

Data Visualization Principles: Color

CSC444

Acknowledgments for today's lecture:
Tamara Munzner, Miriah Meyer, Maureen Stone

Usual Reminders

- Assignment 3 due tonight
- Assignment 4 posted
- Office hours on **tuesday**

Outlook

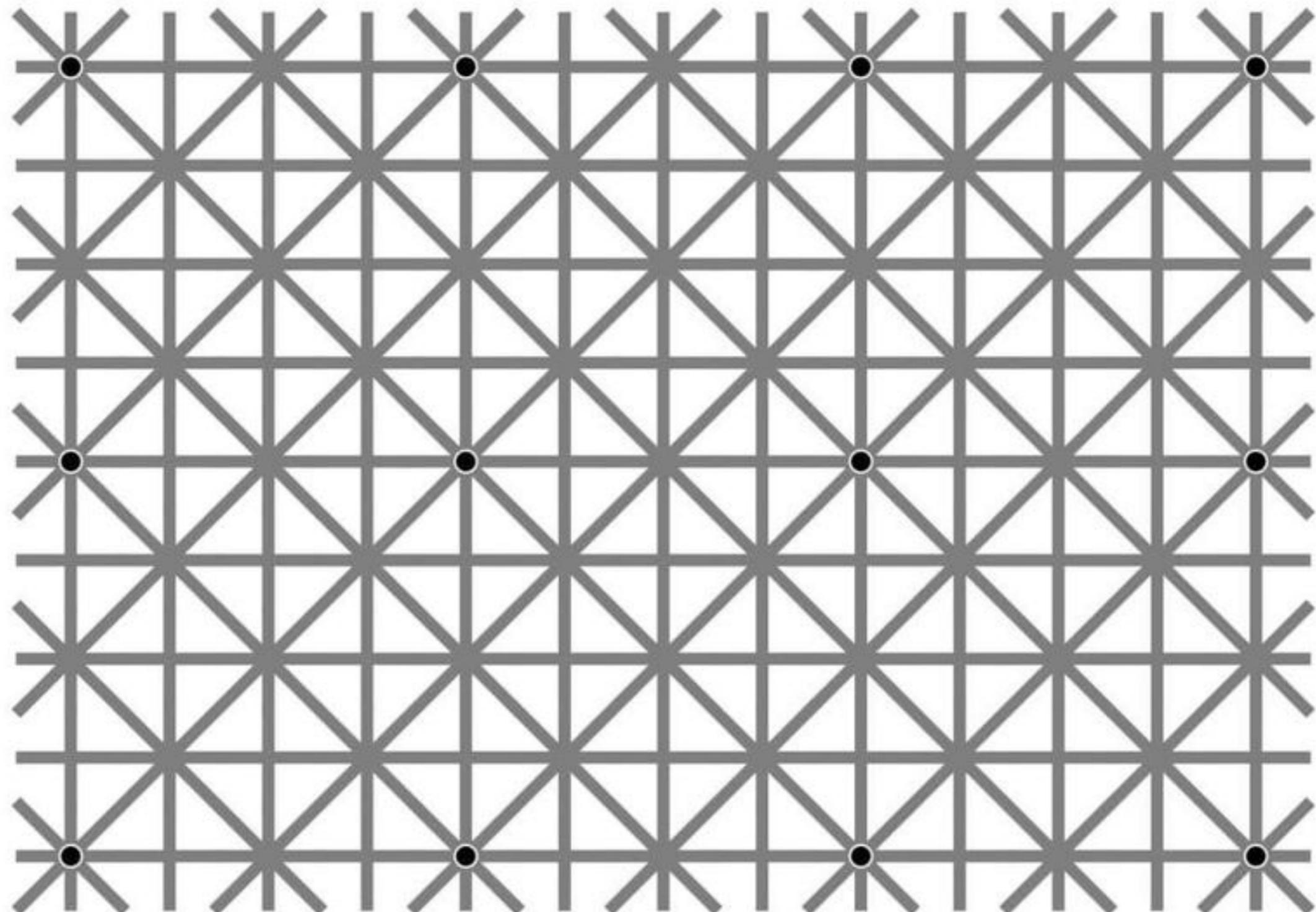
Mechanics

Principles

Techniques

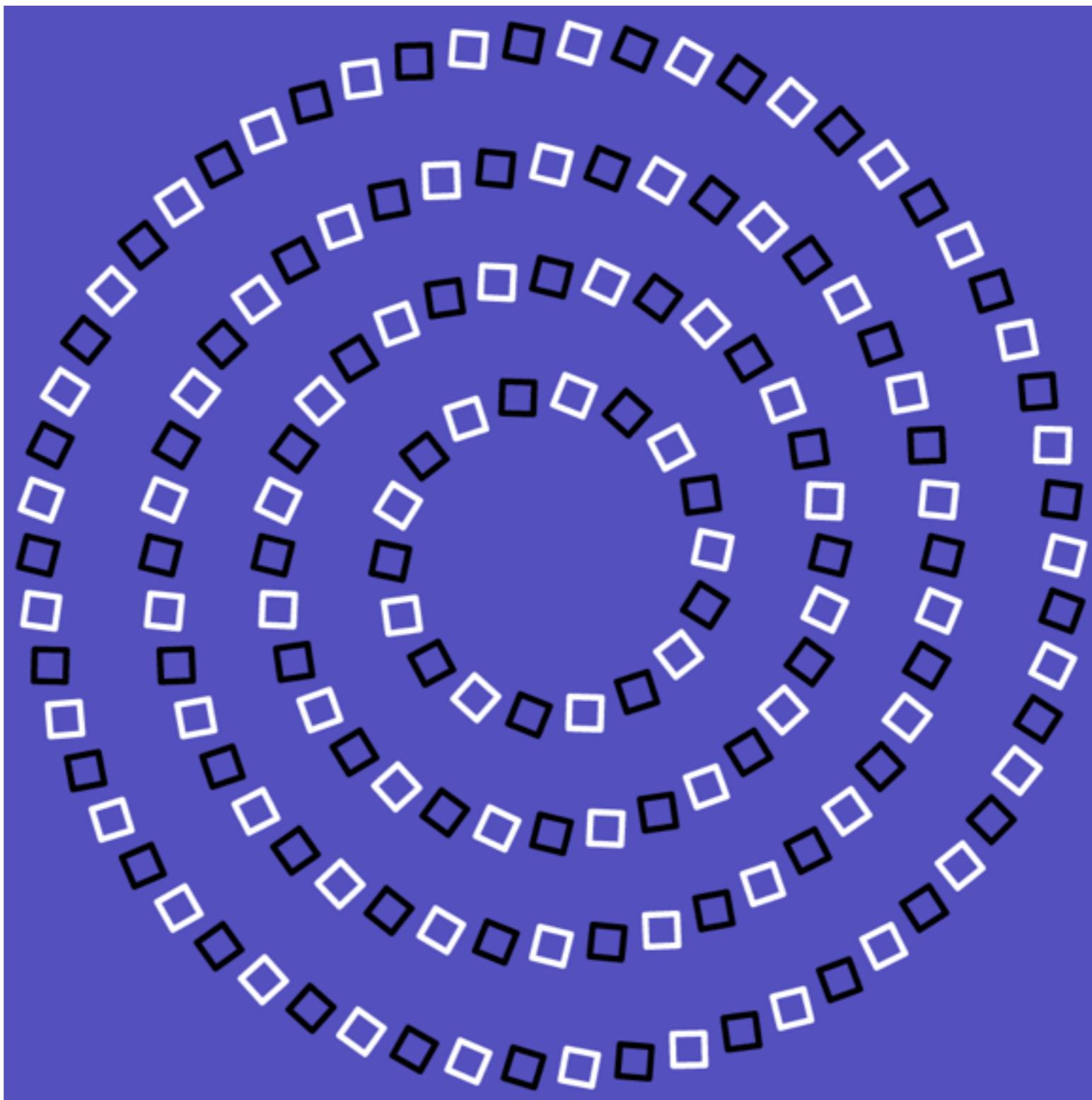
Why worry about principles?

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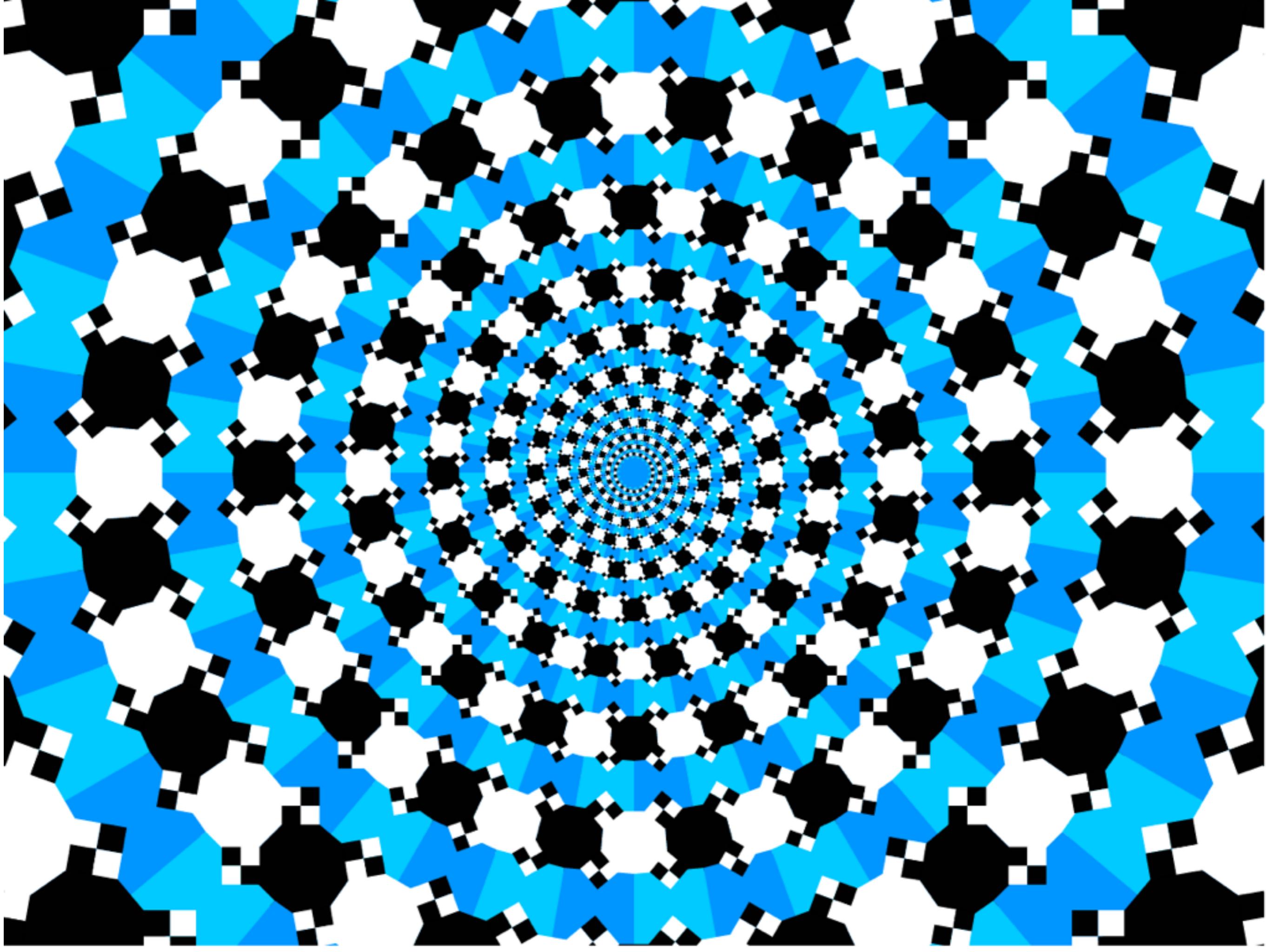


Ninio's extinction illusion

Why worry about principles?



<https://cscheid.net/2014/12/13/not-spirals.html>

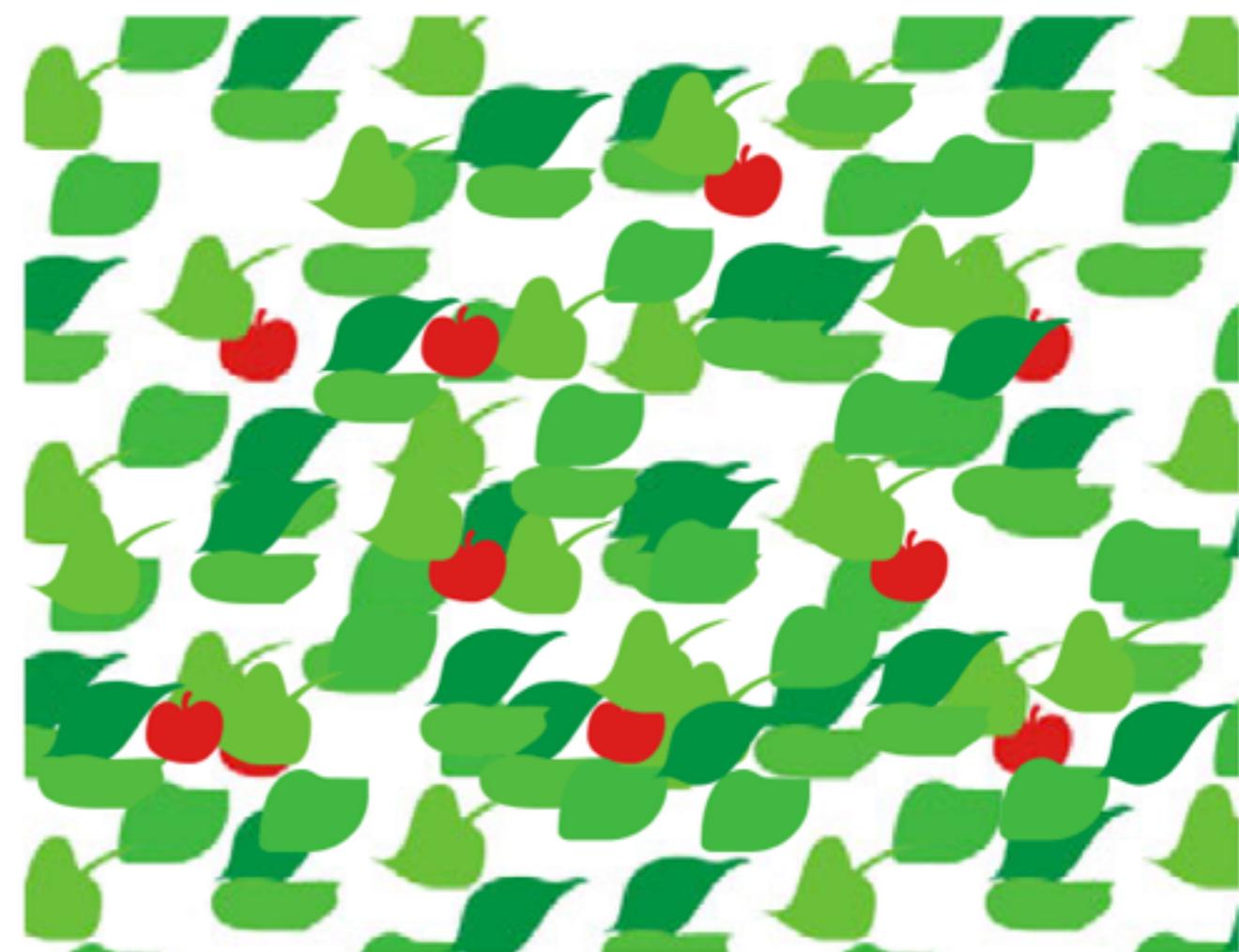


VISION IS COMPLICATED

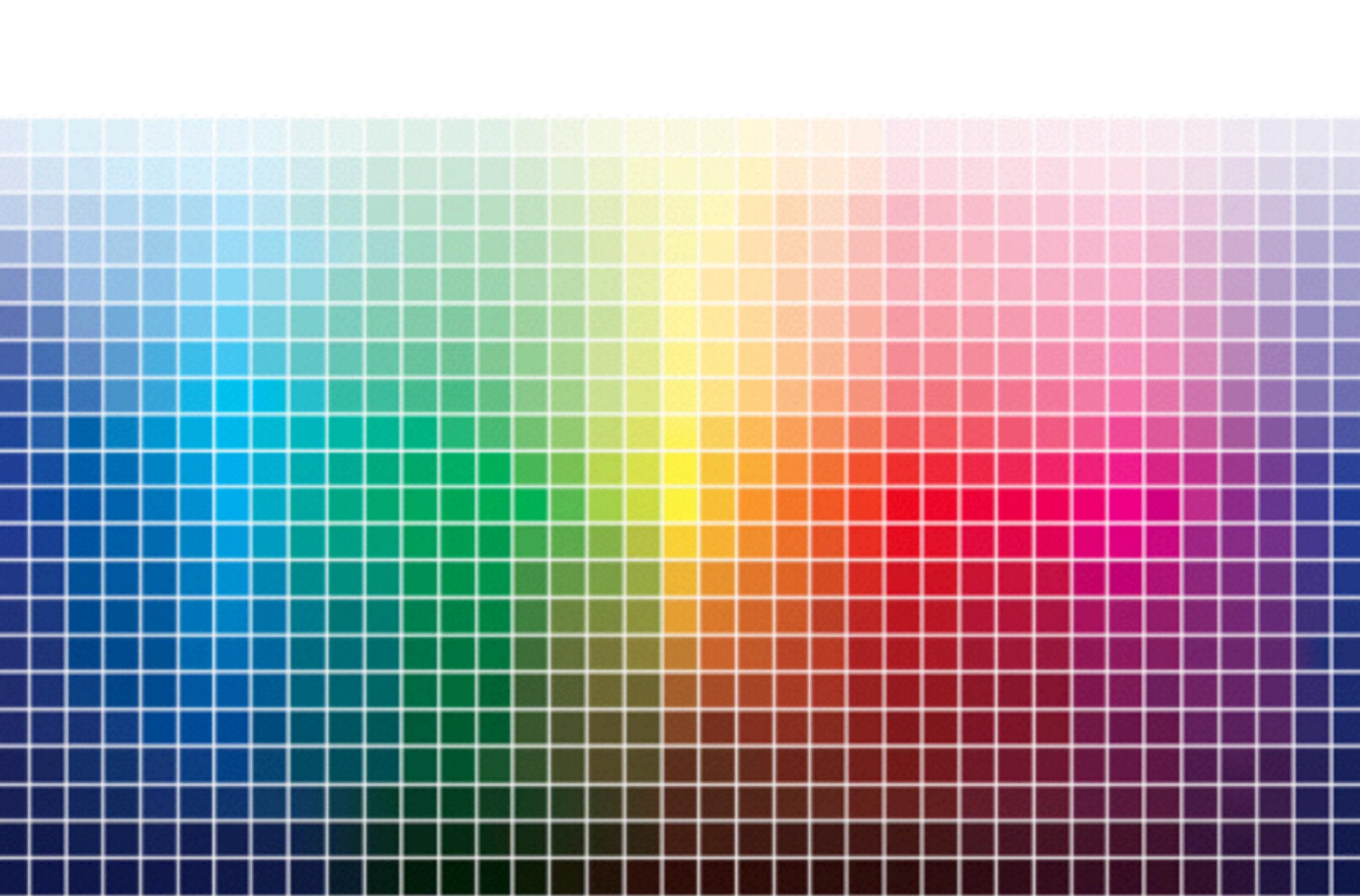
Reading

- “Representing Colors as Three Numbers”, Stone
- Rainbow Colormap (Still) Considered Harmful,
Borland and Russell.
- Optional:
 - Face-based Luminance Matching... Kindlmann et al.

