

# 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

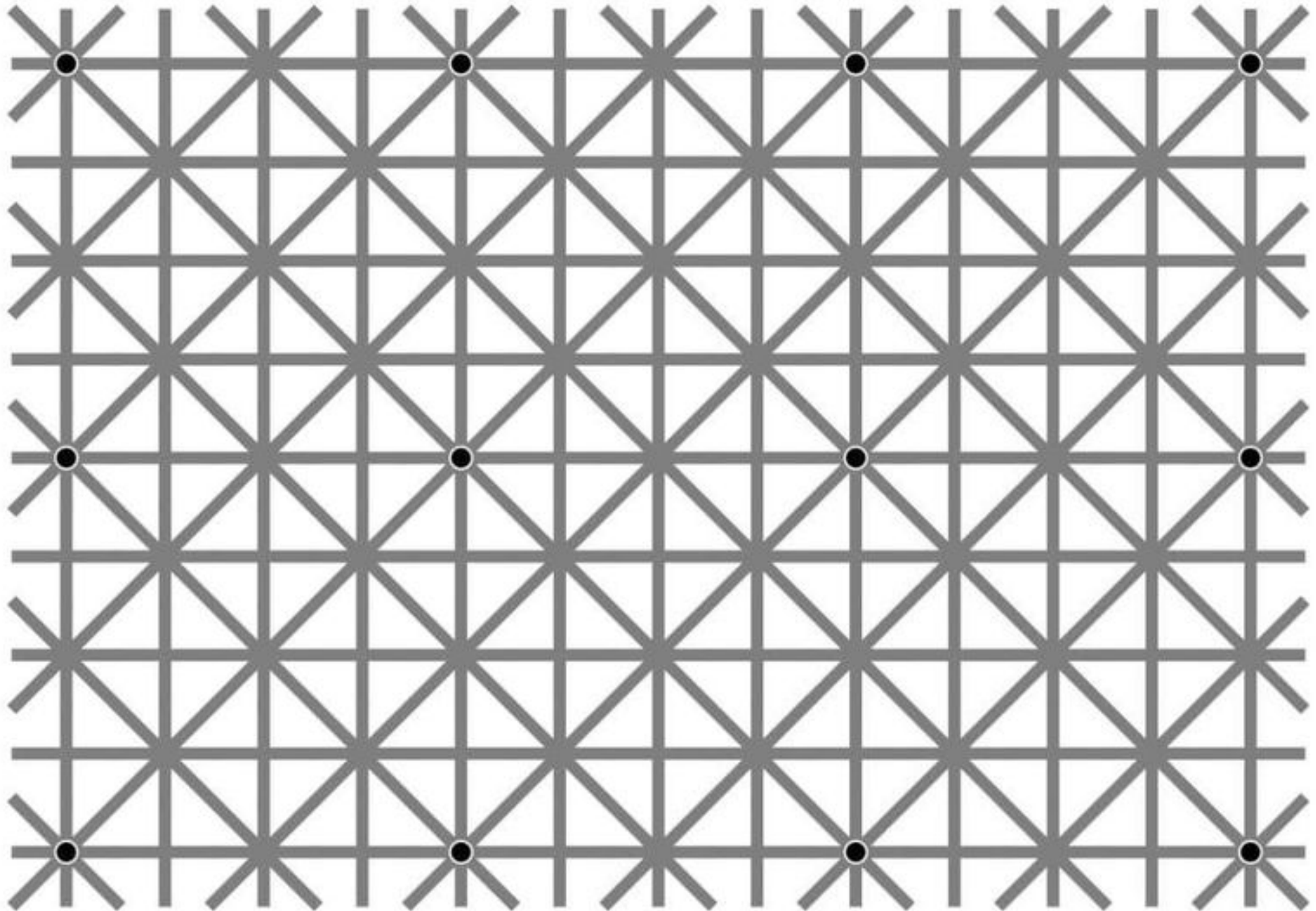
**Principles**

Techniques

**Why worry about principles?**

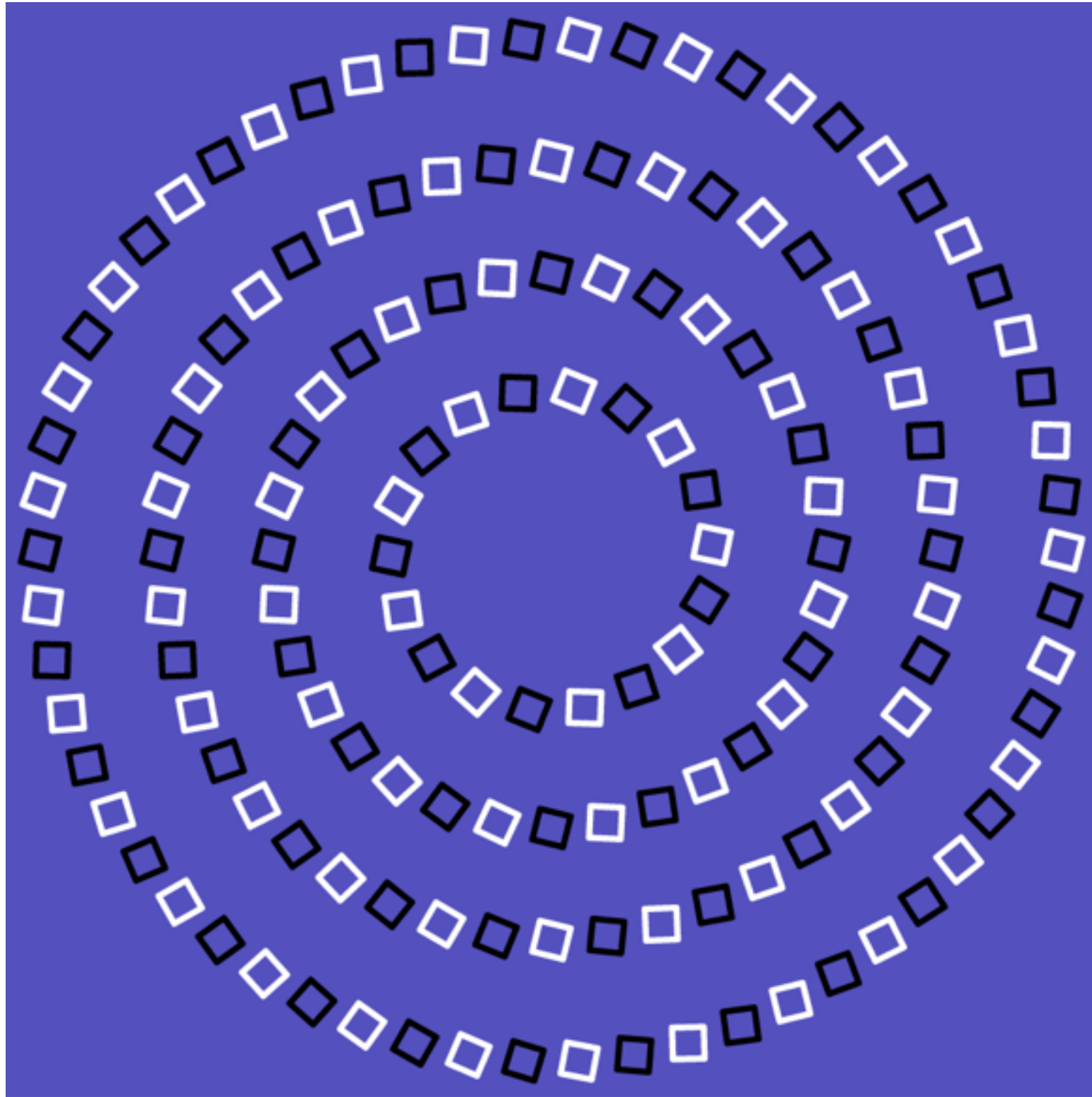


**Why worry about principles?**

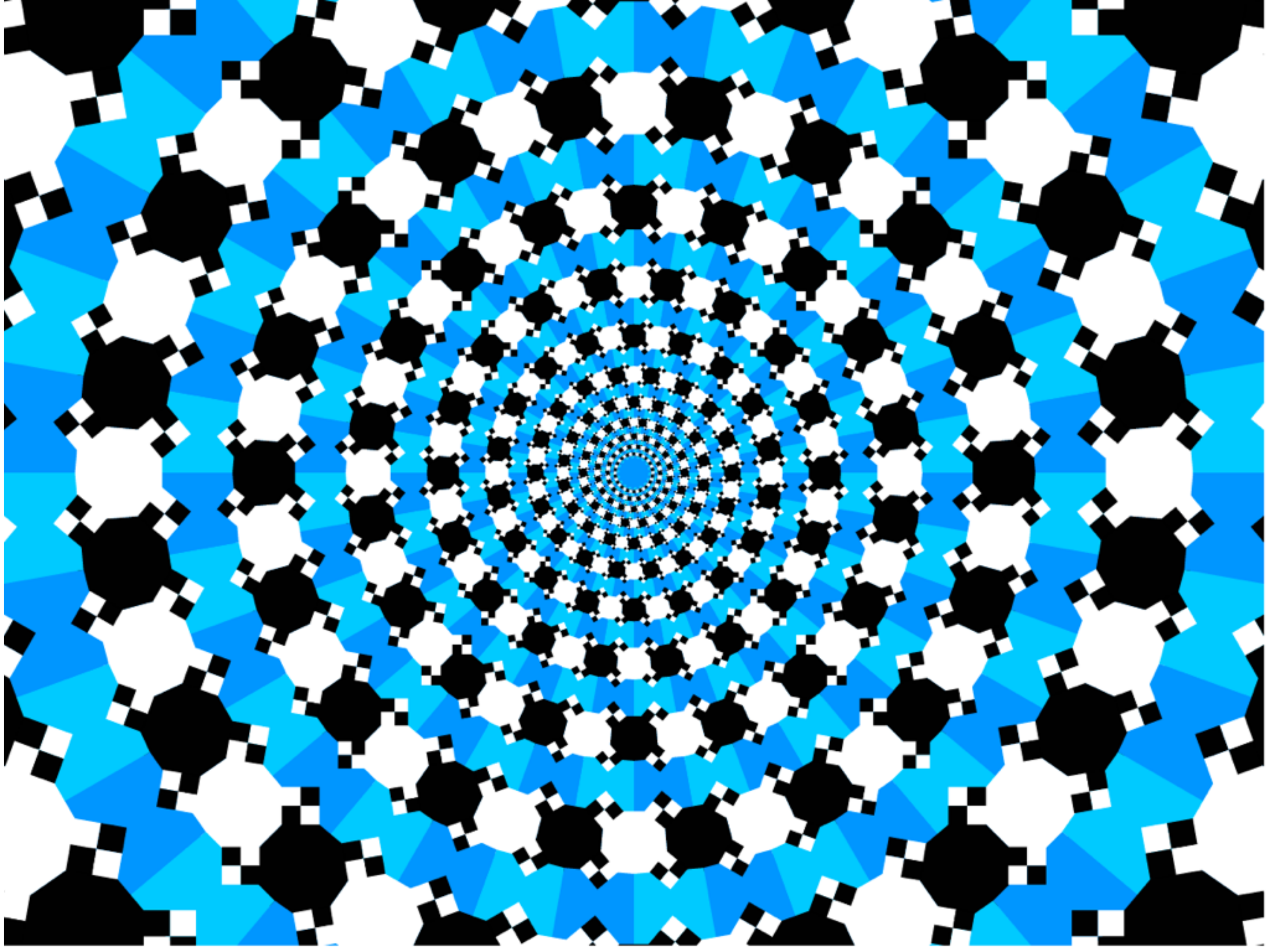


**Ninio's extinction illusion**

# Why worry about principles?



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



