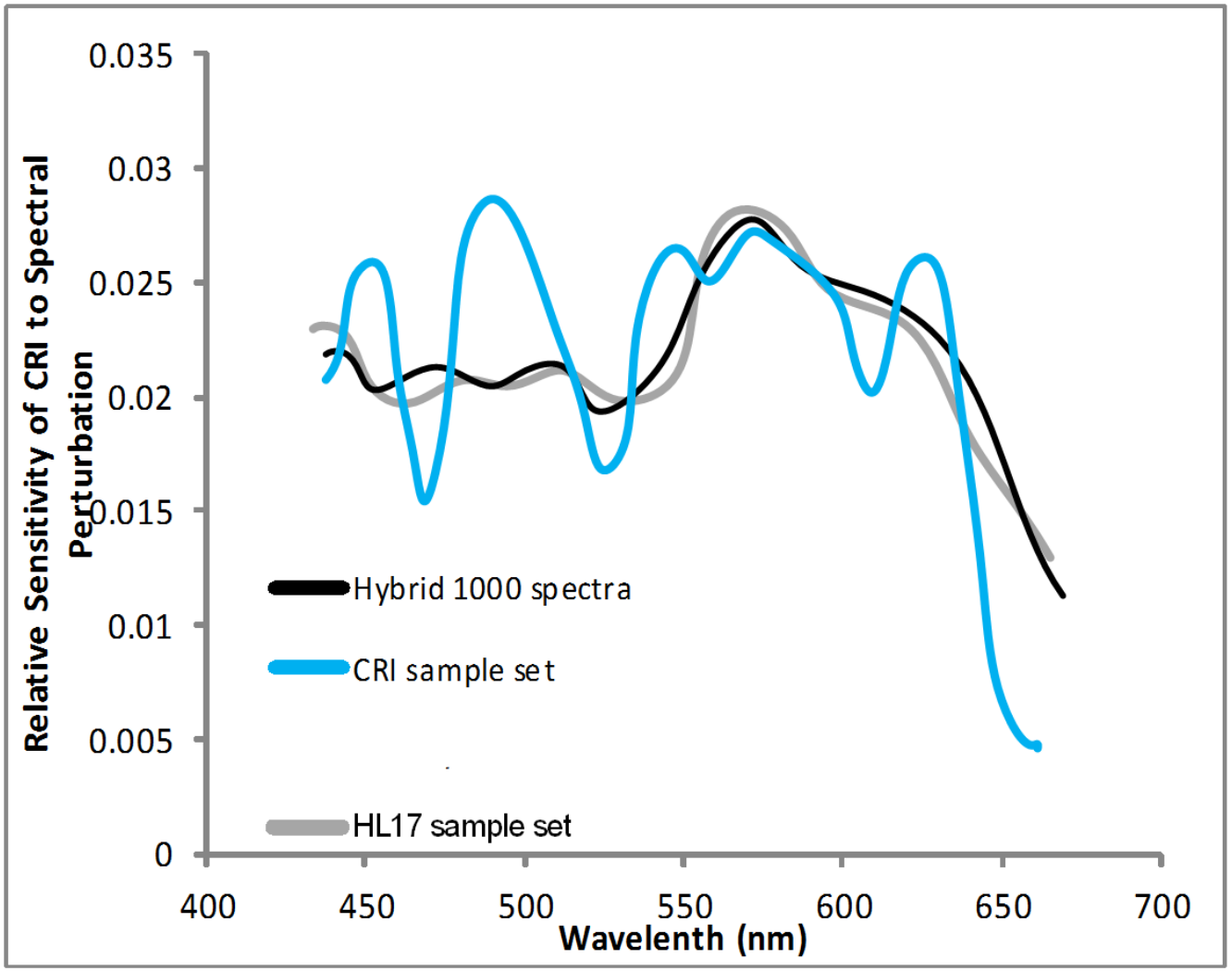
$$R(l)=[0.01]+(Mi-[0.01])*\left(\left[\frac{8}{7}\right]-\left[\frac{2}{175nm}\right]*ABS(\lambda-\lambda_{ci})\right)$$

D) If [25nm]>ABS($l - l_{ci}$) :

$$R(l)=[0.01]+(Mi-[0.01])*\left([1]-\left[\frac{1}{4375nm^2}\right]*(\lambda-\lambda_{ci})^2\right)$$