WHY COLOR?



Colin Ware, Information Visualization



LIGHT AND
COLOR

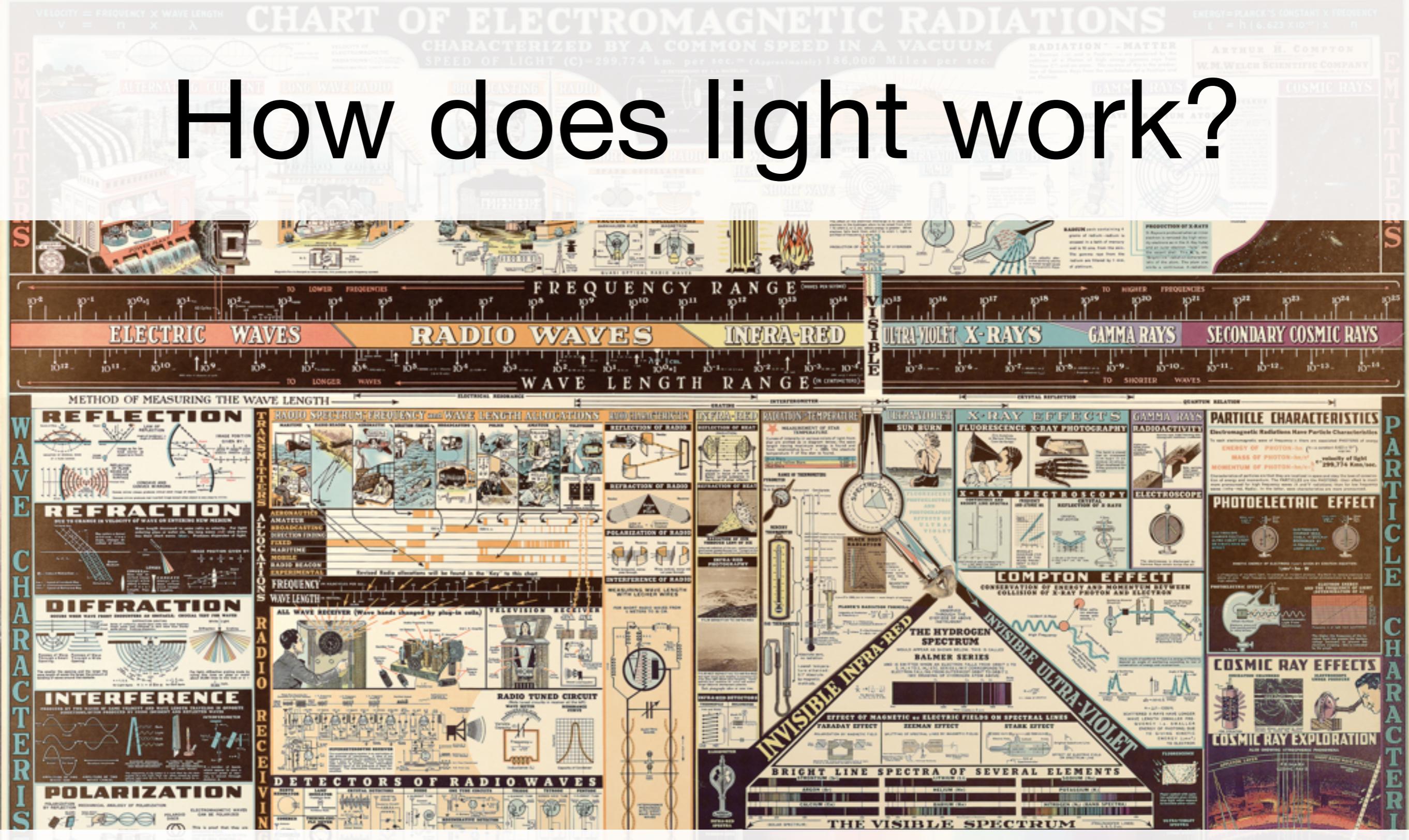
How does the yellow from your
laptop display “equal” the yellow
from the **sun**, and that from a
painting?

How does light work?

- Each photon has a “wavelength”, roughly the frequency in which it wiggles as it travels through space
- **Visible light** is the same thing as **FM radio** is the same thing as **X-rays** is the same thing as **microwaves**



How does light work?



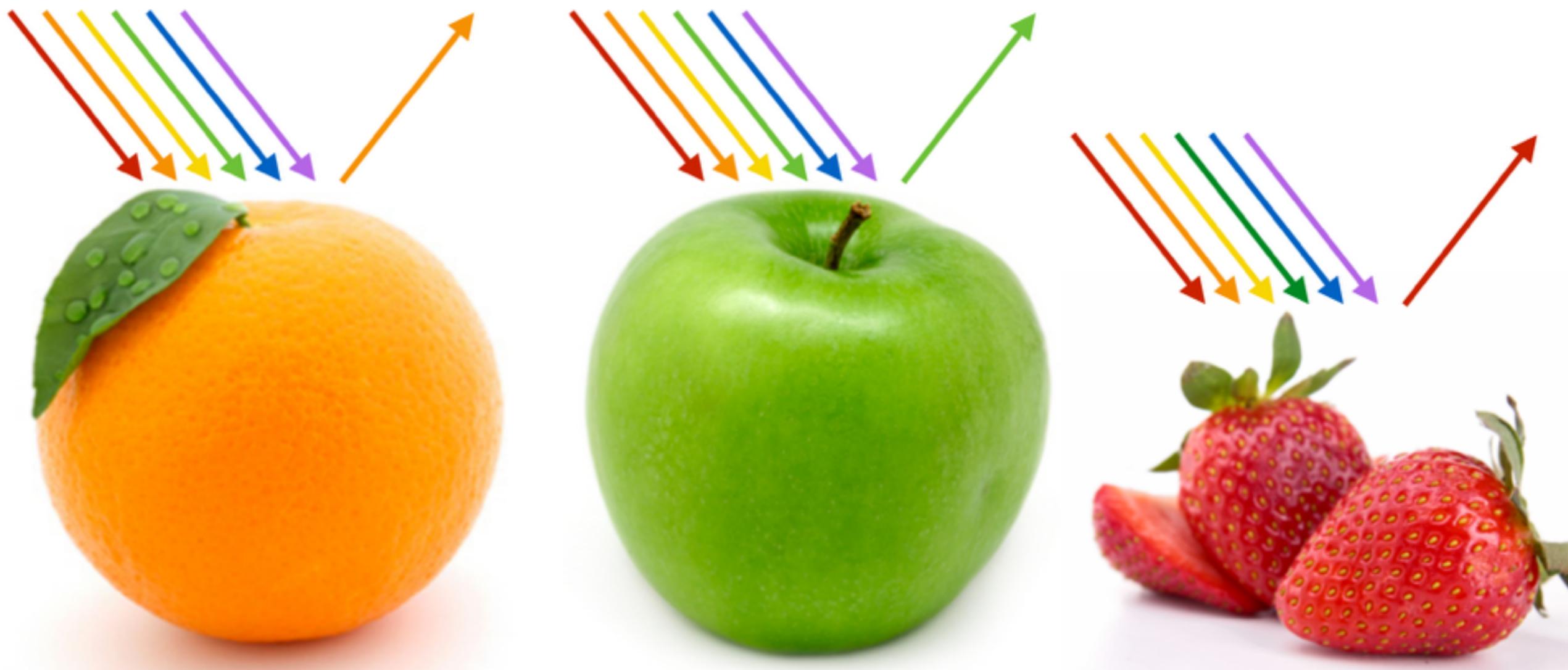
<https://www.flickr.com/photos/llnl/9403051123/>

How does light work?

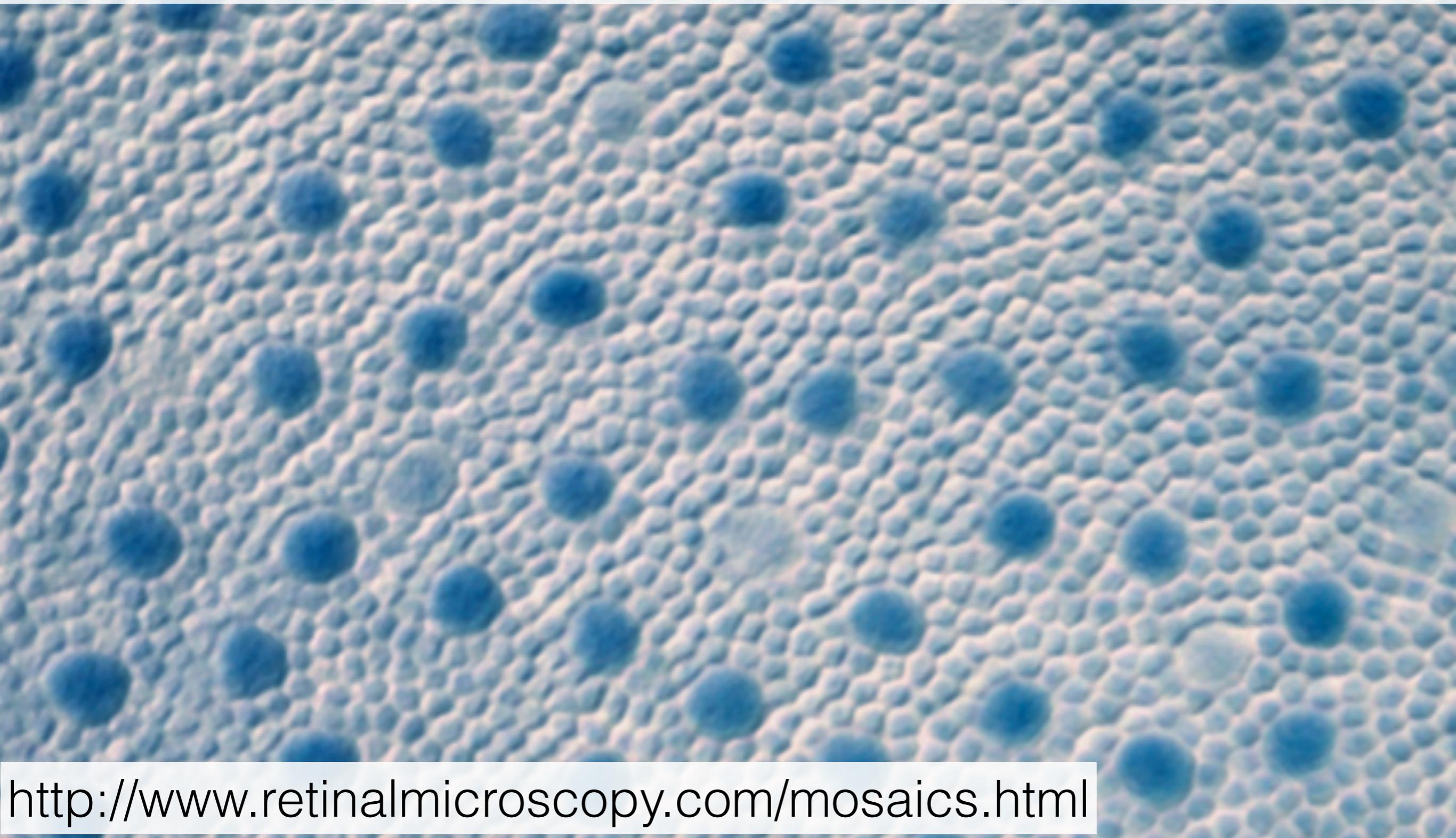
[http://www.chemistryland.com/CHM107Lab/Exp7/
Spectroscope/Spectroscope.html](http://www.chemistryland.com/CHM107Lab/Exp7/Spectroscope/Spectroscope.html)



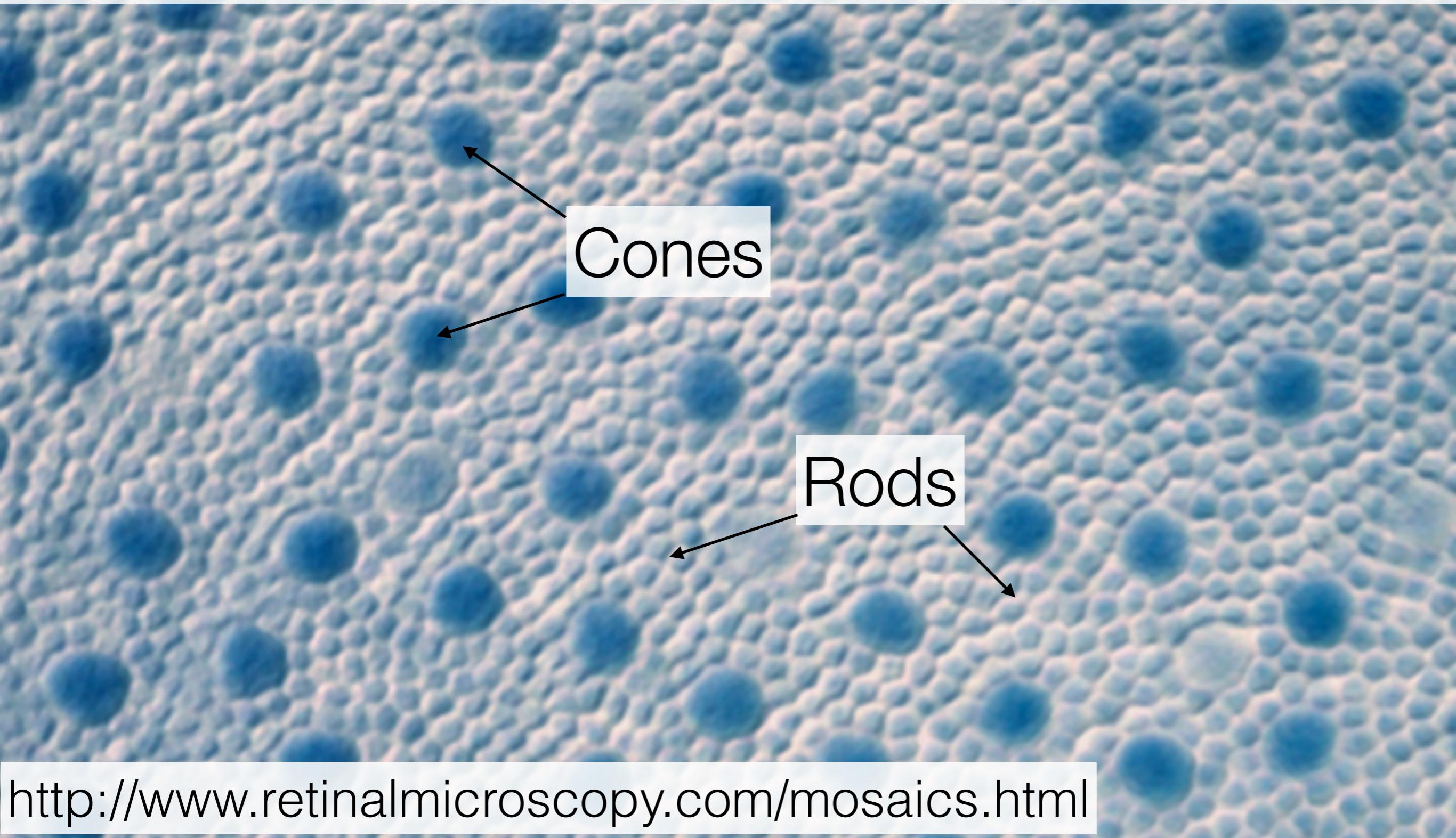
How does light work?