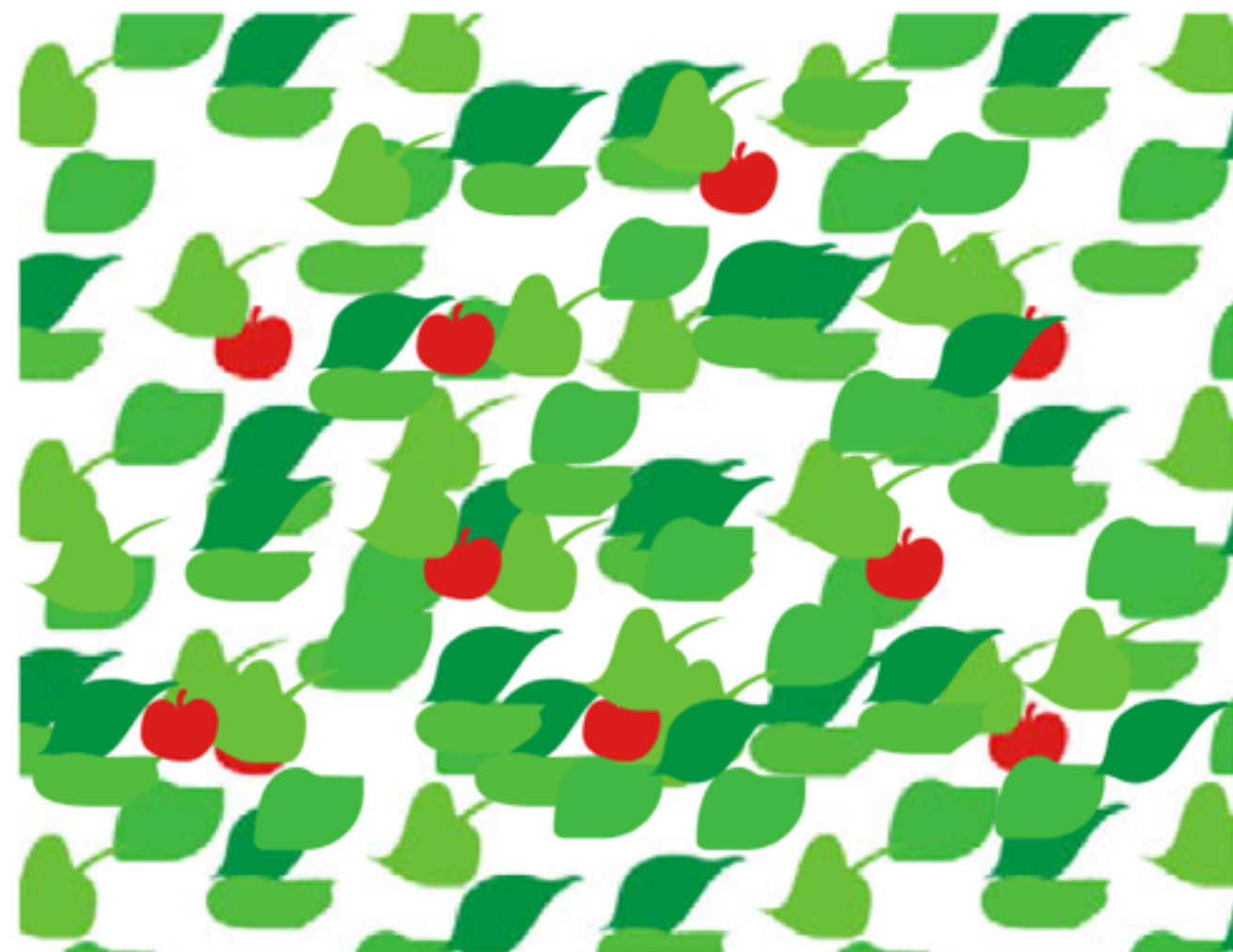
VISION IS COMPLICATED

# Reading

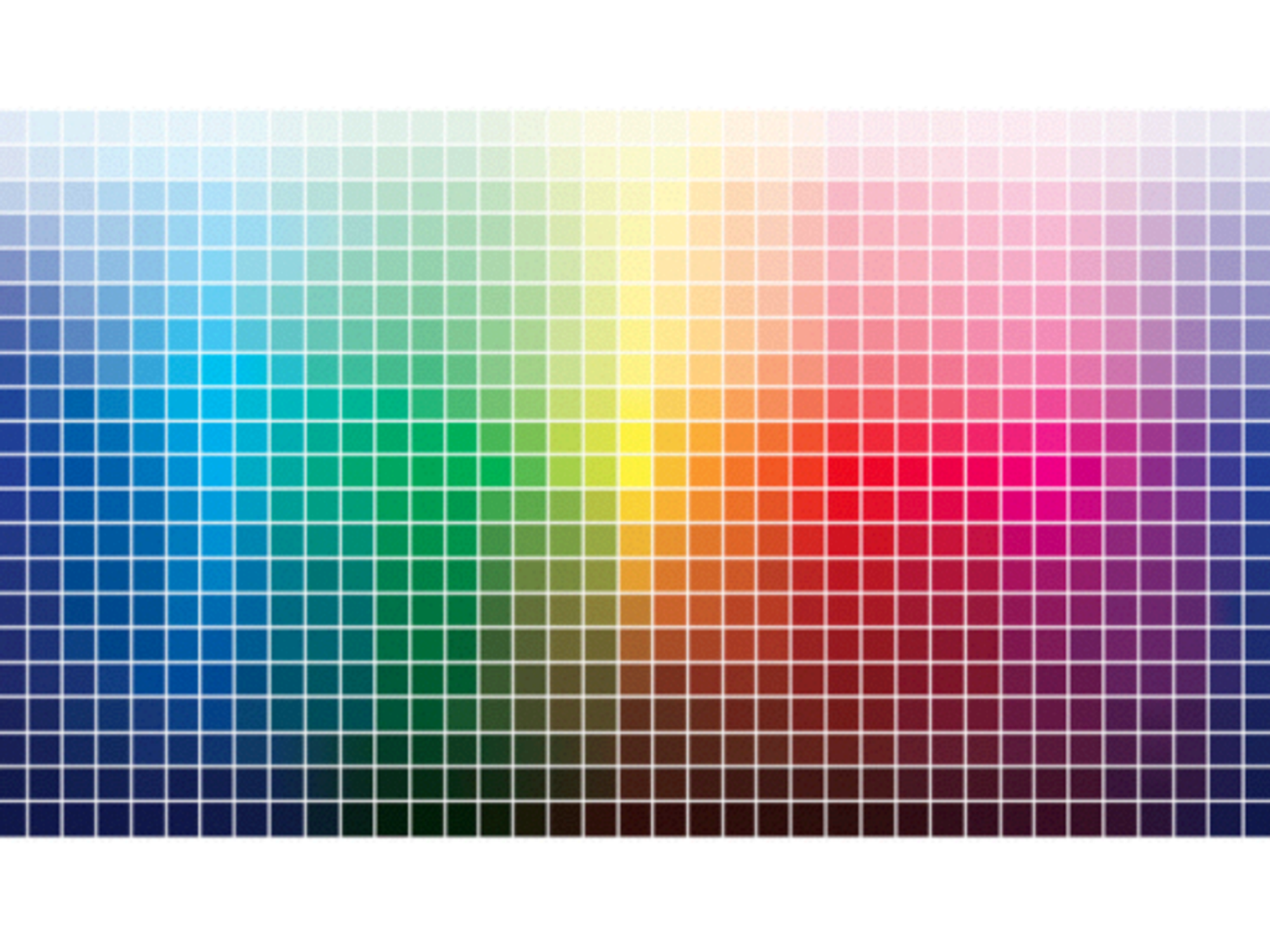
- “Representing Colors as Three Numbers”, Stone
- Rainbow Colormap (Still) Considered Harmful,  
Borland and Russell.
- Optional:
  - Face-based Luminance Matching... Kindlmann  
et al.

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**?