HL17 Spectral Set



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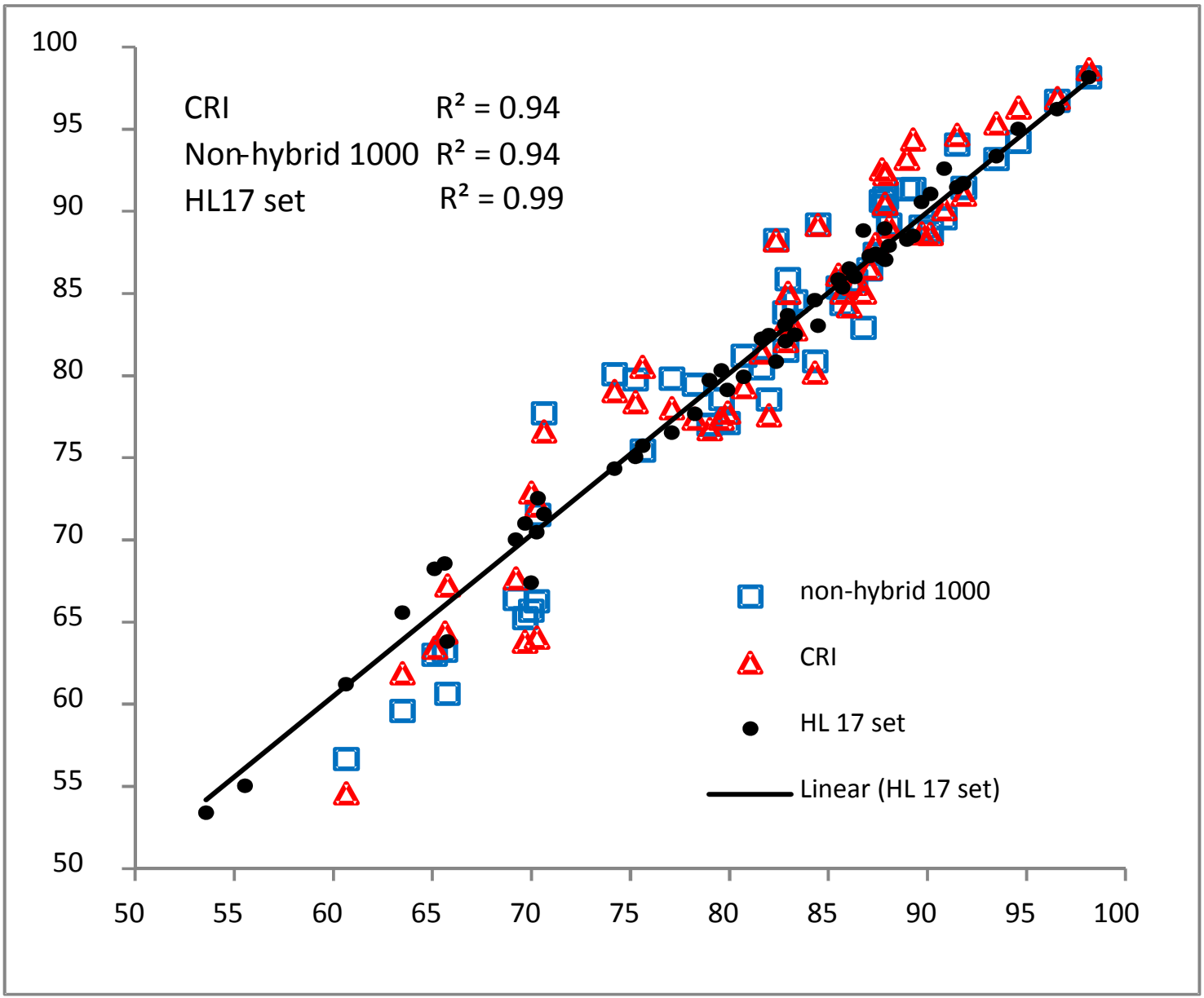

CRI values compared to Hybrid Leeds Data

Conclusions

- The HL17 set is proposed for CRI sample set
- This reduces sample error from 5 points to <1
- The CRI should then work well with LEDs
- More research is needed:
  - to verify good agreement with many observers
  - on psychological benefits of illumination with CRI>90

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