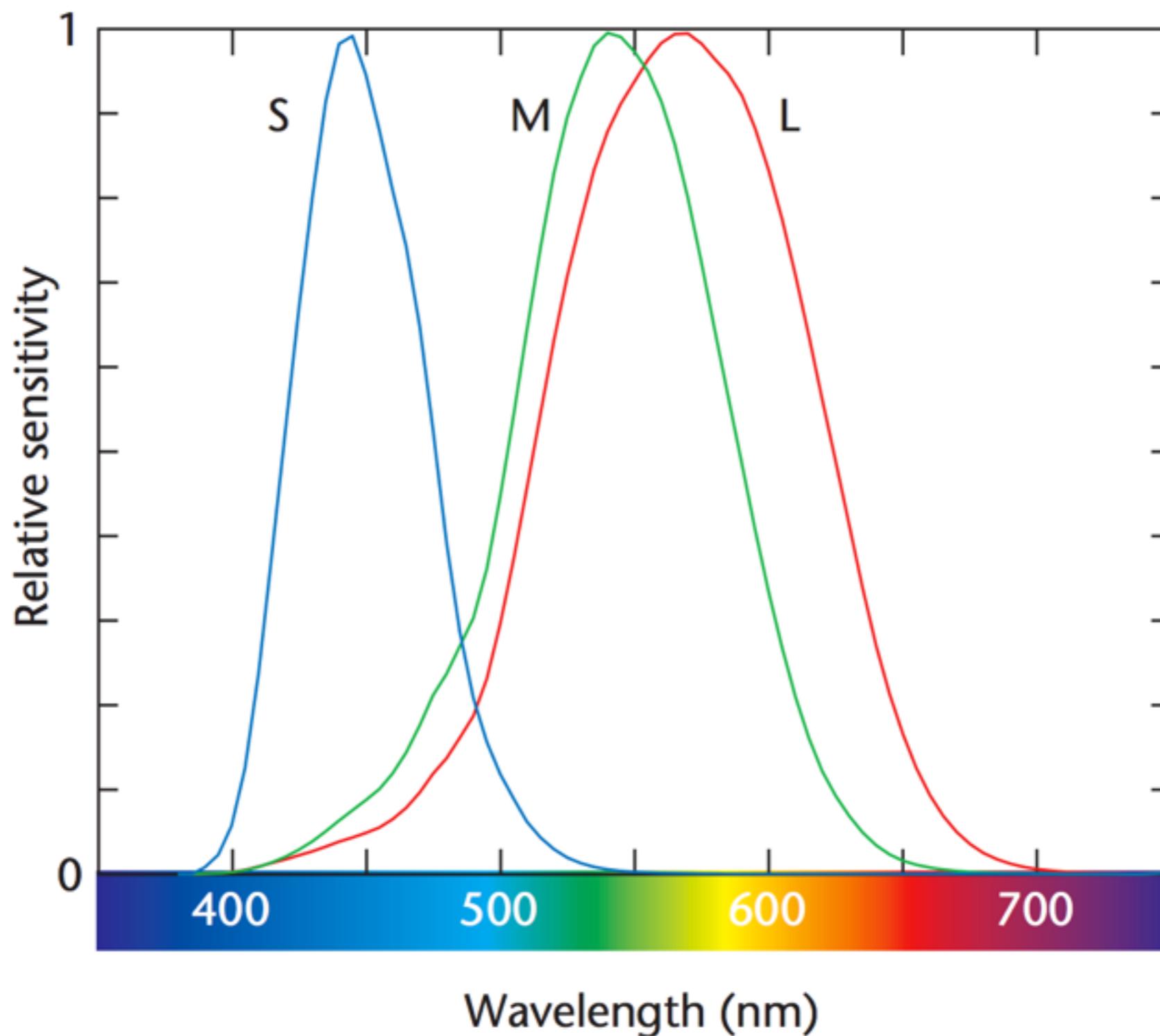
How does your eye work?



How does your eye work?

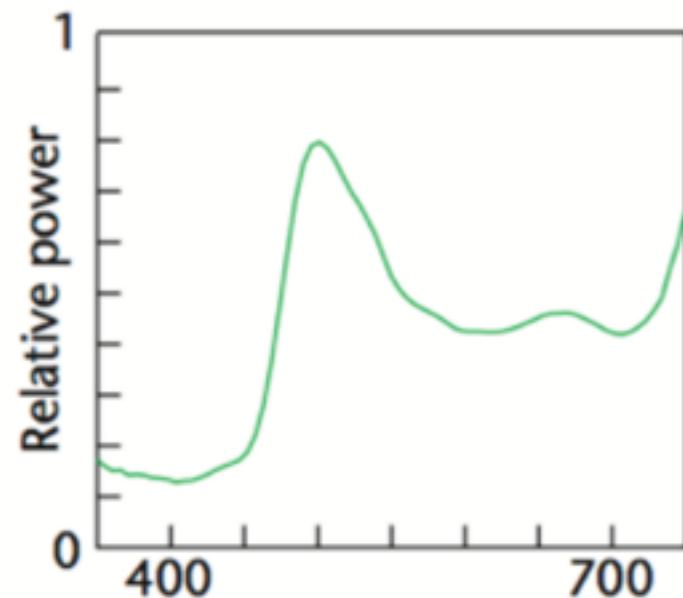


How does your eye work?

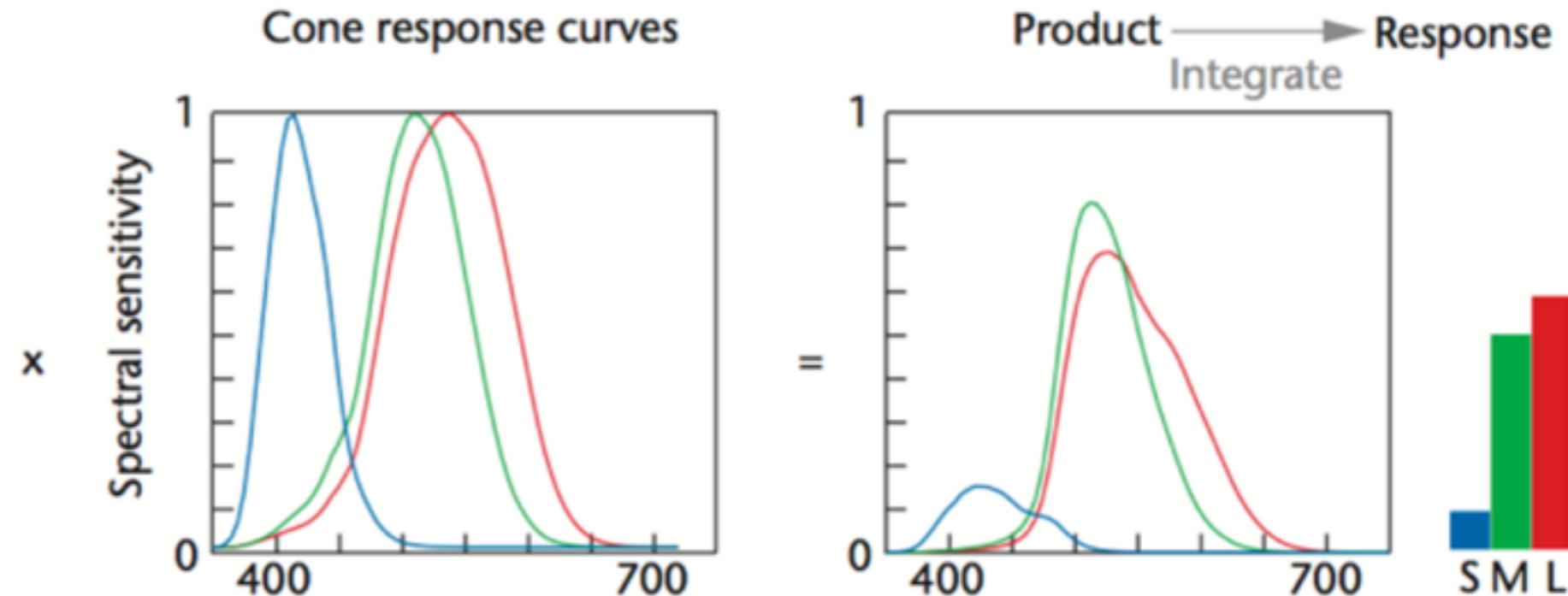


TRICHRAMY

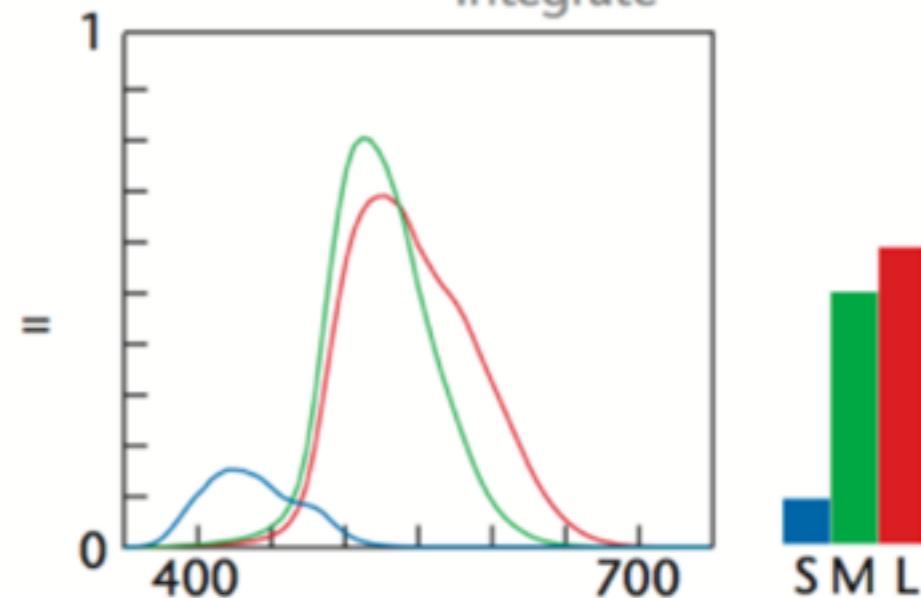
Input stimulus



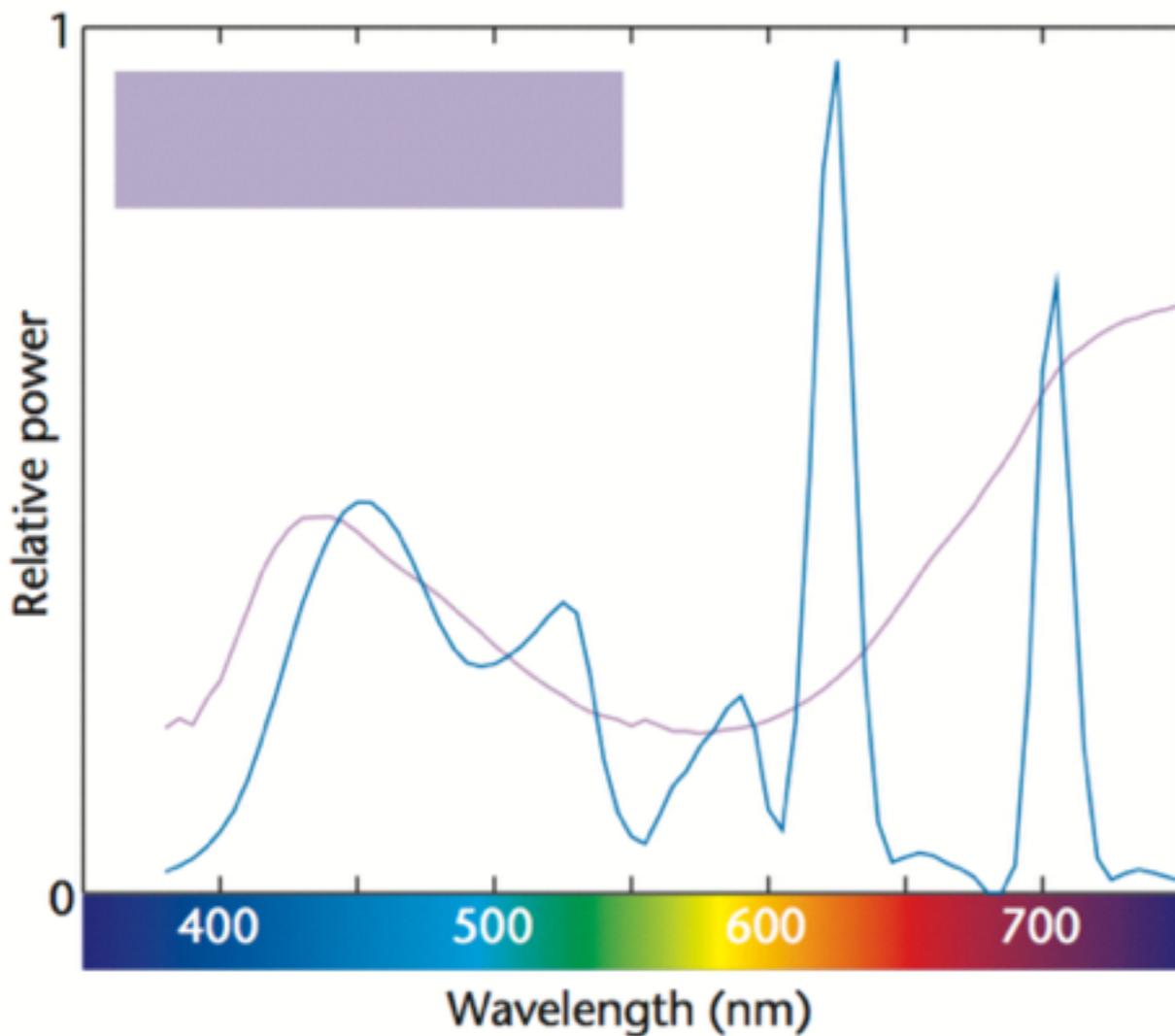
Cone response curves



Product \longrightarrow Response
Integrate



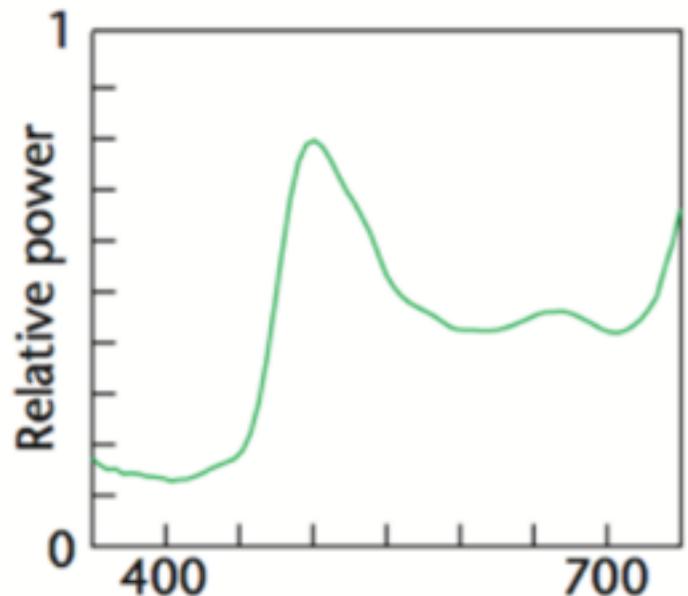
Three numbers!