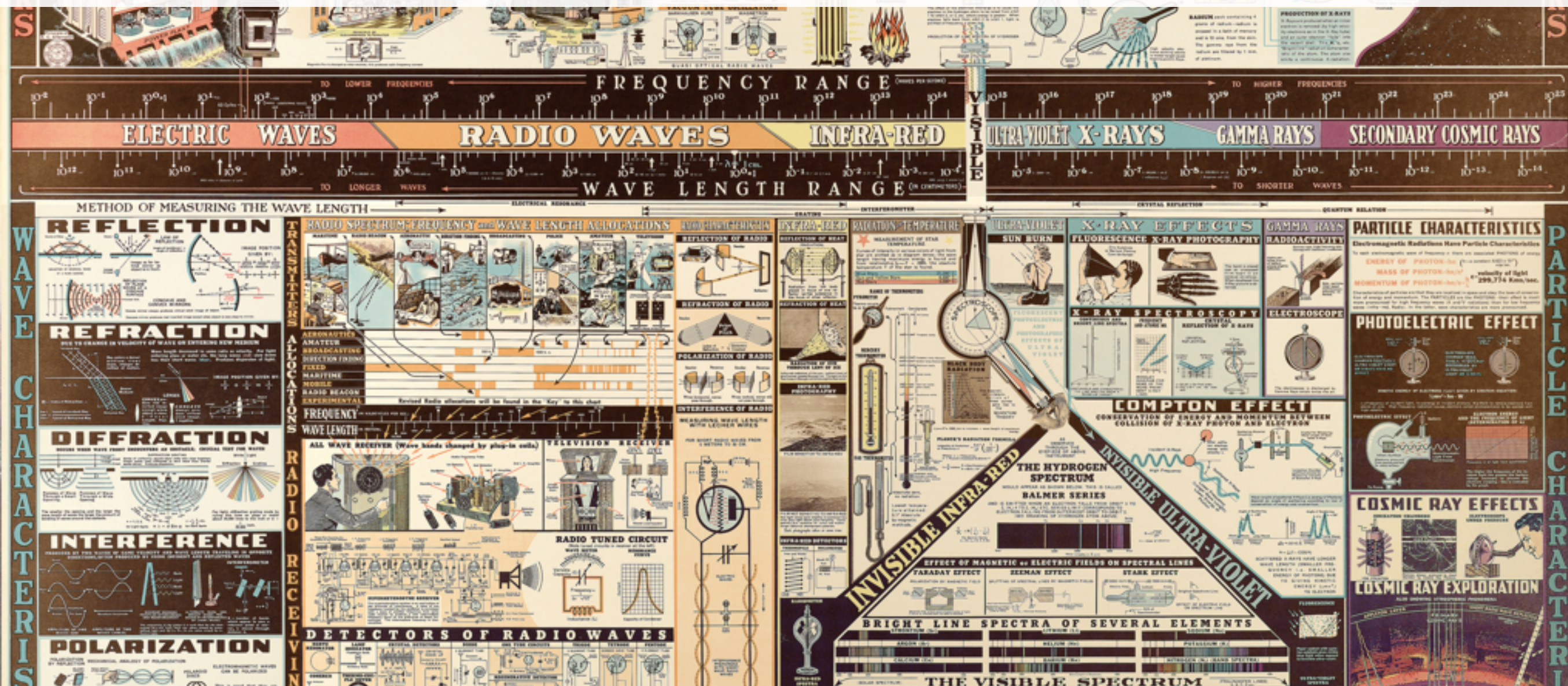
# How does light work?

- 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?



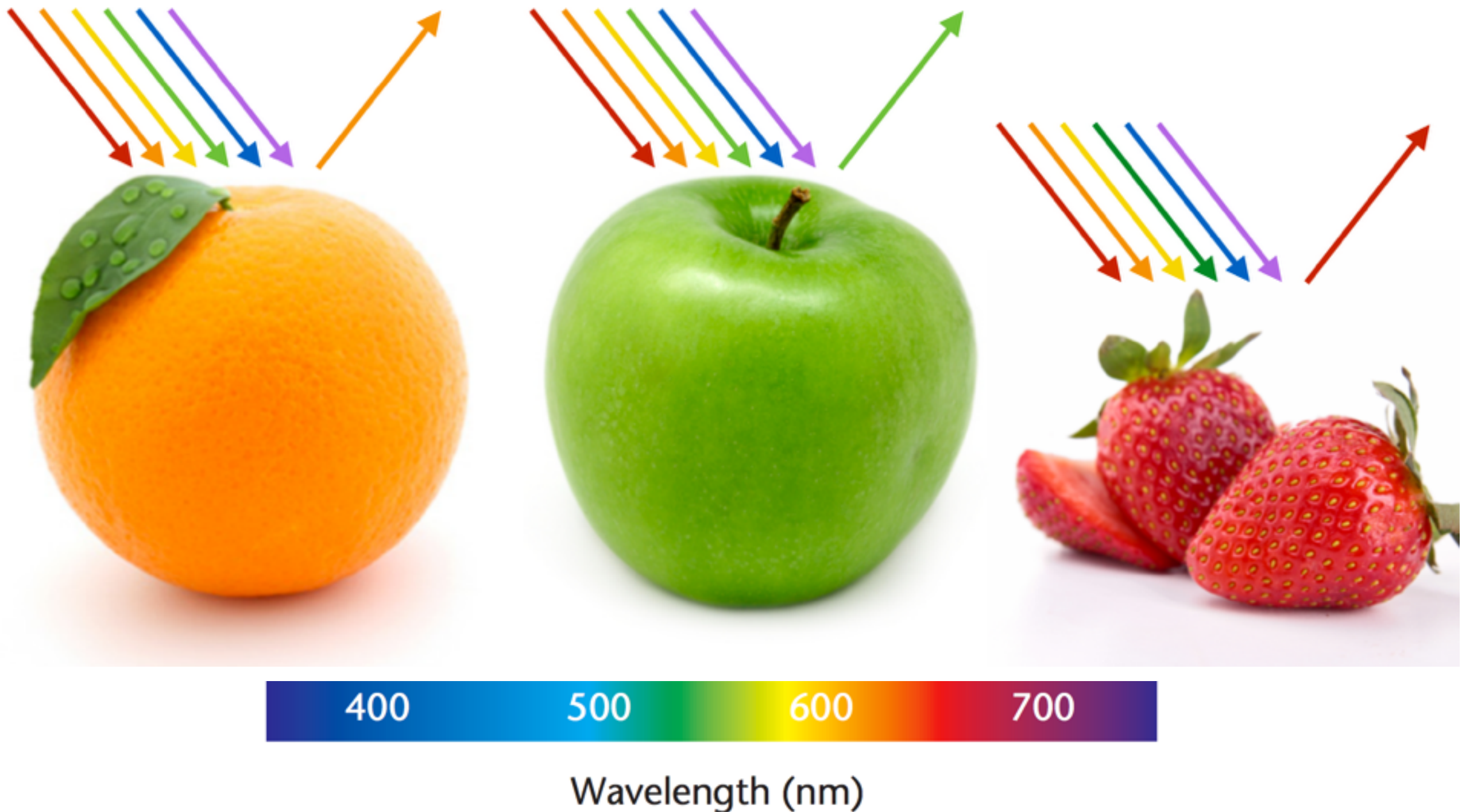


# How does light work?

<http://www.chemistryland.com/CHM107Lab/Exp7/Spectroscope/Spectroscope.html>

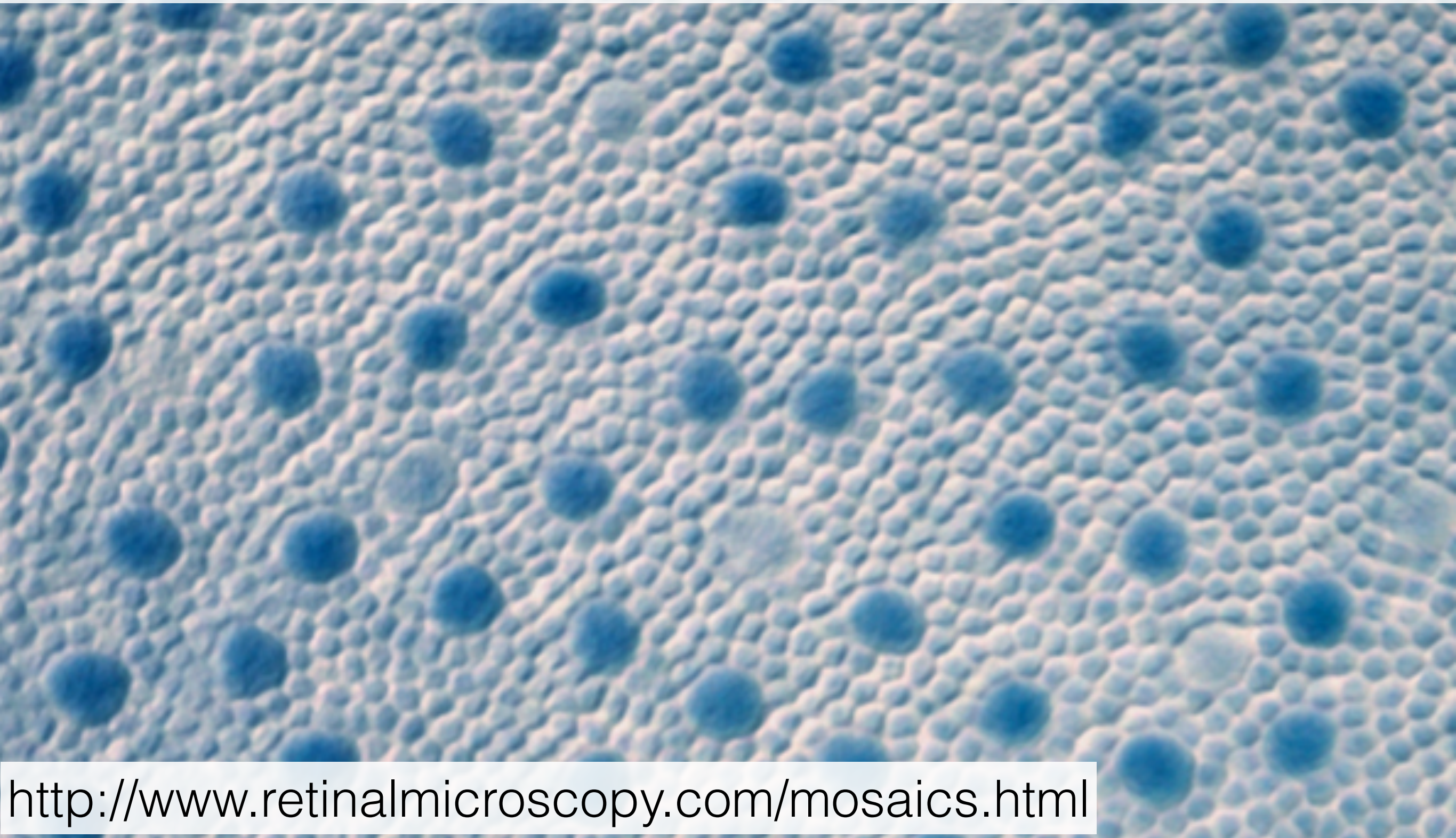


# How does light work?





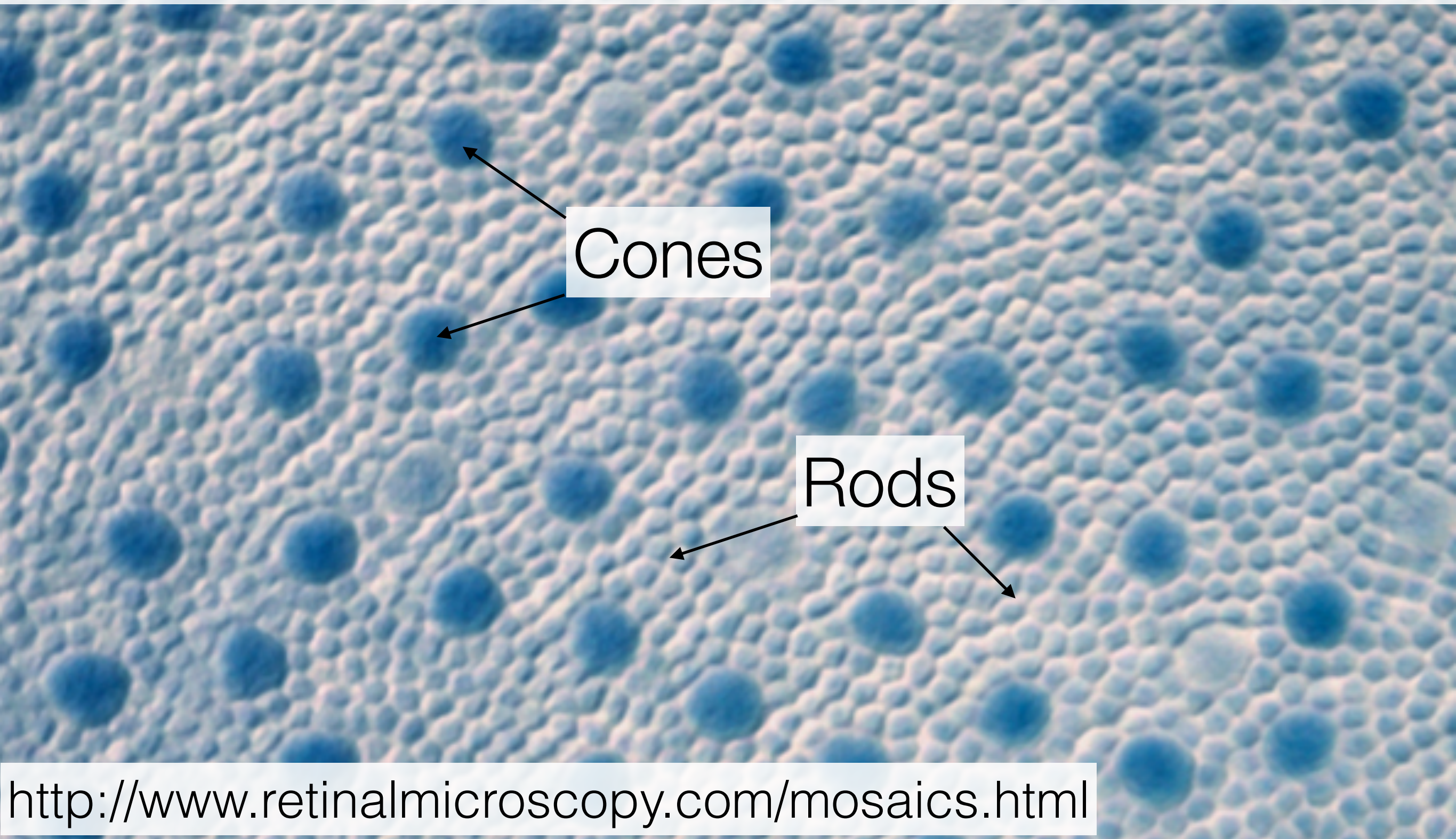
# How does your eye work?