same three numbers,
same impression

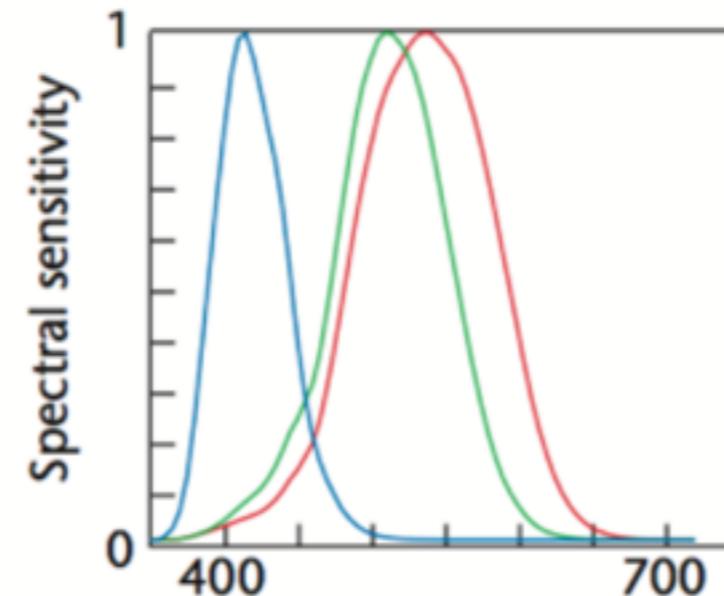
METAMERISM

Input stimulus



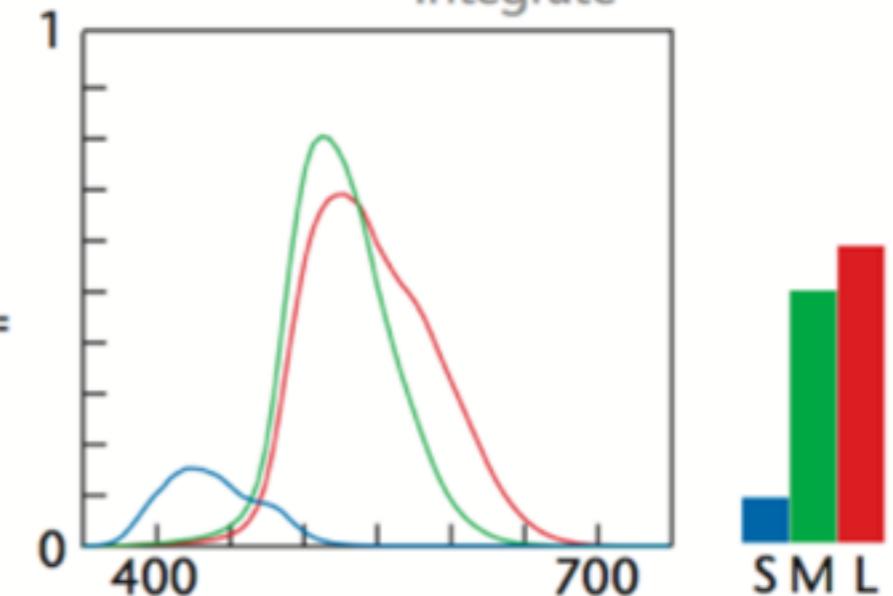
x

Cone response curves

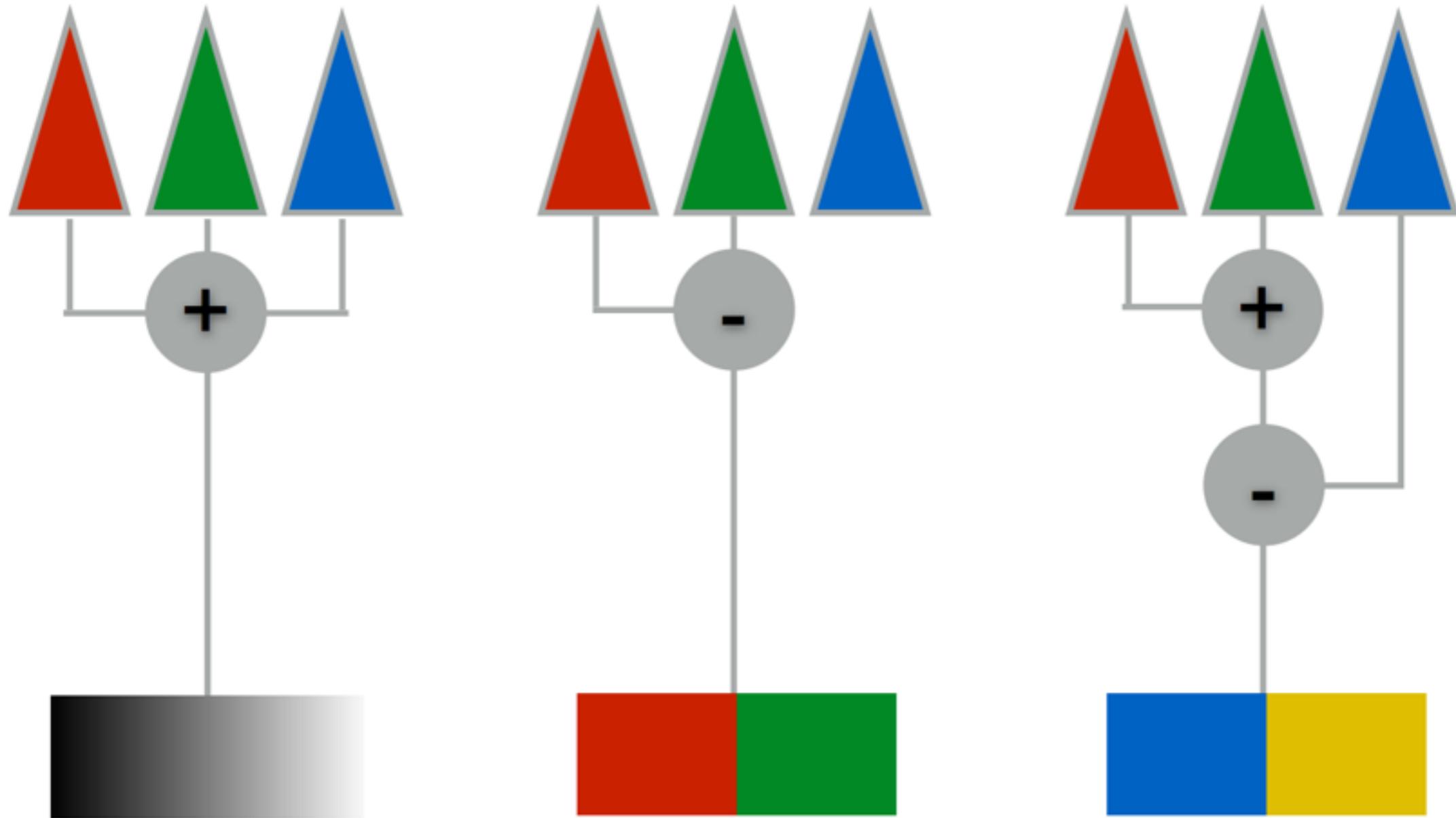


=

Product \longrightarrow Response
Integrate

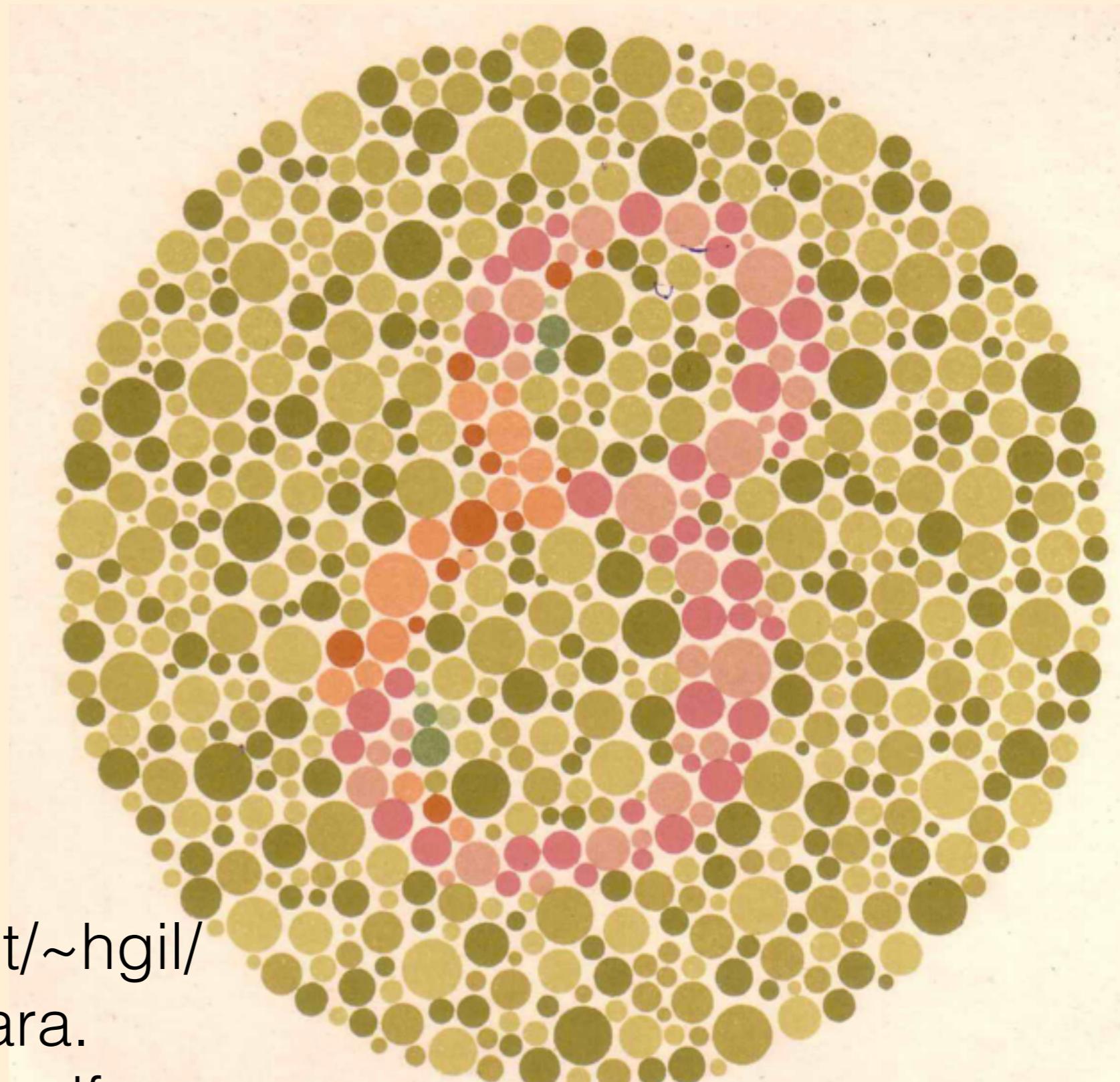


OPPONENT PROCESS MODEL



COLOR VISION DEFICIENCIES

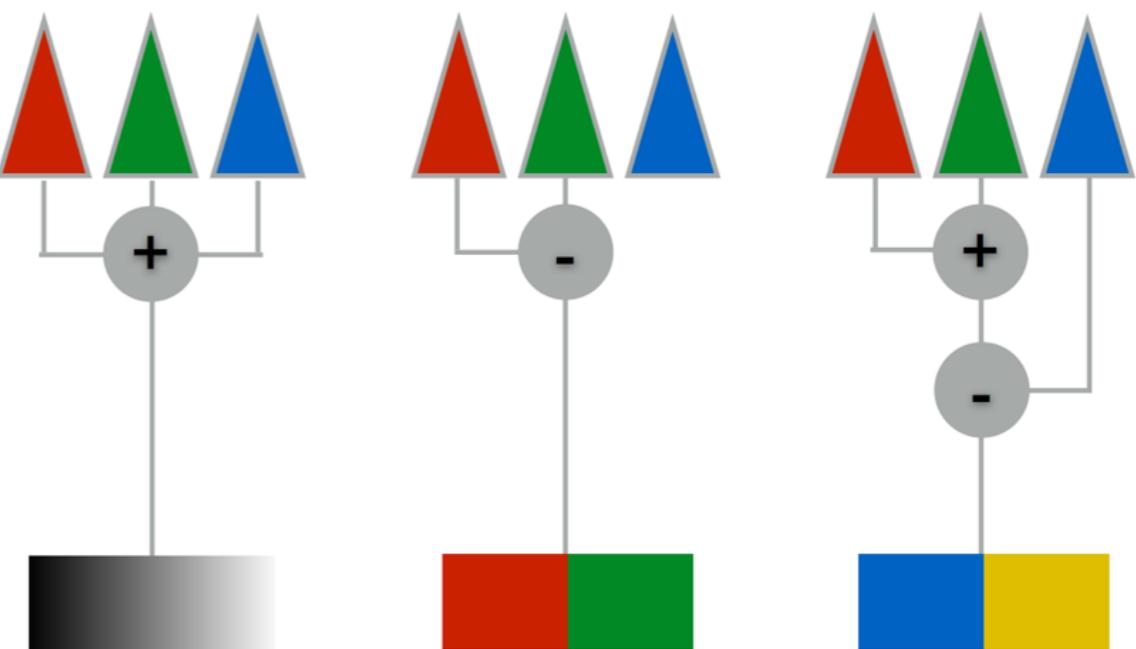
Ishihara Plates



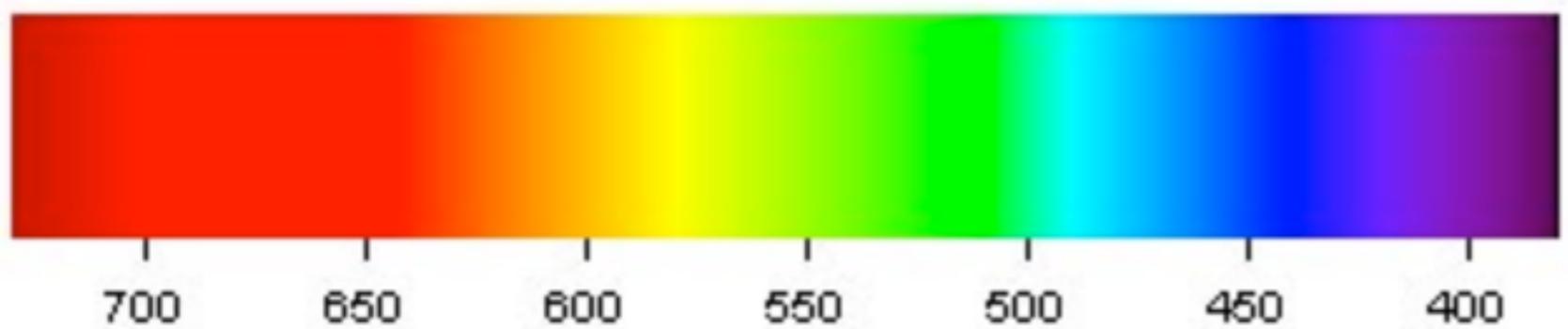
[http://www.dfisica.ubi.pt/~hgil/
p.v.2/Ishihara/Ishihara.
24.Plate.TEST.Book.pdf](http://www.dfisica.ubi.pt/~hgil/p.v.2/Ishihara/Ishihara.24.Plate.TEST.Book.pdf)

What goes wrong?

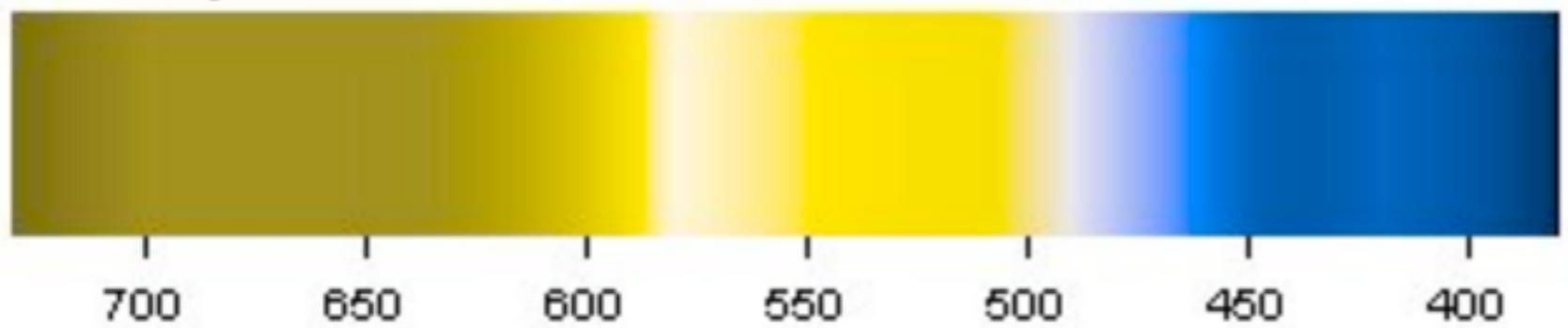
- Two broad classes of problems:
 - Only some types of cones present in the eye (rare)
 - red-green dichromacy, blue-yellow dichromacy
 - Two types of cones with abnormally close response curves
 - relatively common for red-green



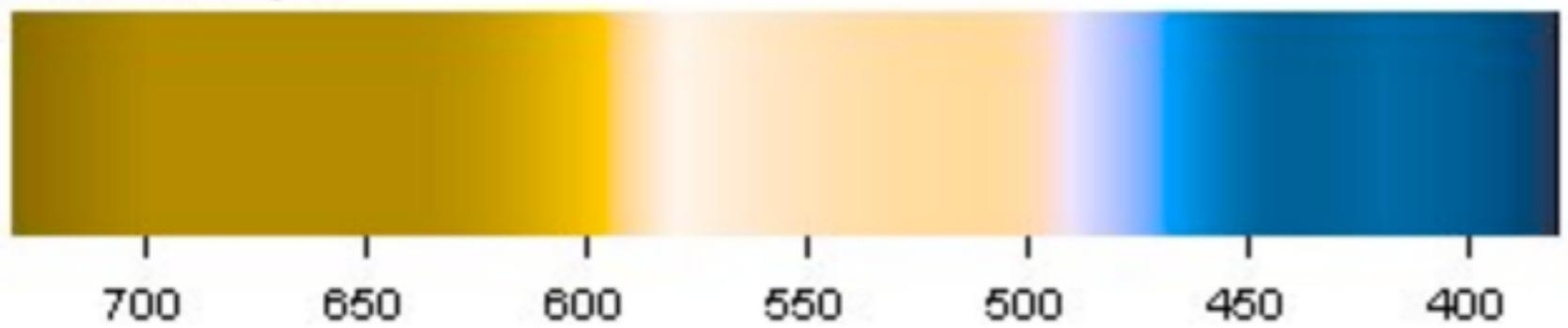
Normal



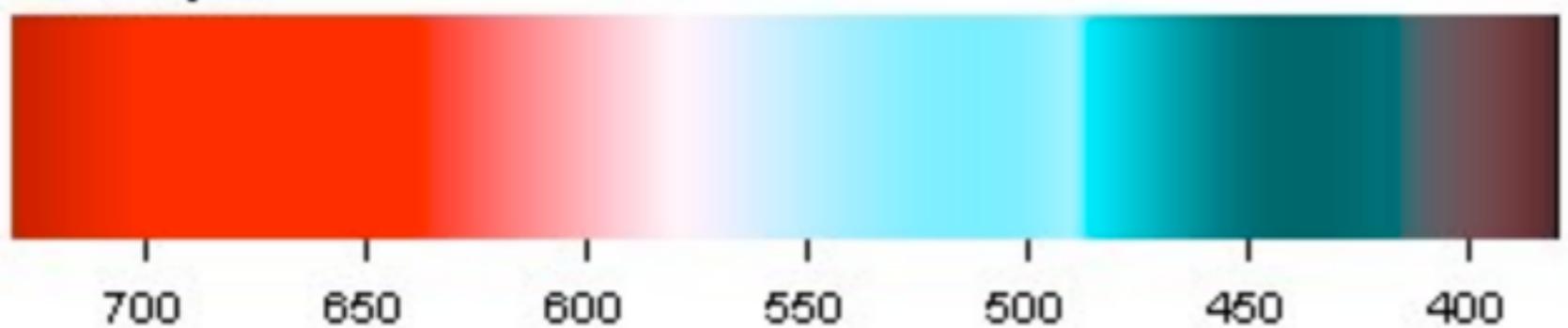
Protanopia



Deuteranopia



Tritanopia



WHAT ARE THE
PRIMARY COLORS?