<http://www.retinalmicroscopy.com/mosaics.html>



# How does your eye work?

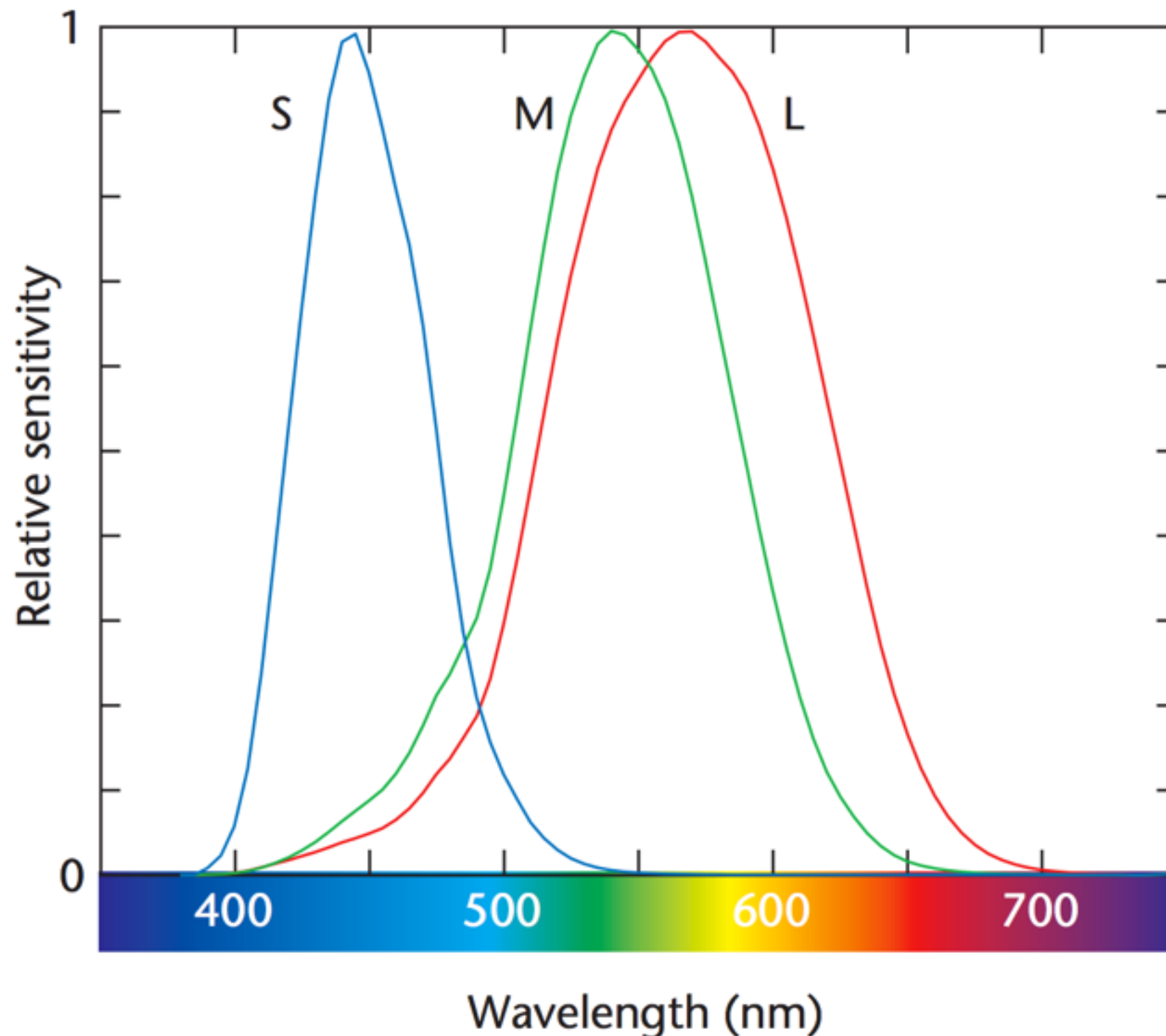


Cones

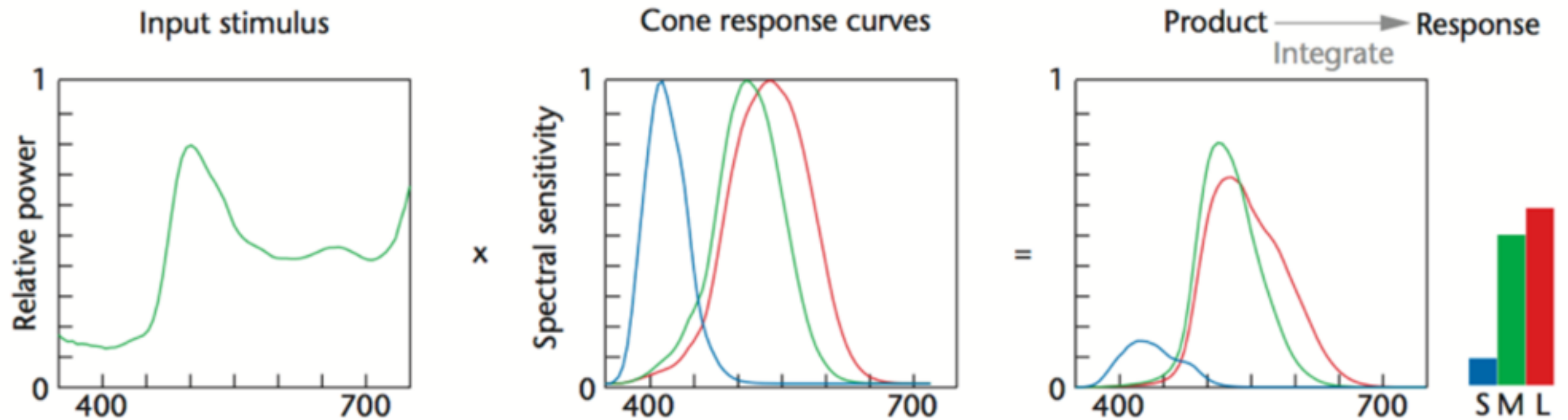
Rods



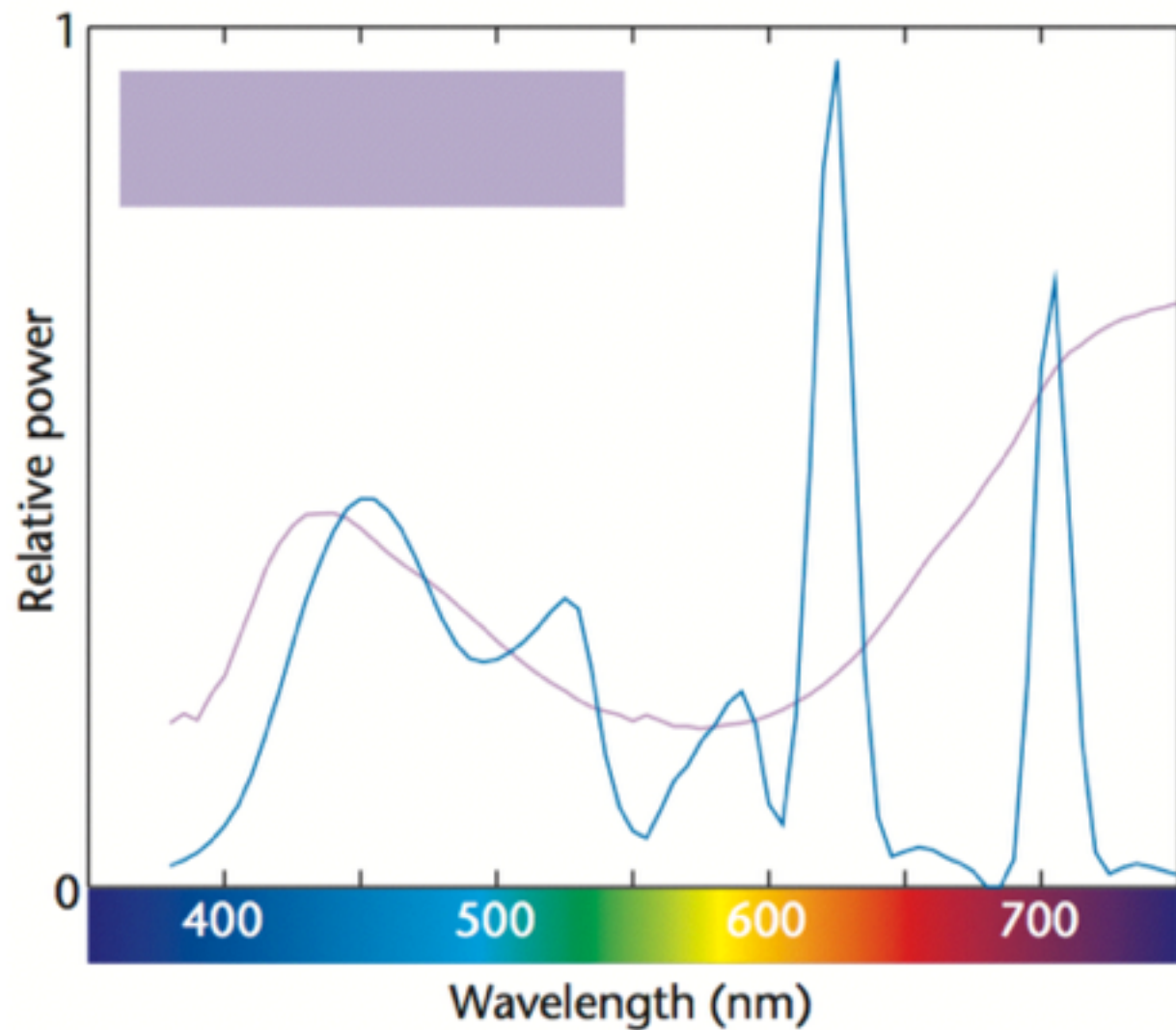
# How does your eye work?



# TRICHROMACY

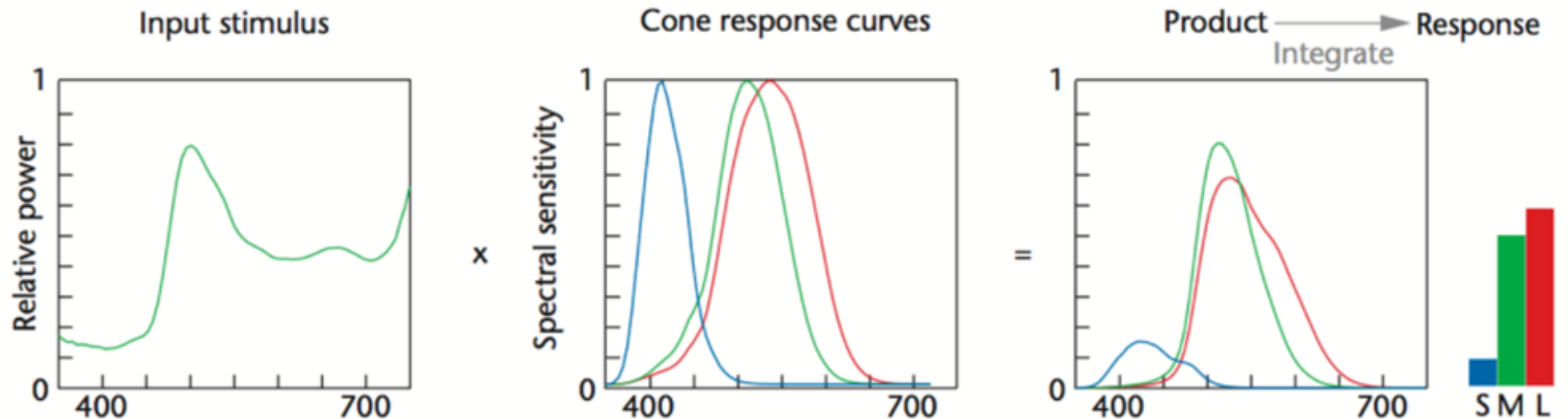


**Three numbers!**

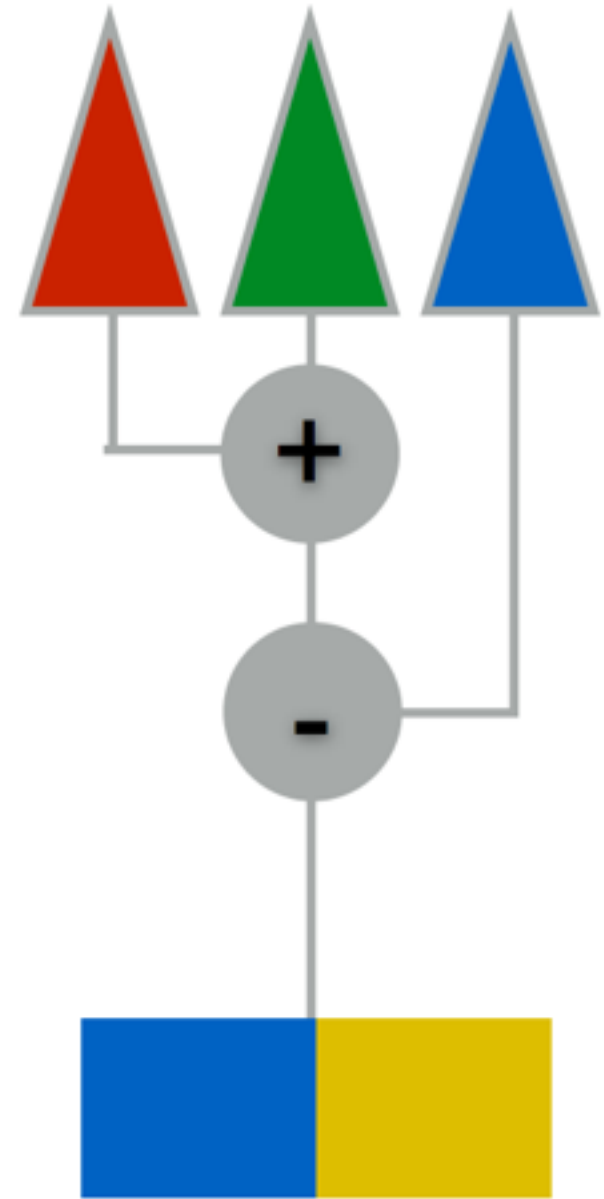
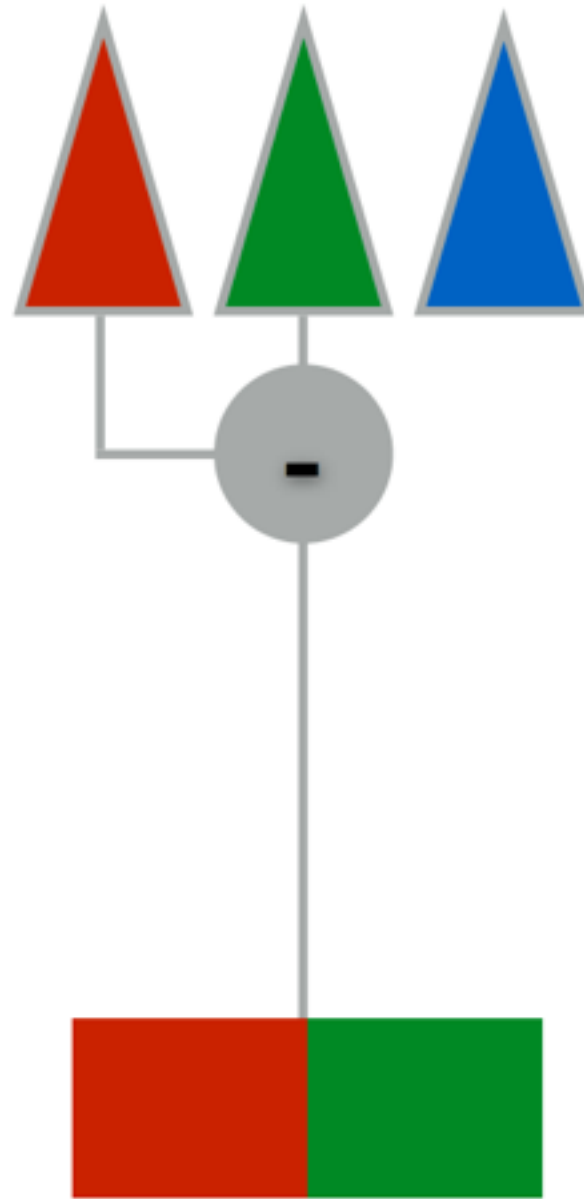
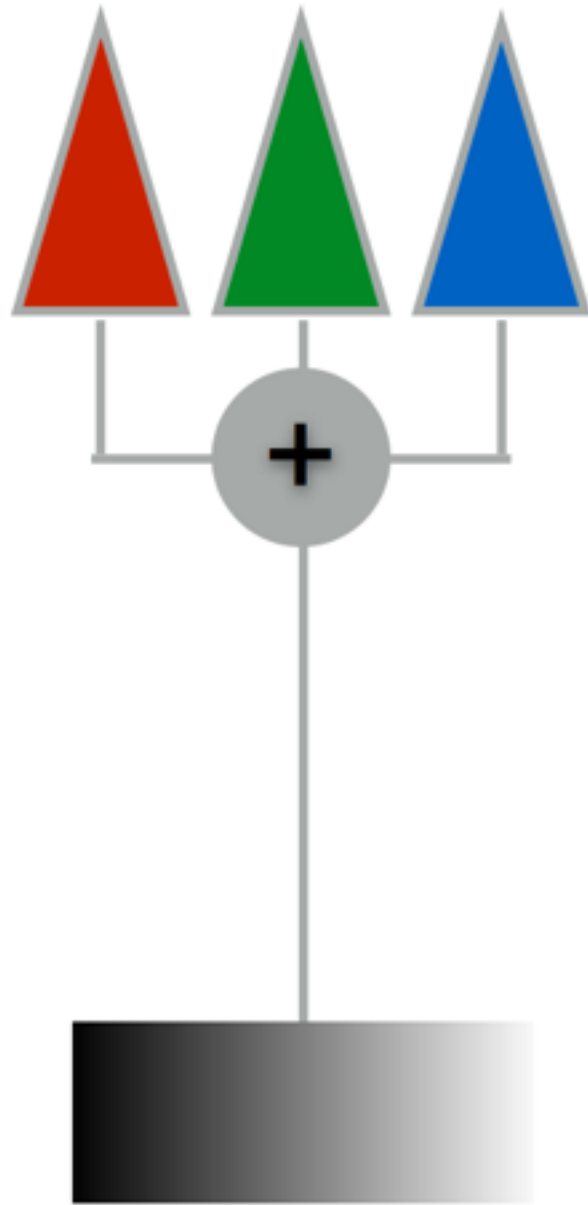


**same** three numbers,  
**same** impression

# METAMERISM



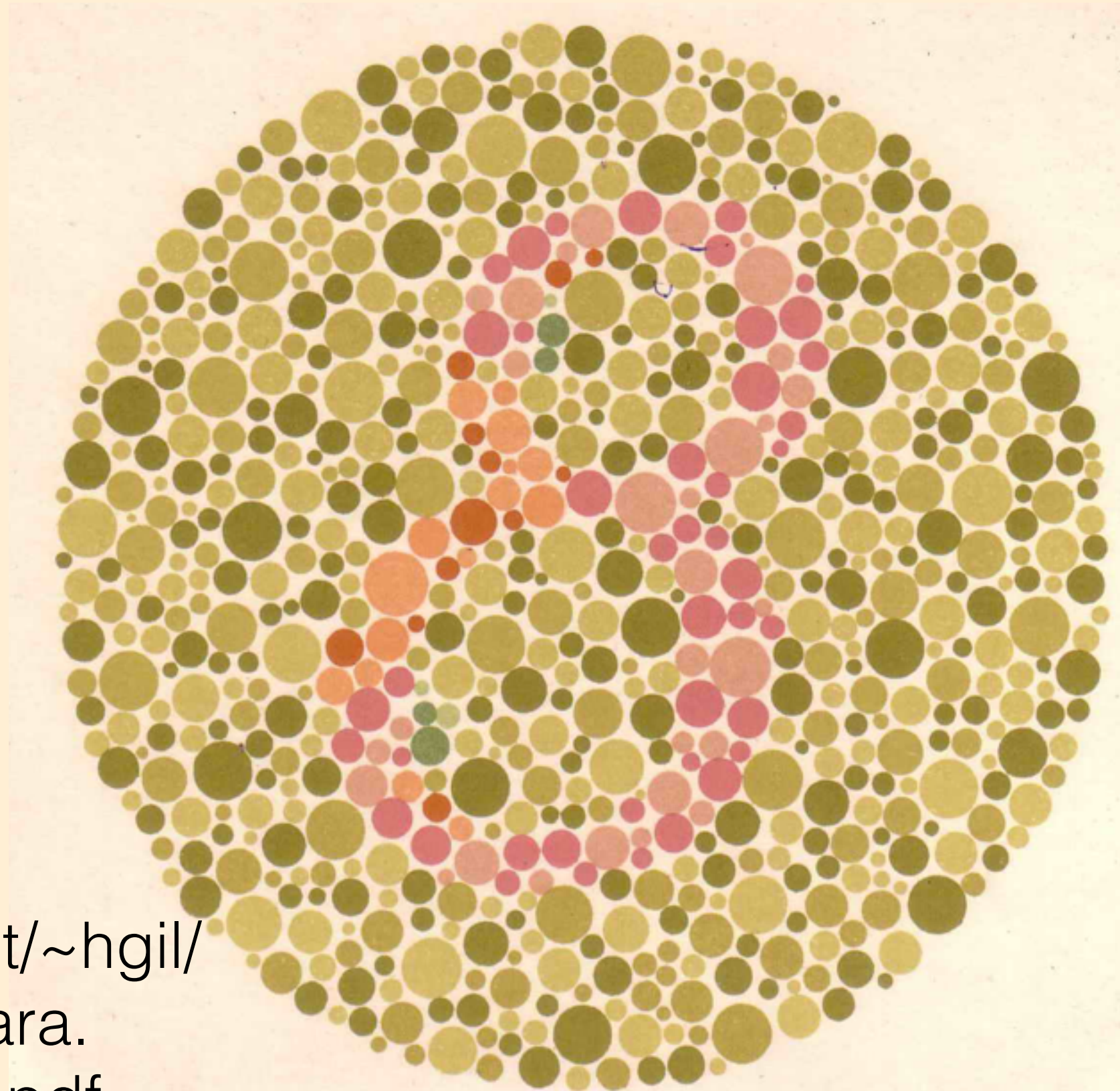
# OPPONENT PROCESS MODEL



# COLOR VISION DEFICIENCIES



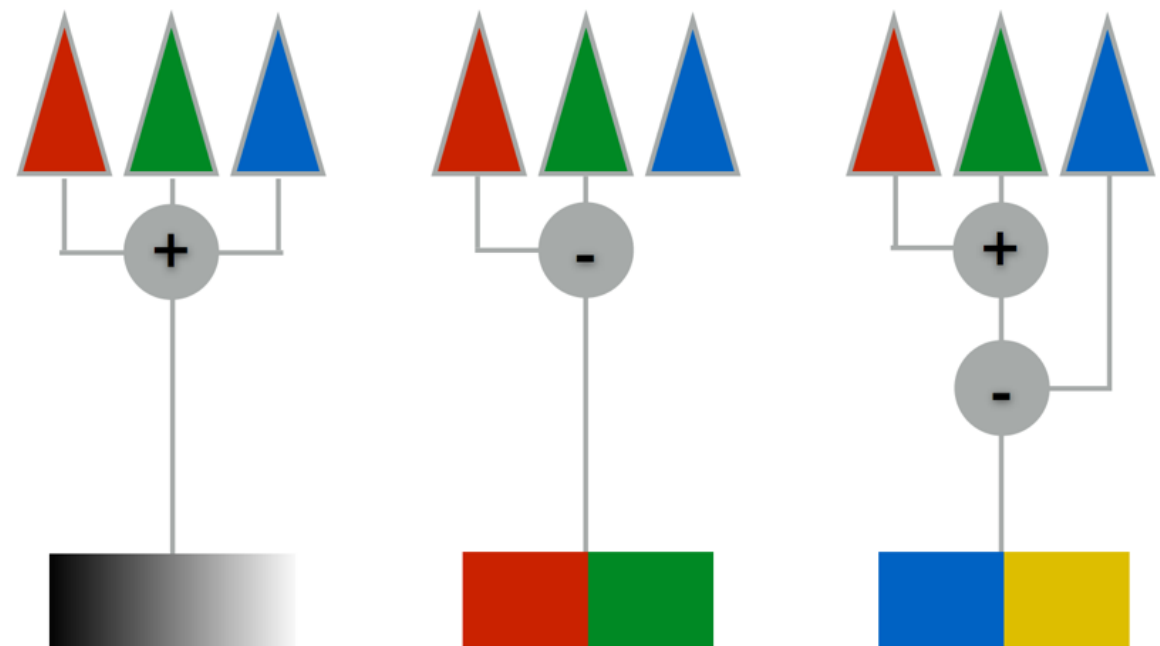
# Ishihara Plates



[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)

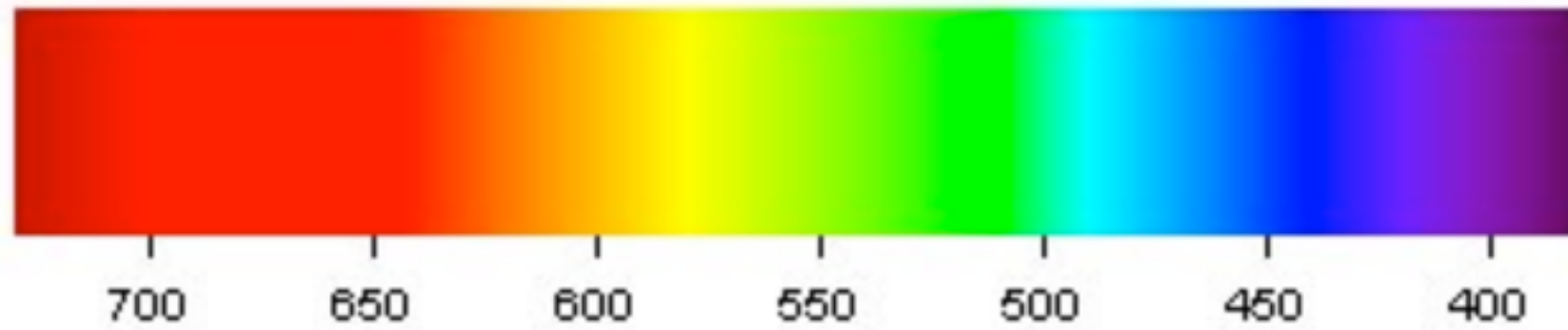
# What goes wrong?