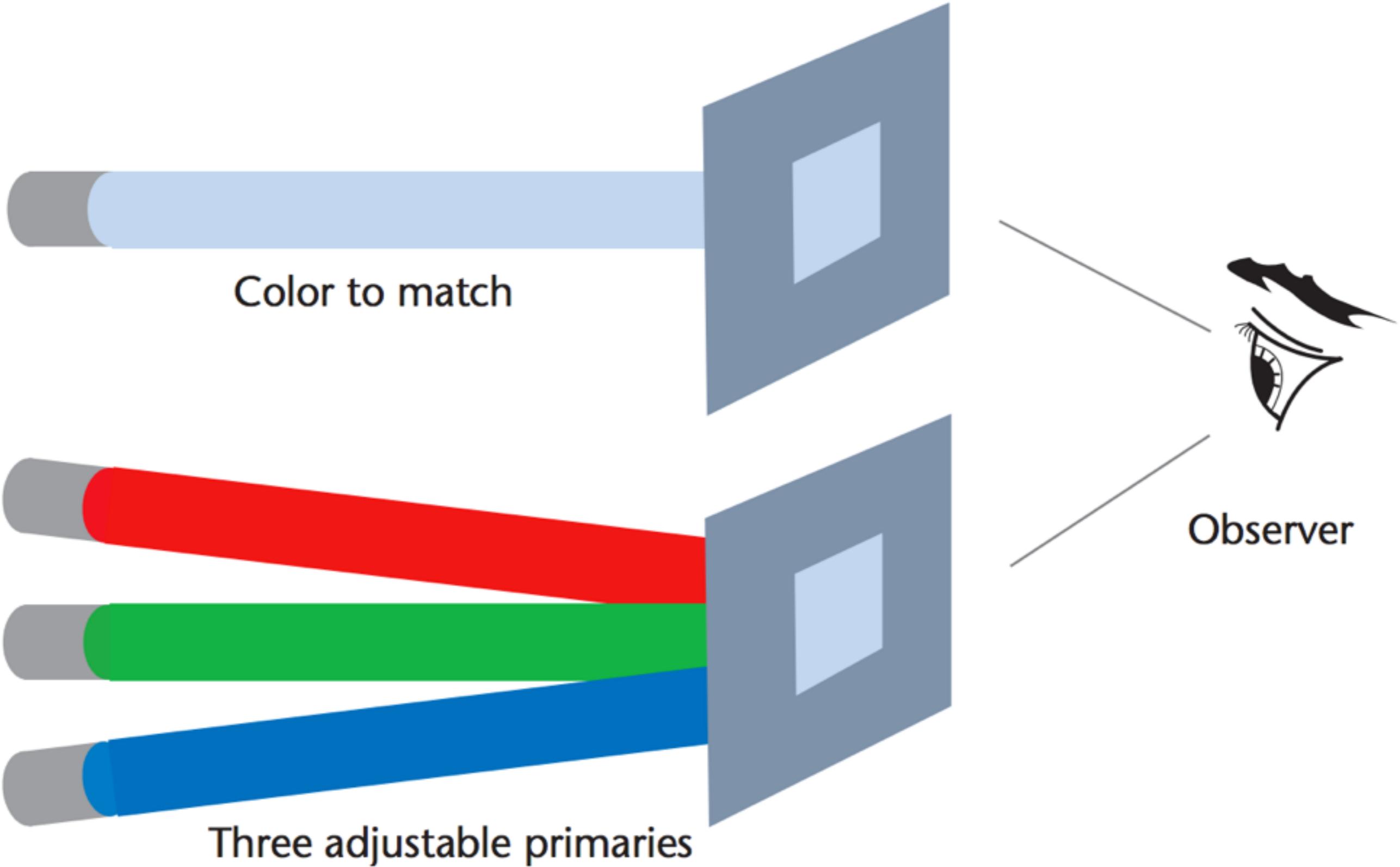
WHAT ARE THE PRIMARY COLORS?

1. red, green, blue
2. red, yellow, blue
3. orange, green, violet
4. cyan, magenta, yellow

WHAT ARE THE PRIMARY COLORS?

1. red, green, blue
2. red, yellow, blue
3. orange, green, violet
4. cyan, magenta, yellow
5. **all of the above**

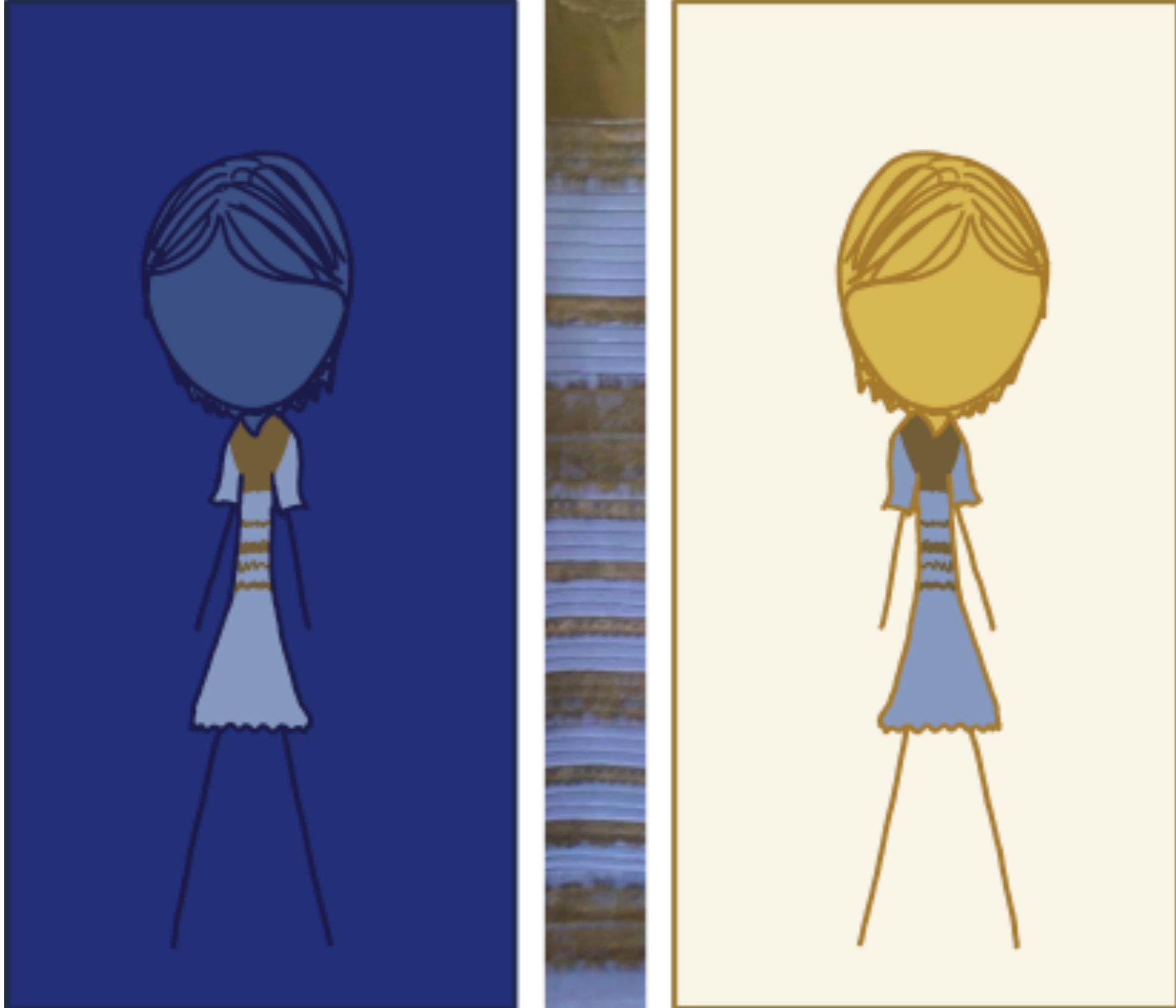
Any three “independent”
ways of combining color
works (!)



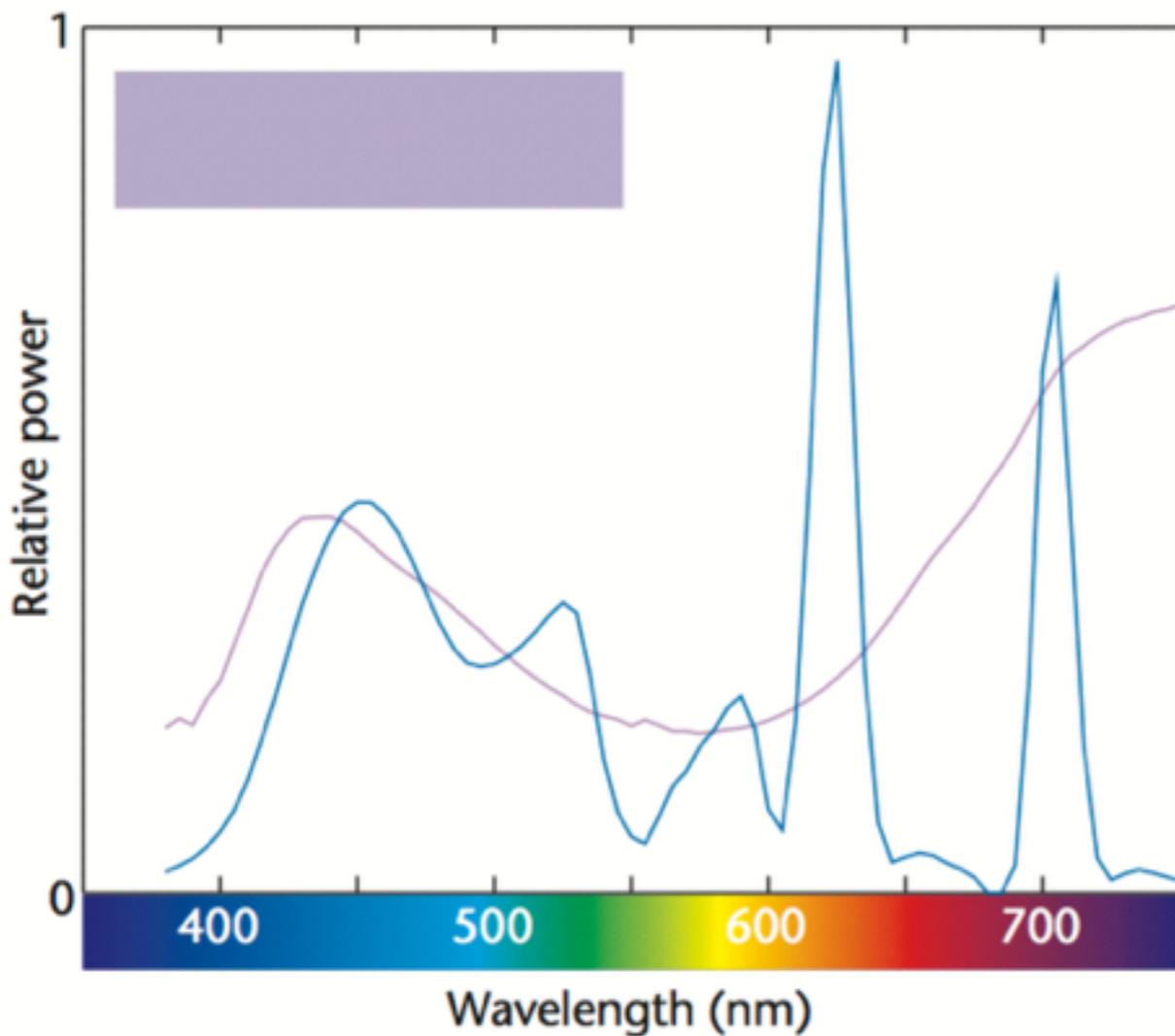
Any three “independent” ways of combining color works (!) ... and it works against **any background color!**



<http://swiked.tumblr.com/post/112073818575/guys-please-help-me-is-this-dress-white-and>

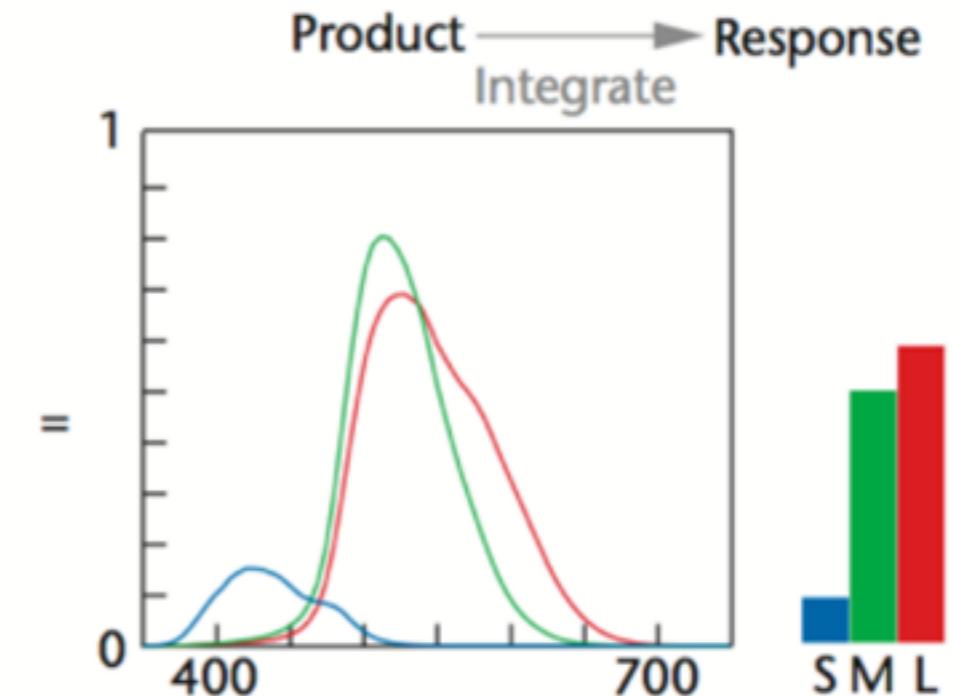
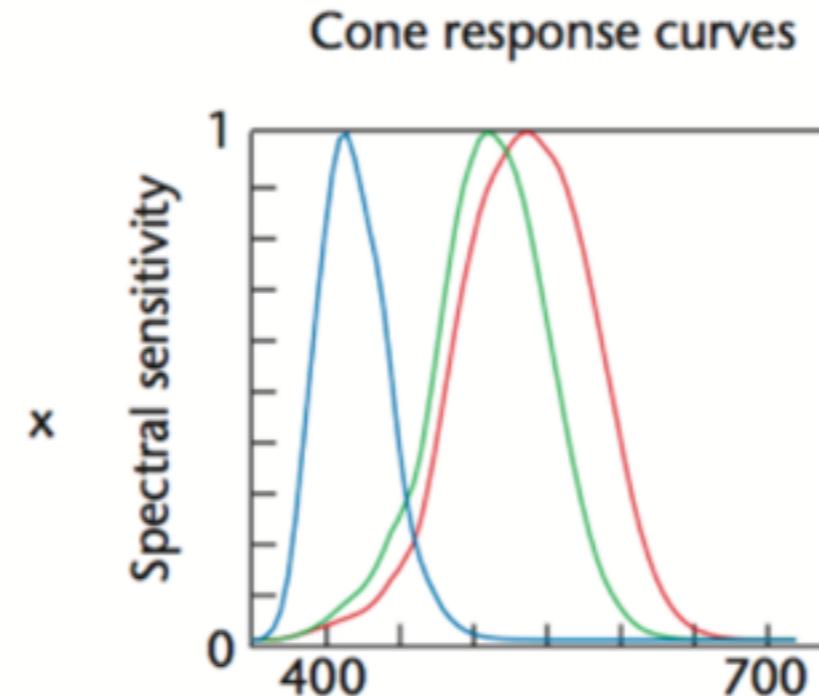
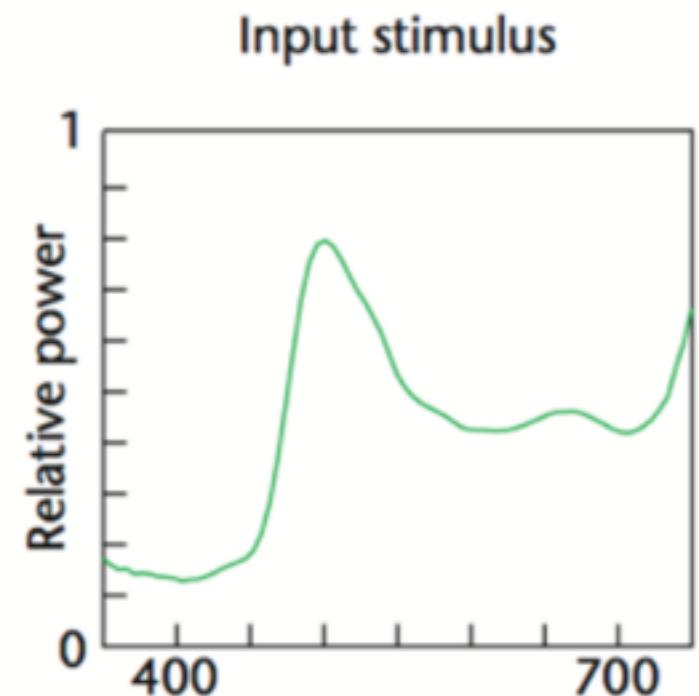