- 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

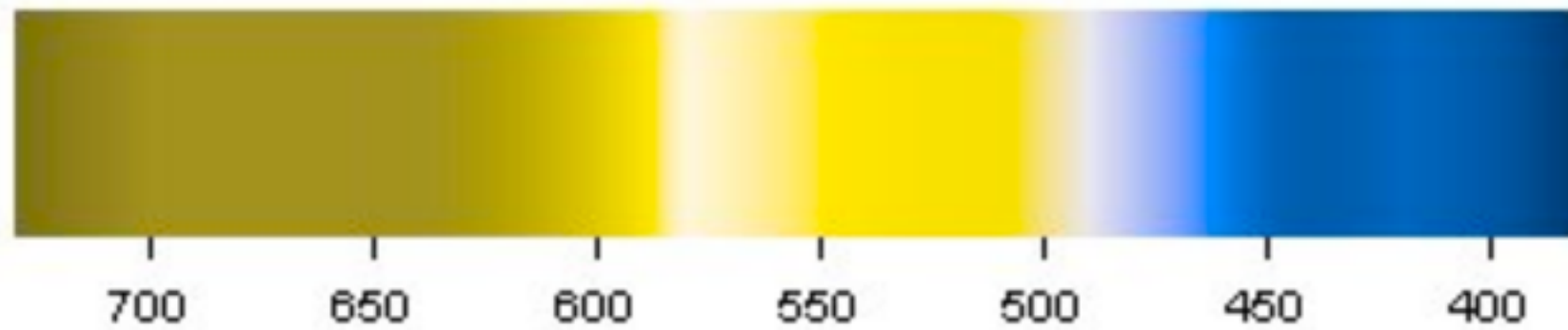




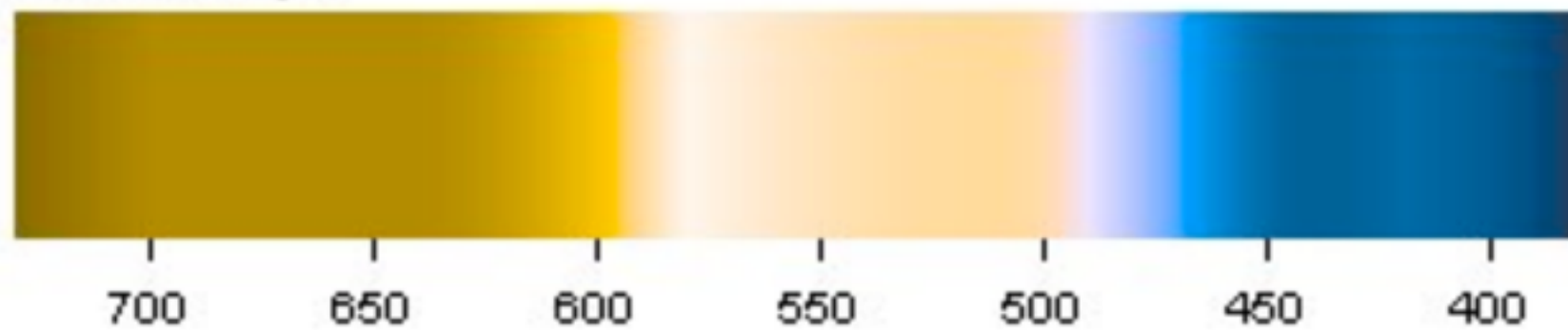
**Normal**



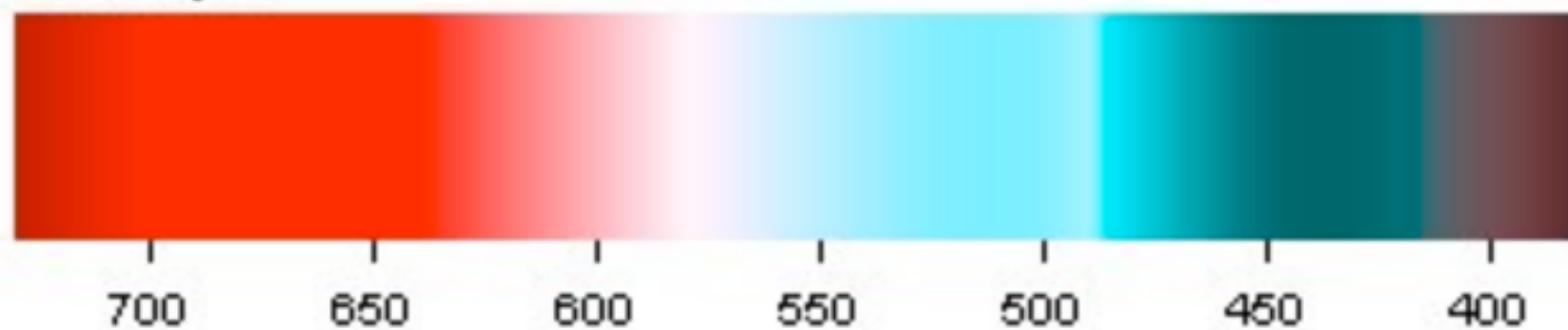
**Protanopia**



**Deuteranopia**



**Tritanopia**





WHAT ARE THE  
PRIMARY COLORS?

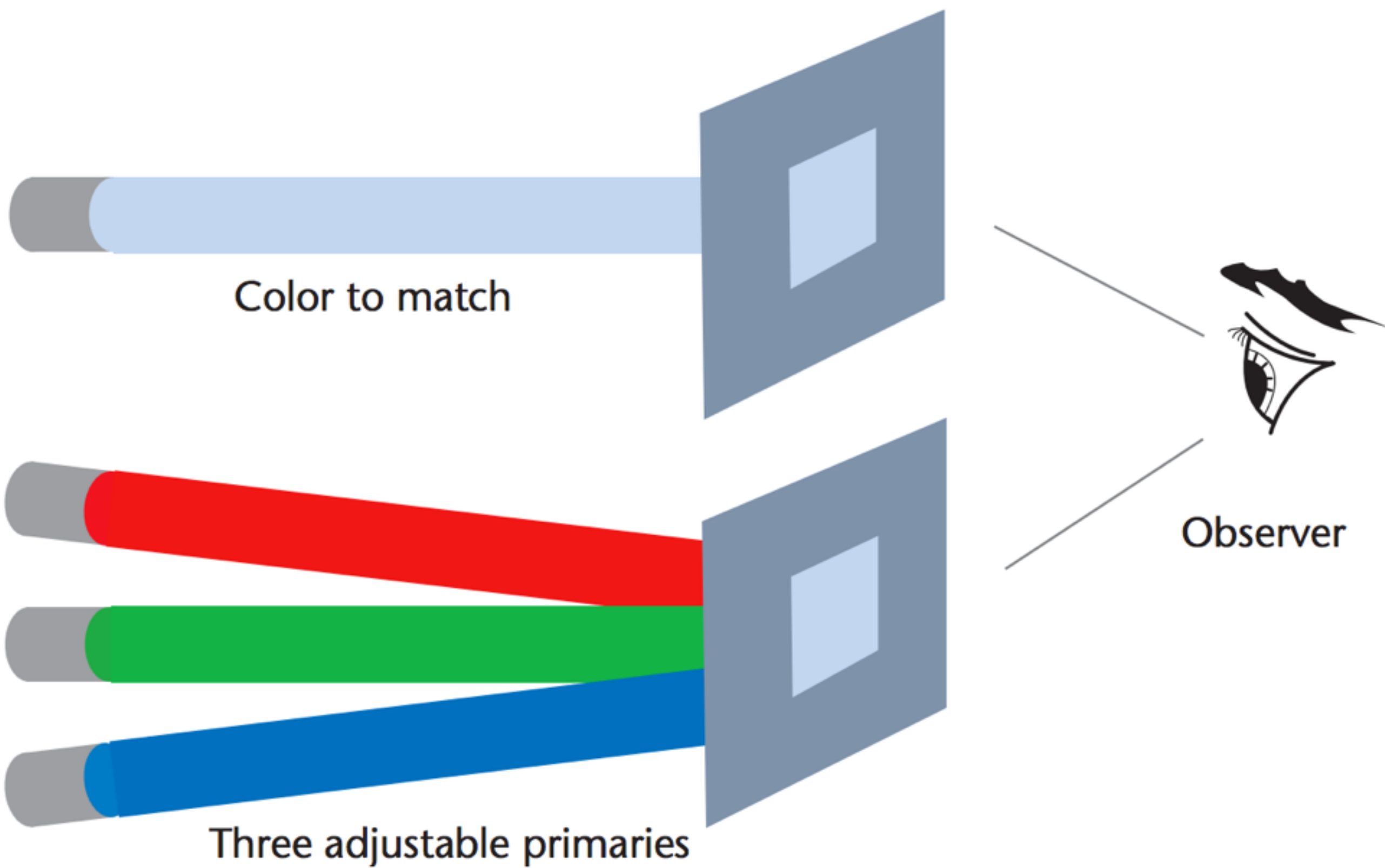
# WHAT ARE THE PRIMARY COLORS?

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 (!)