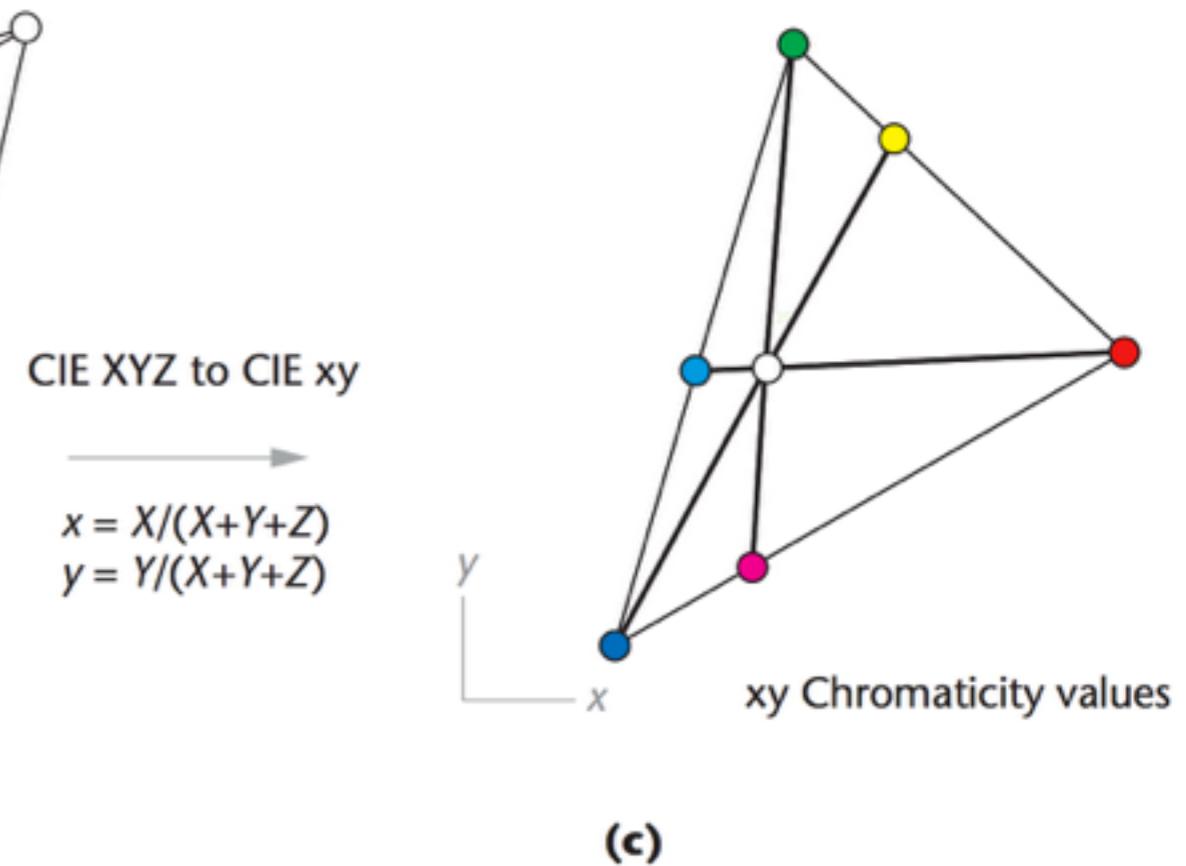
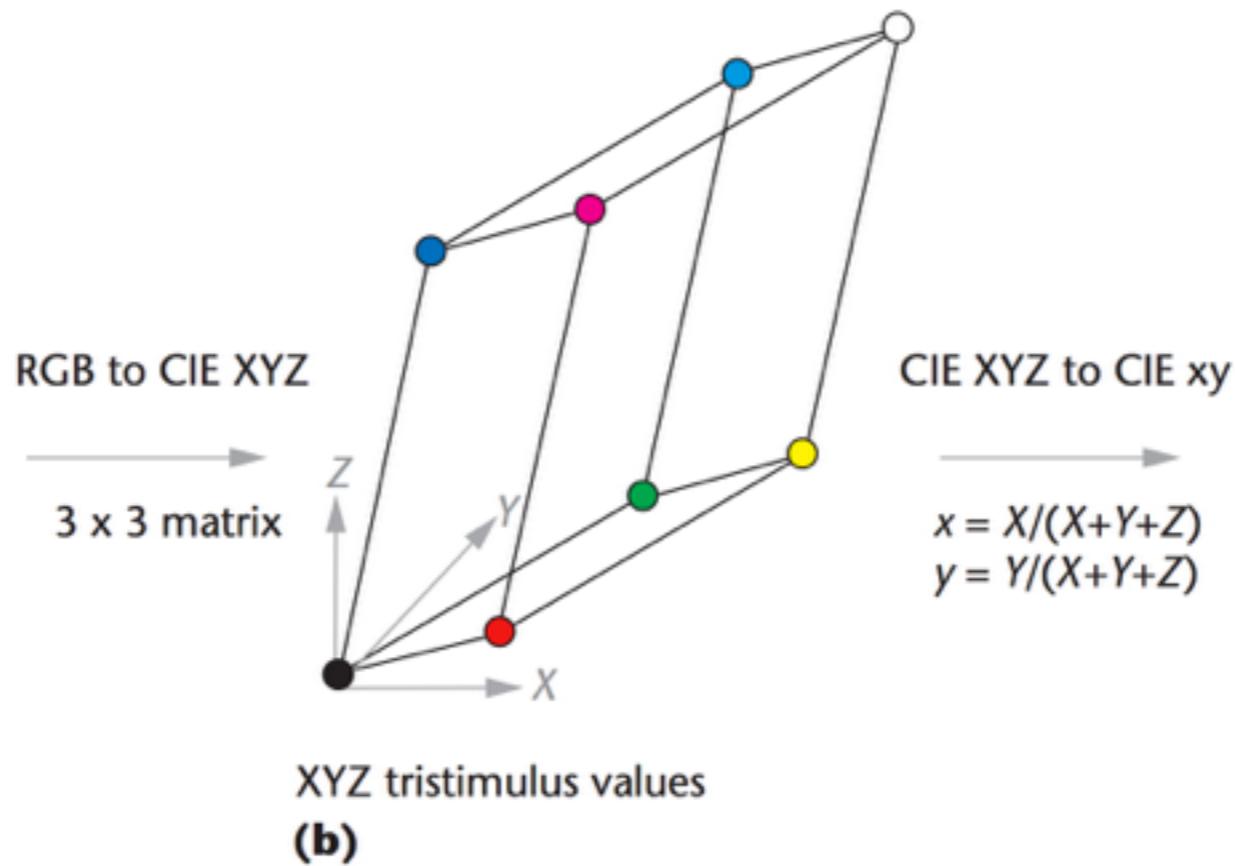
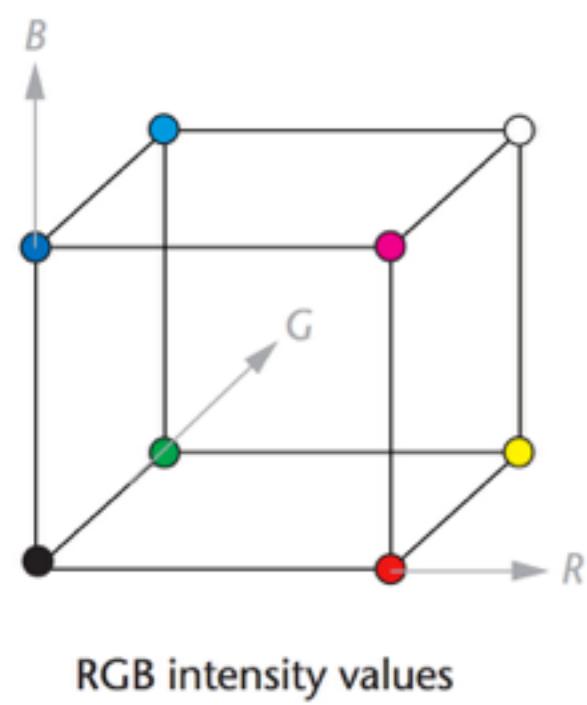
<https://xkcd.com/1492/>

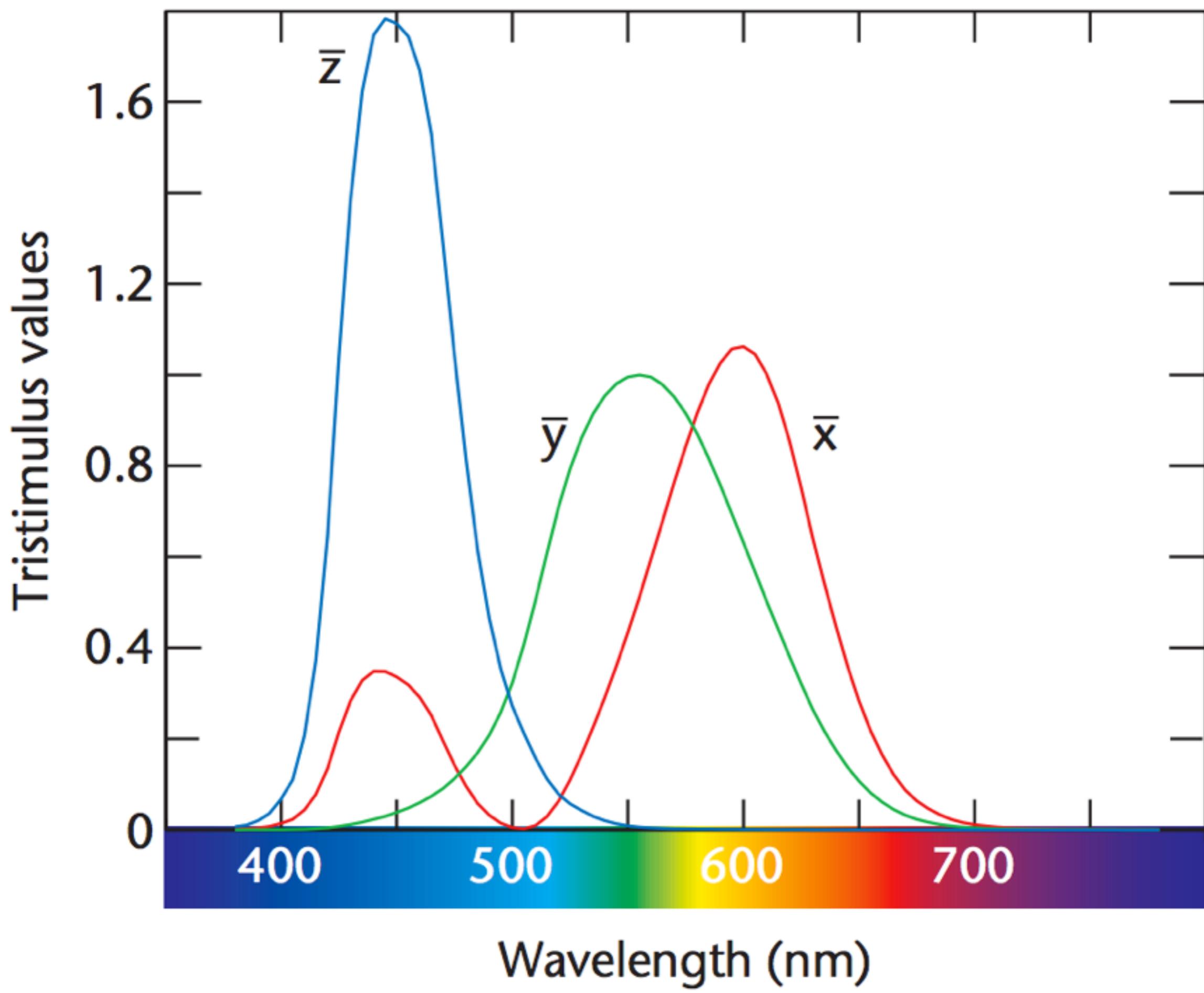


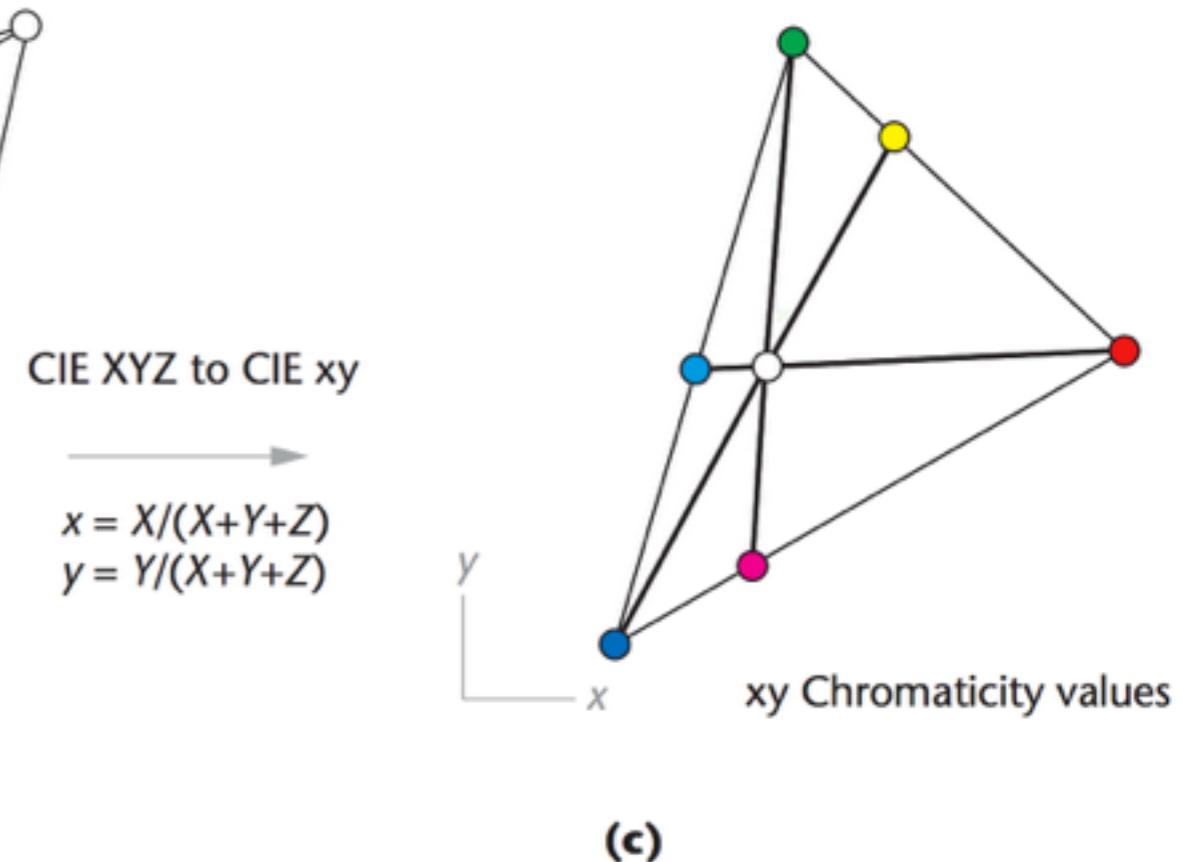
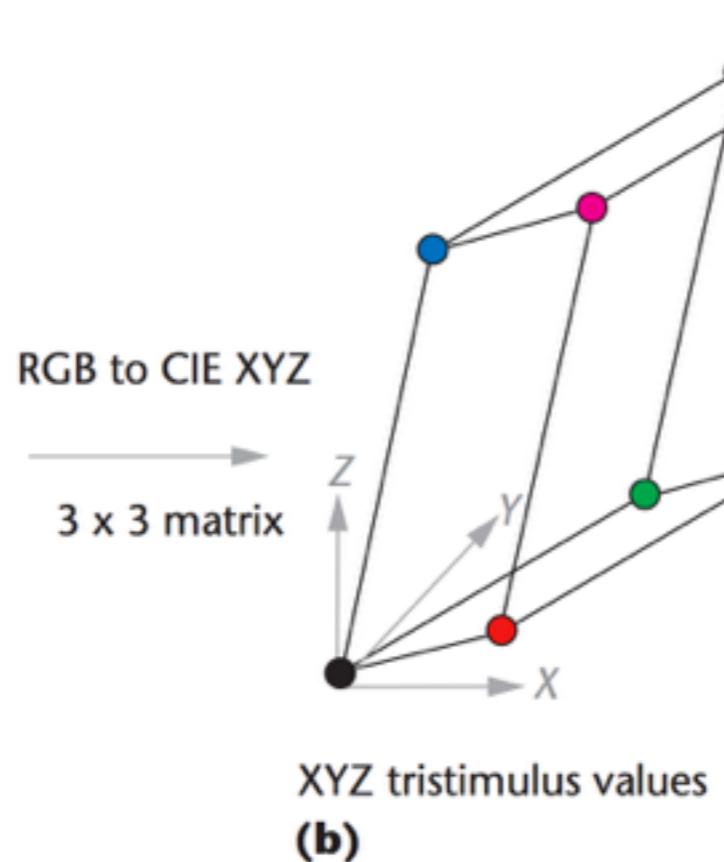
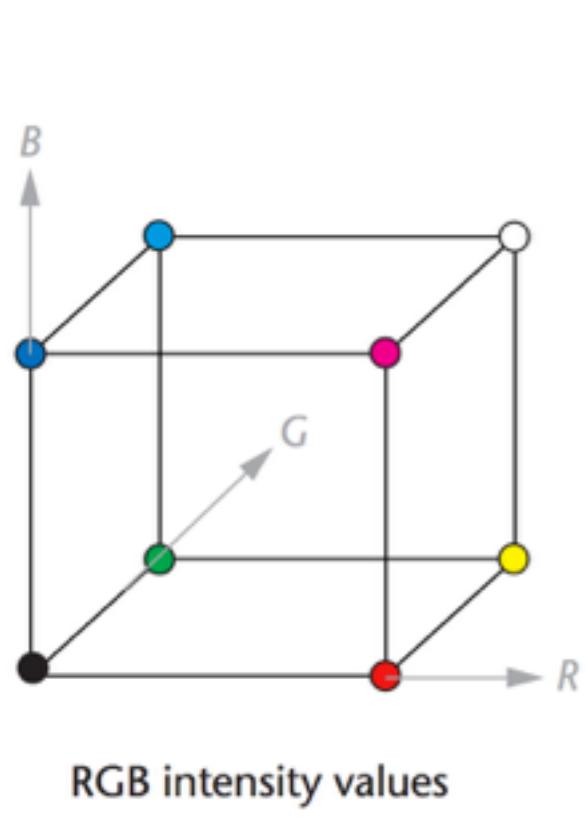
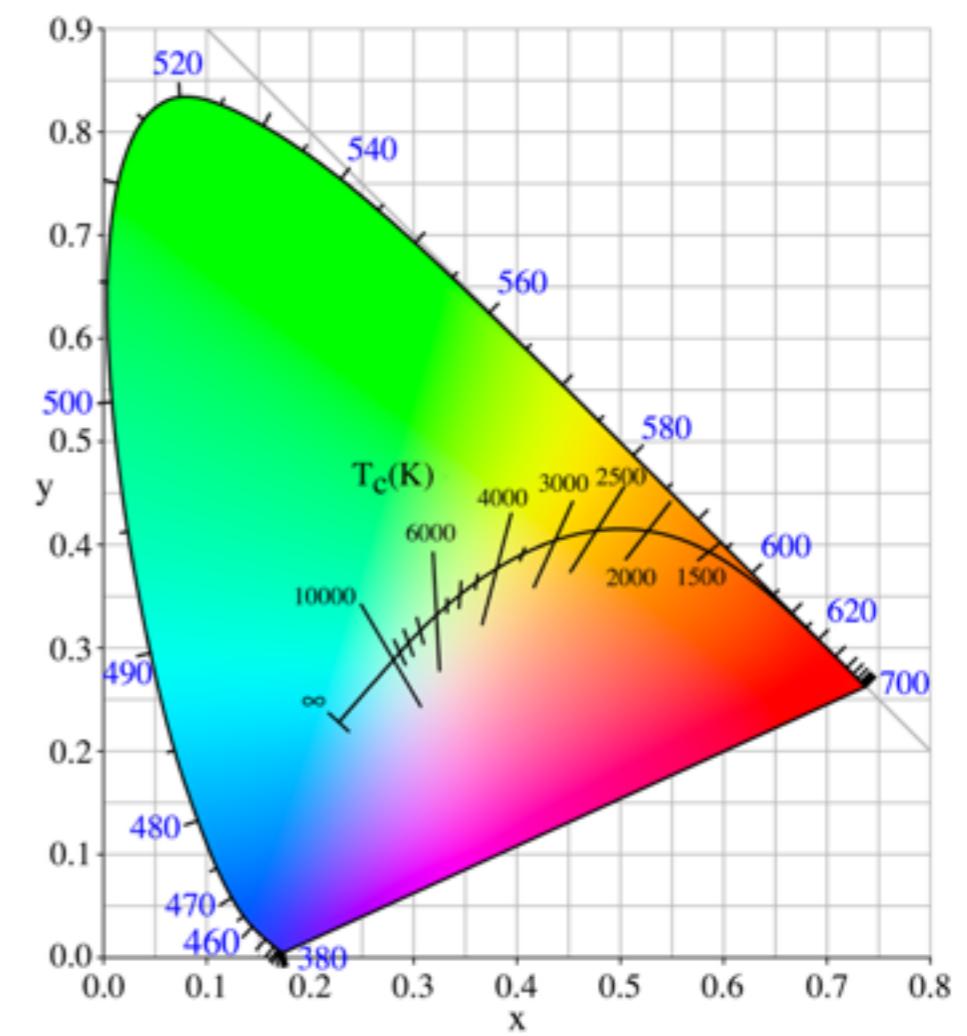
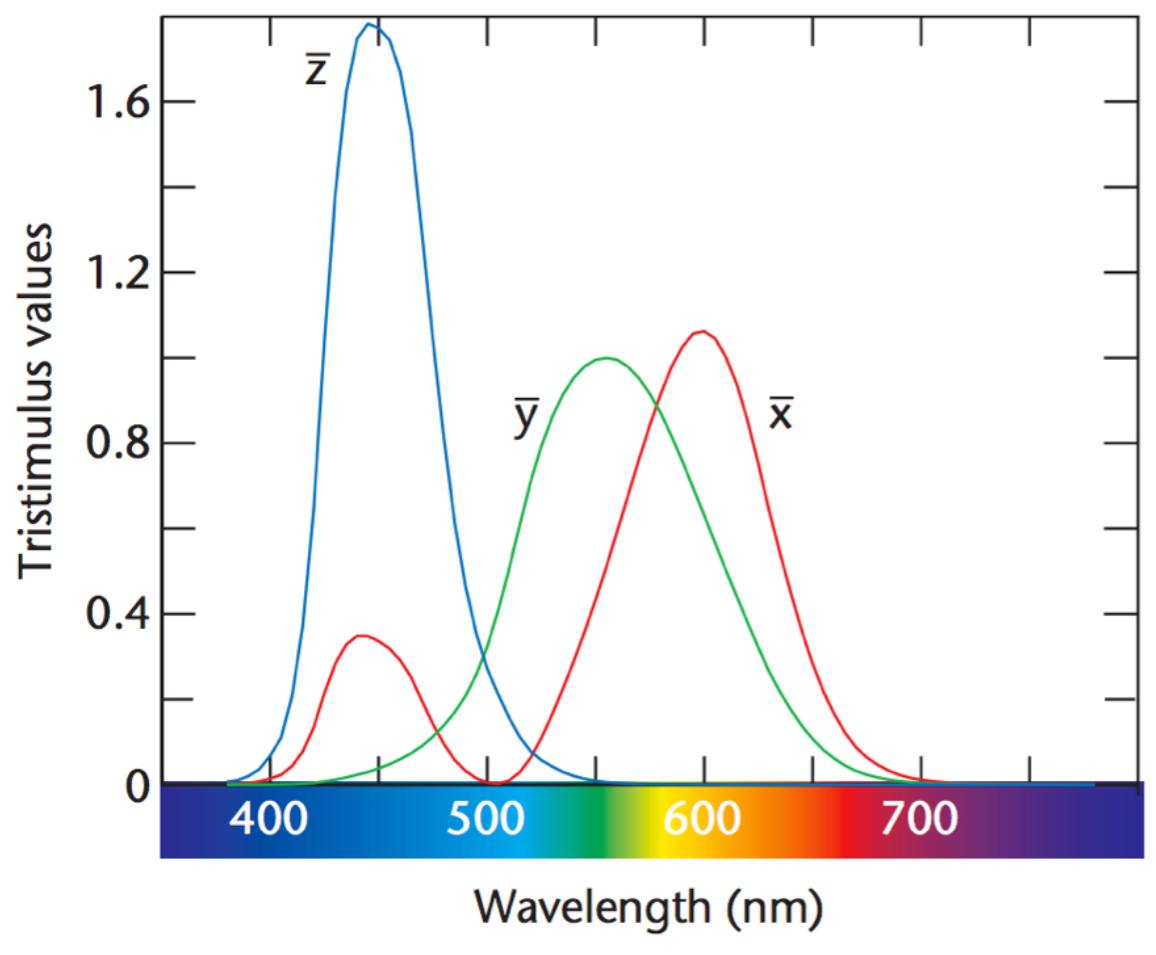
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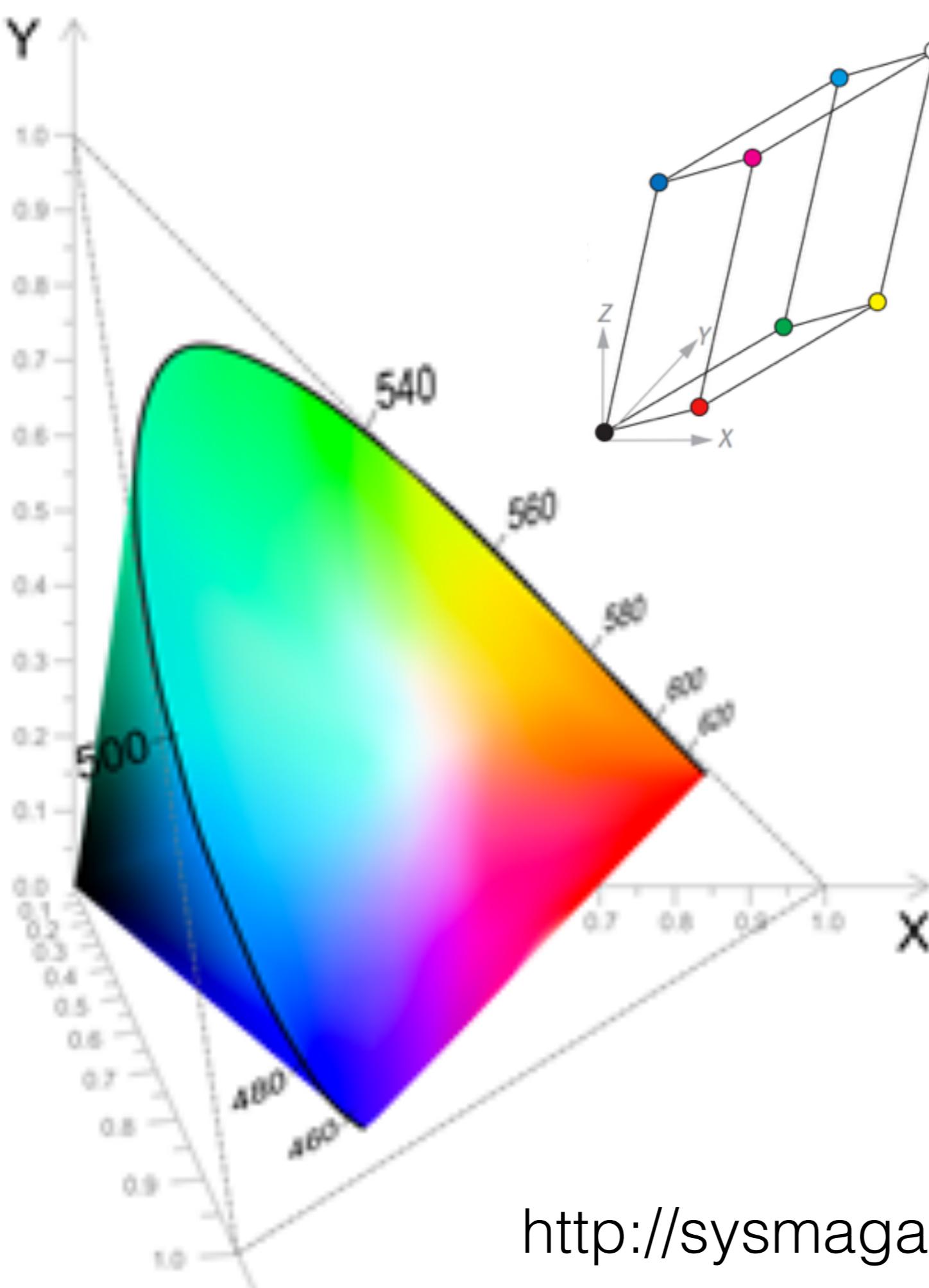
METAMERISM







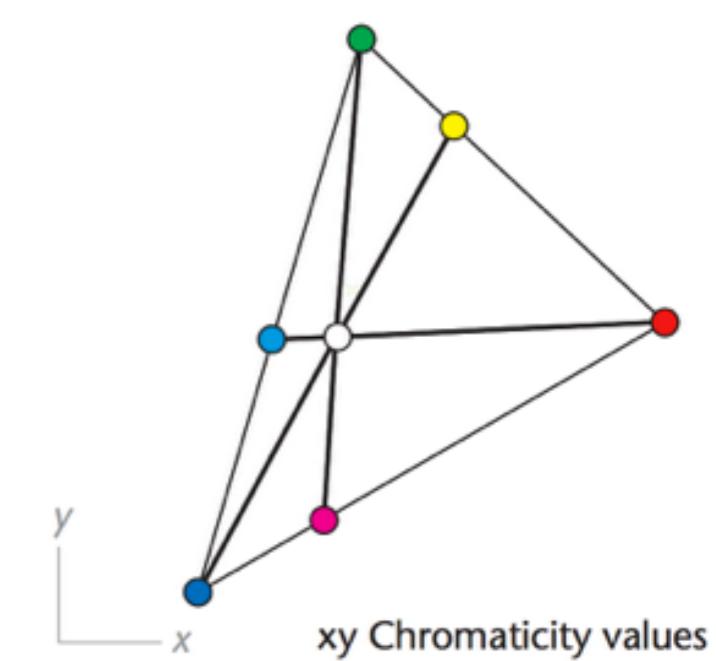




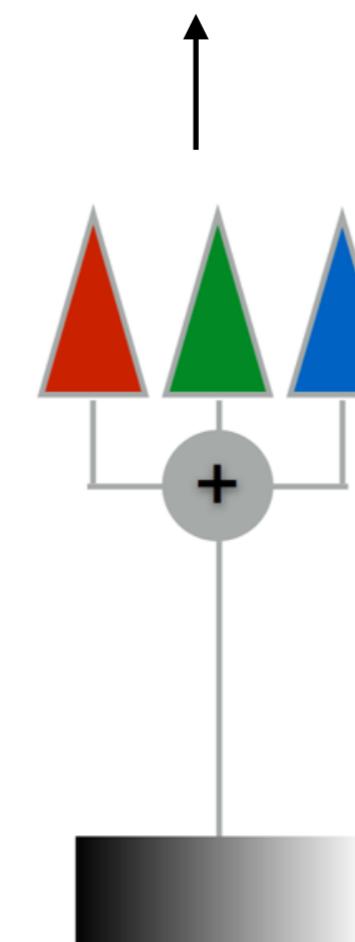
CIE XYZ to CIE xy

$$x = X/(X+Y+Z)$$

$$y = Y/(X+Y+Z)$$

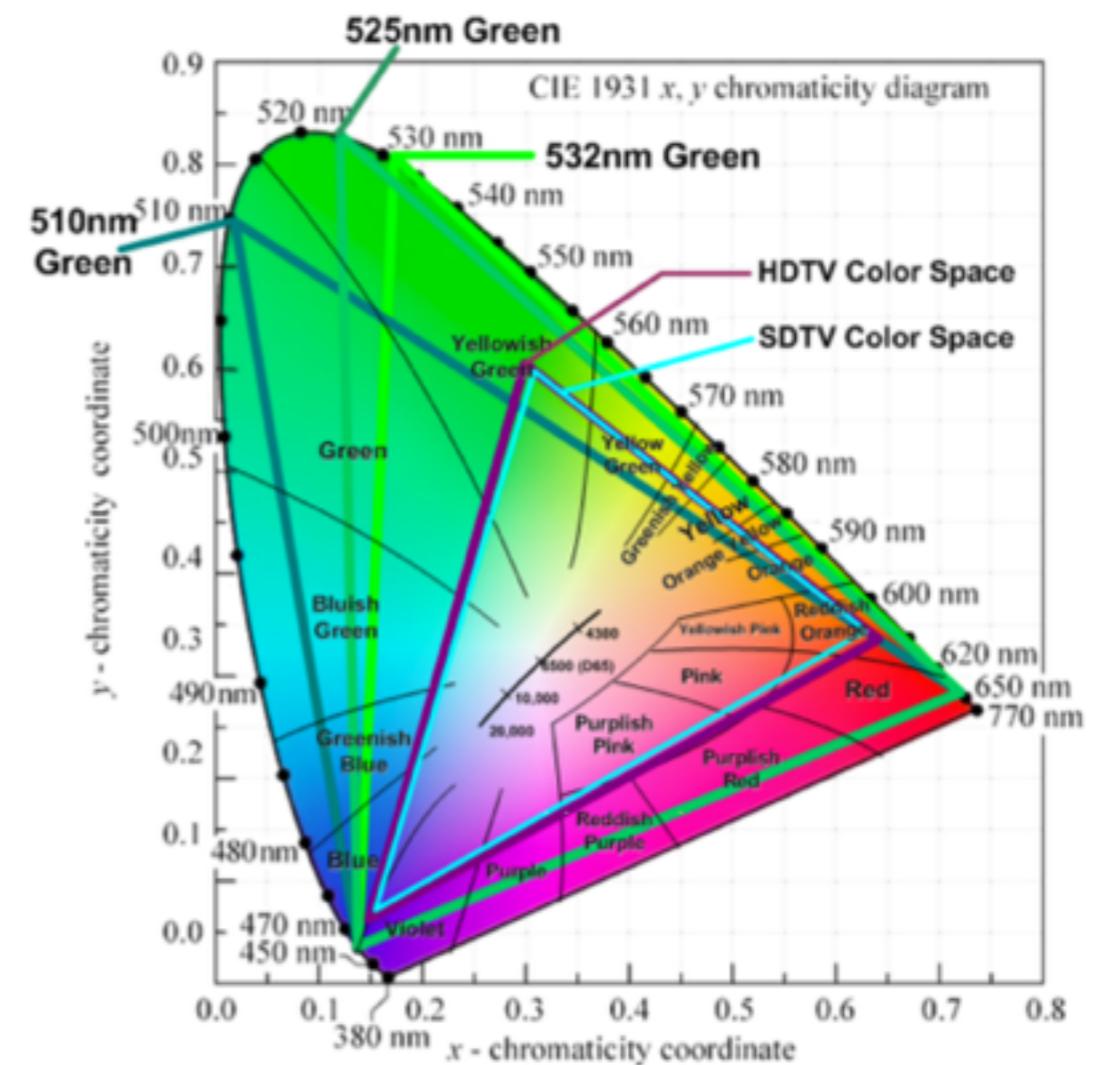
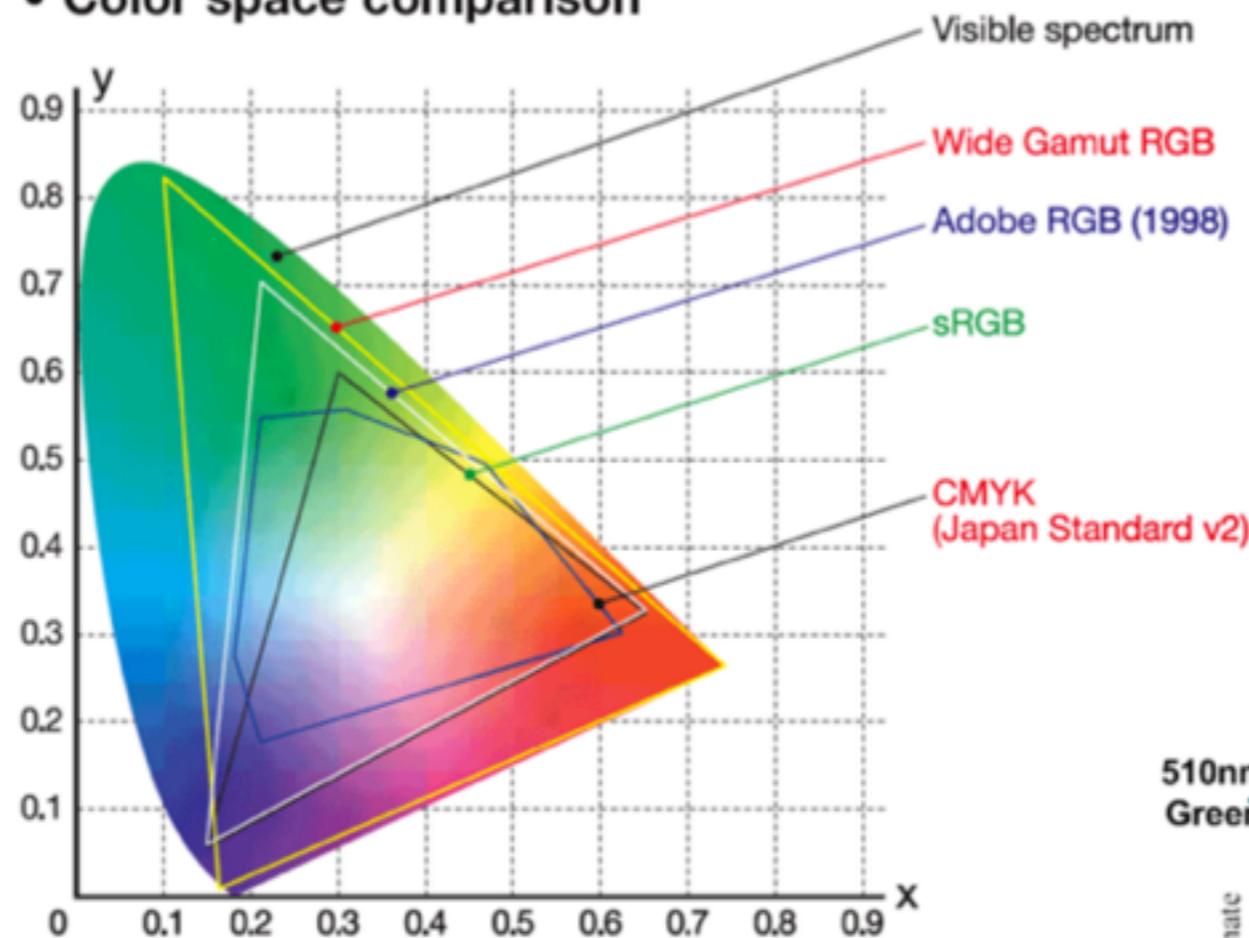


Dividing by
“luminance”



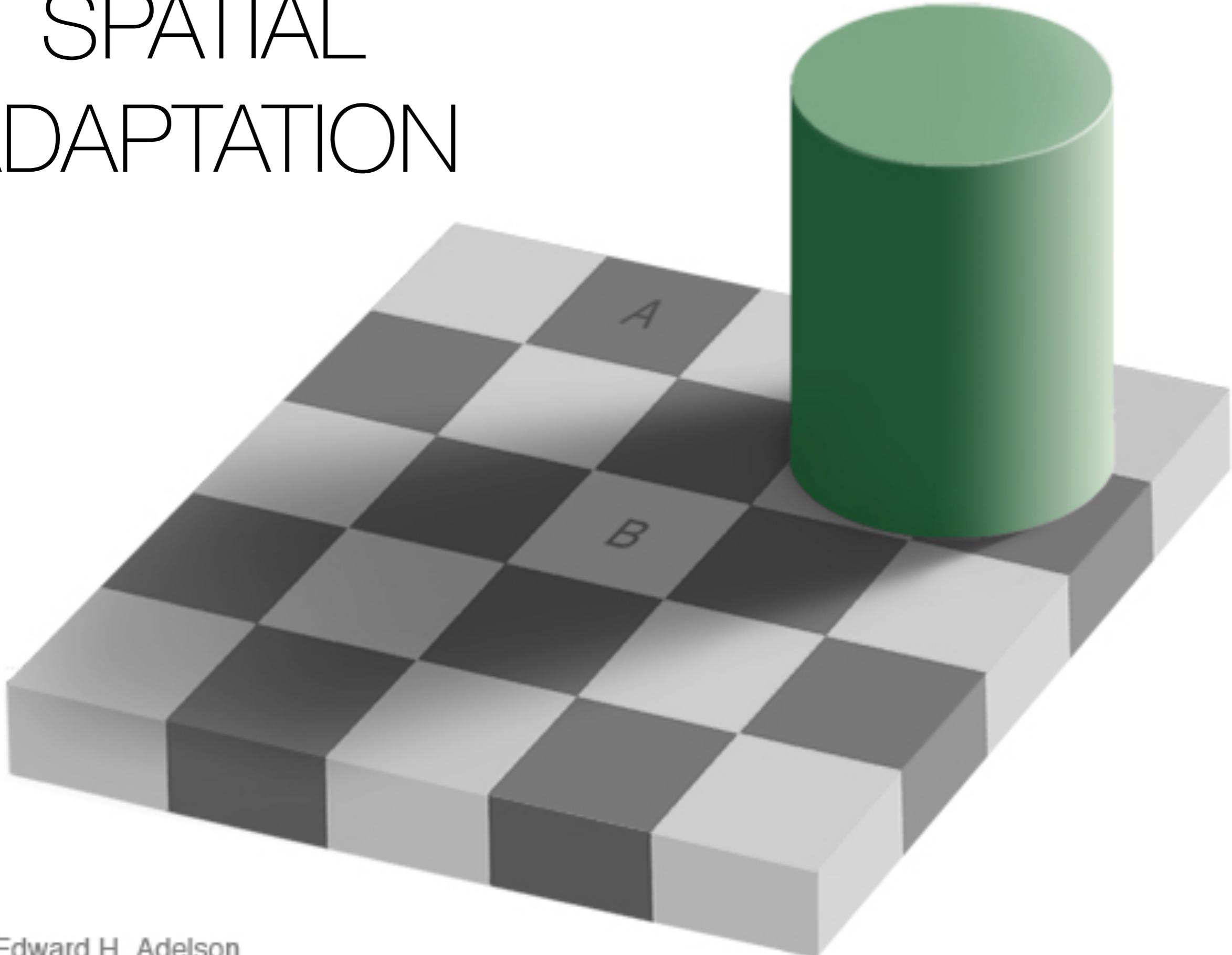
COLOR GAMUTS

- Color space comparison



CONSTANCY AND
ADAPTATION

SPATIAL ADAPTATION



Edward H. Adelson

SPATIAL ADAPTATION

A

B

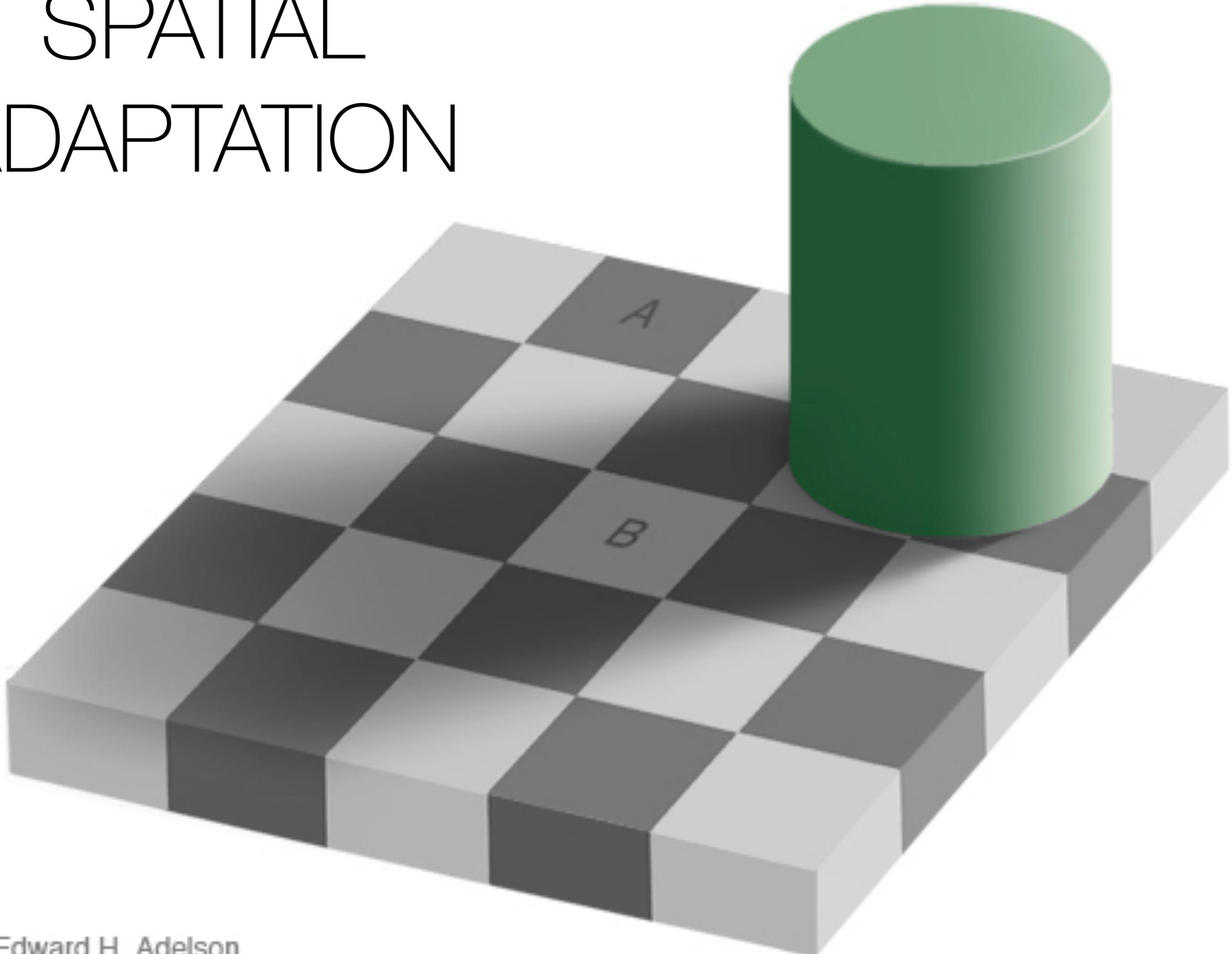
SPATIAL ADAPTATION

A

B

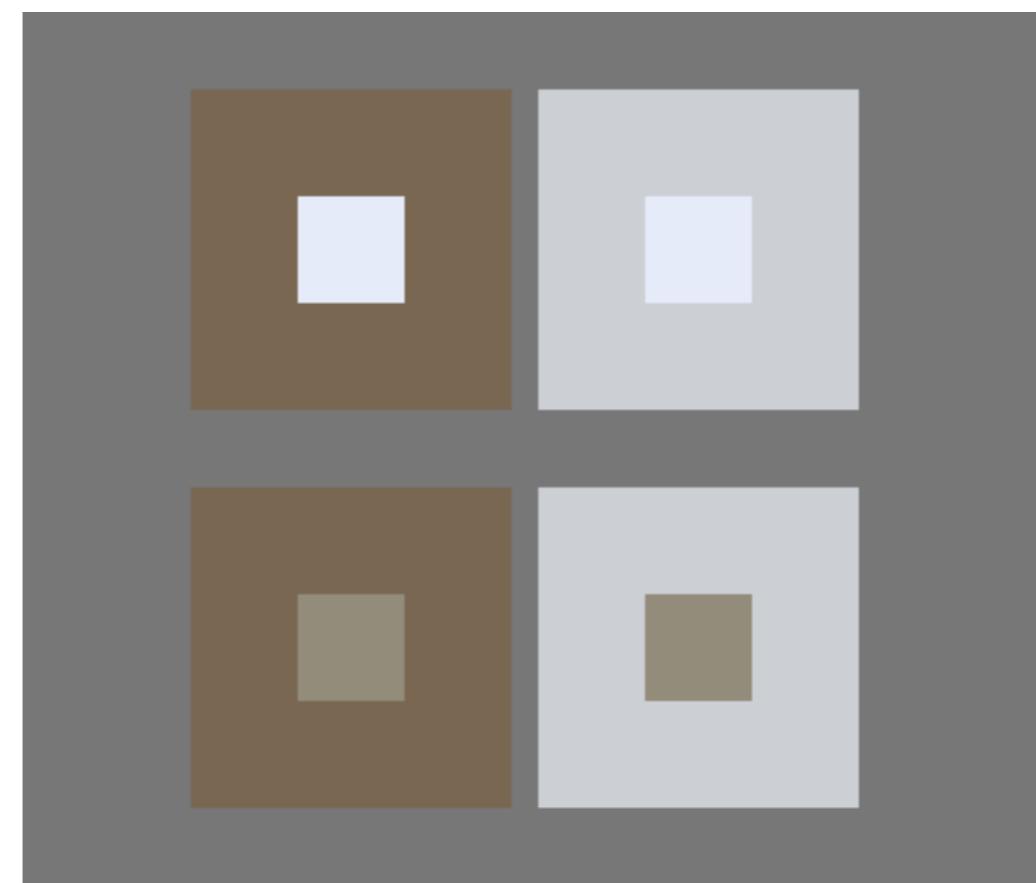
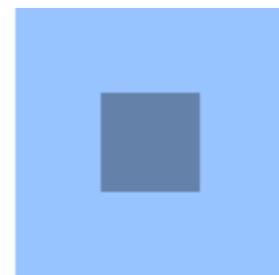
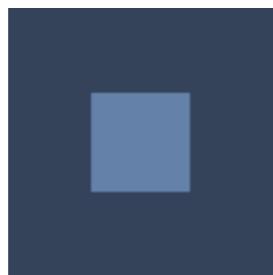


SPATIAL ADAPTATION



Edward H. Adelson

SIMULTANEOUS CONTRAST







TEMPORAL ADAPTATION

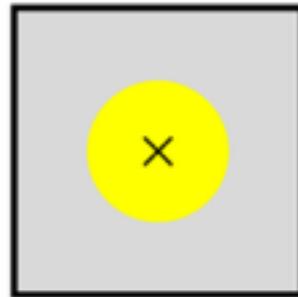
<http://www.moillusions.com/black-and-white-in-colour-again.html/13191556xteeocm7>

Impossible Colors (!)

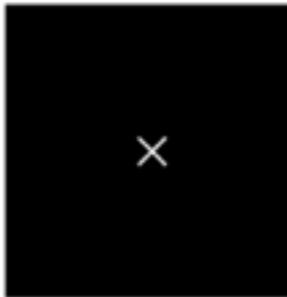
<http://upload.wikimedia.org/wikipedia/commons/5/56/Chimerical-color-demo.svg>

CHIMERICAL COLOR DEMO TEMPLATES

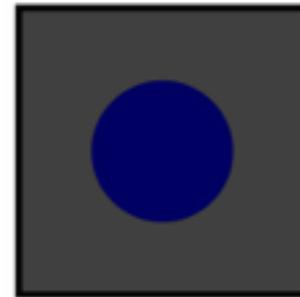
Fatigue template
(stare at "x")



Target field
(glance at "x")

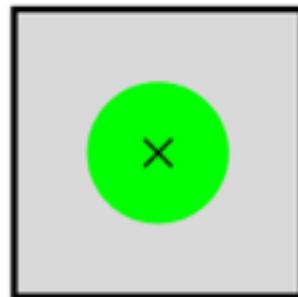


Approximate
Rendering



STYGIAN BLUE
(simultaneously deep
blue and black)

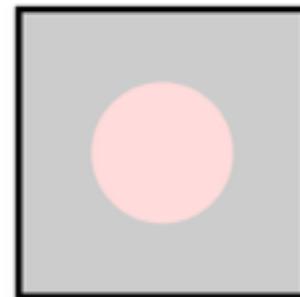
Fatigue template
(stare at "x")



Target field
(glance at "x")

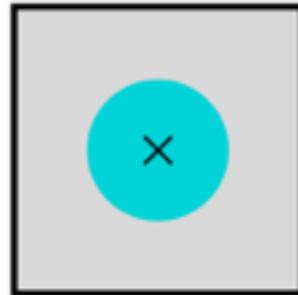


Approximate
Rendering

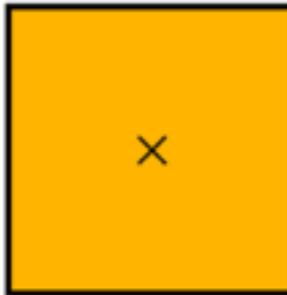


SELF-LUMINOUS RED
(simultaneously red and
brighter than white)

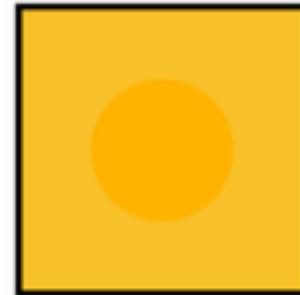
Fatigue template
(stare at "x")



Target field
(glance at "x")



Approximate
Rendering



HYPERBOLIC ORANGE
(more than 100%
color saturation)