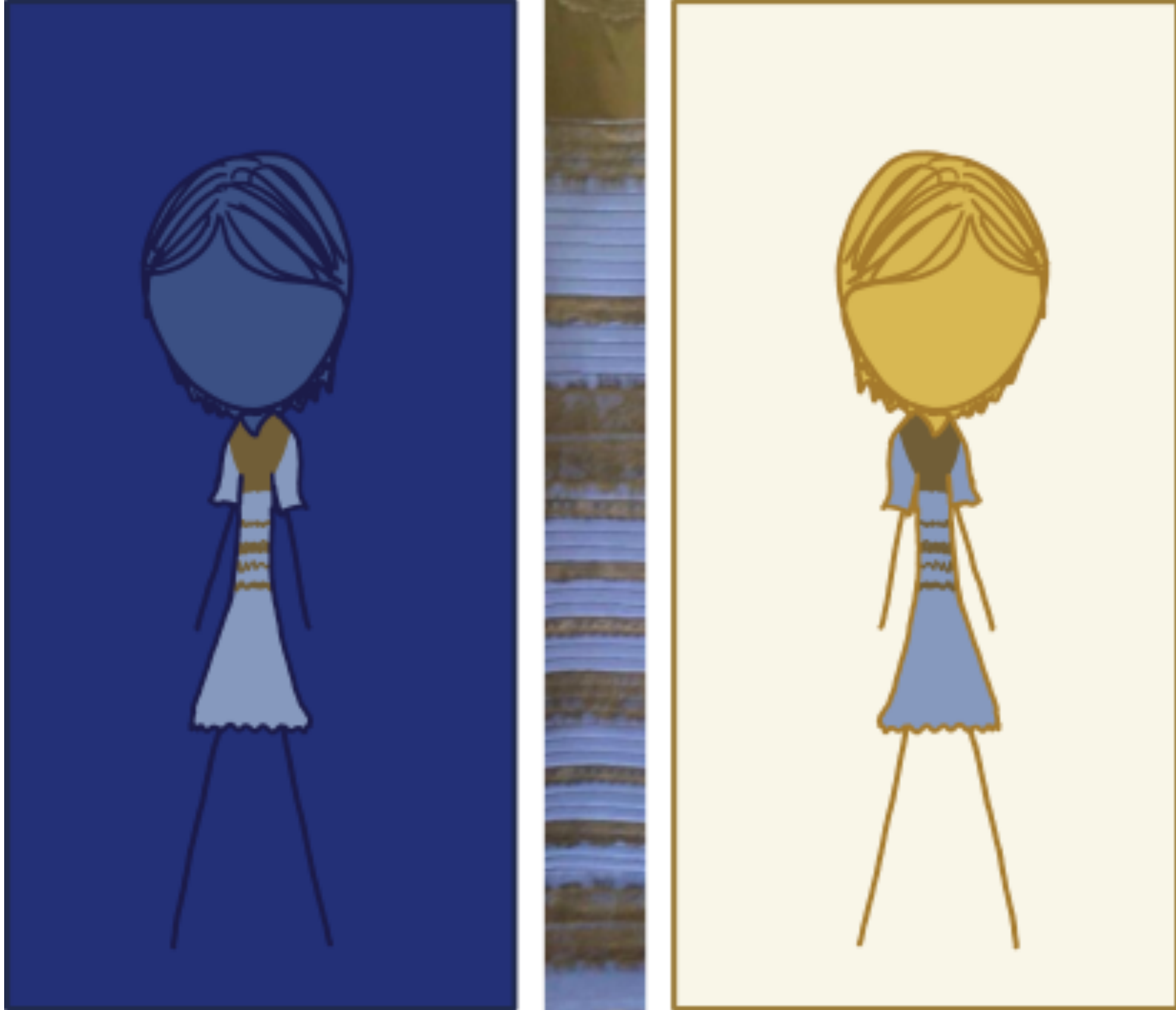


Any three “independent” ways of  
combining color works (!) ... and it  
works against **any background  
color!**



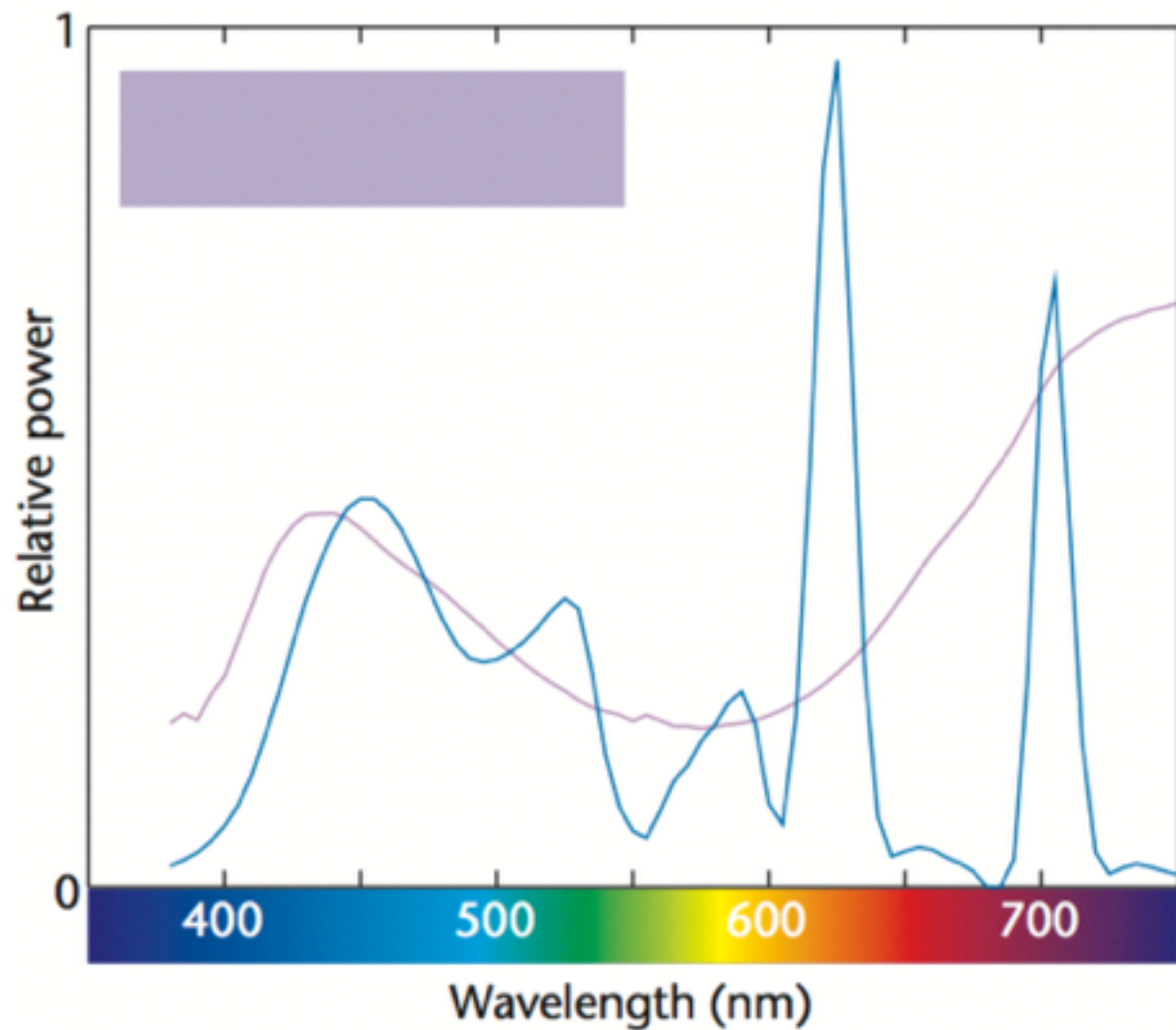
<http://swiked.tumblr.com/post/112073818575/guys-please-help-me-is-this-dress-white-and>





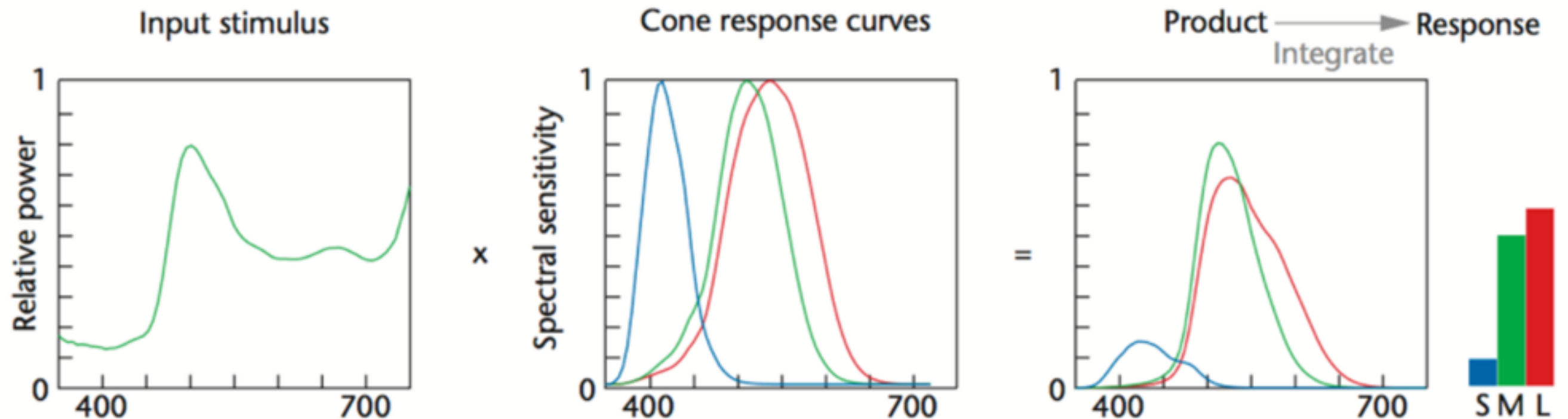
<https://xkcd.com/1492/>

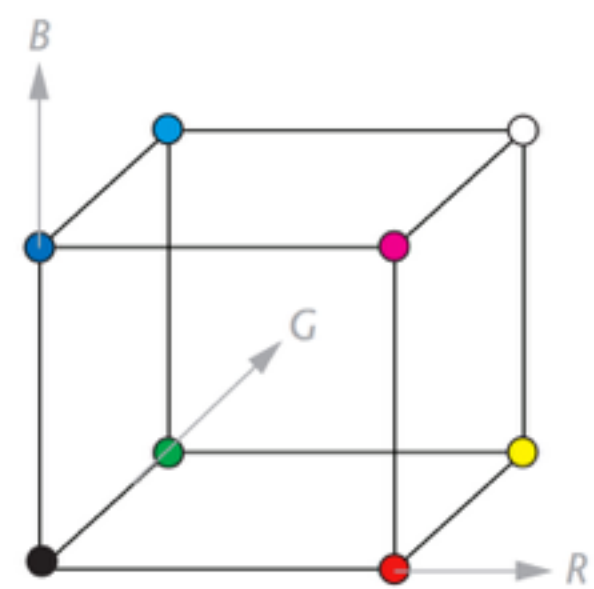




**same** three numbers,  
**same** impression

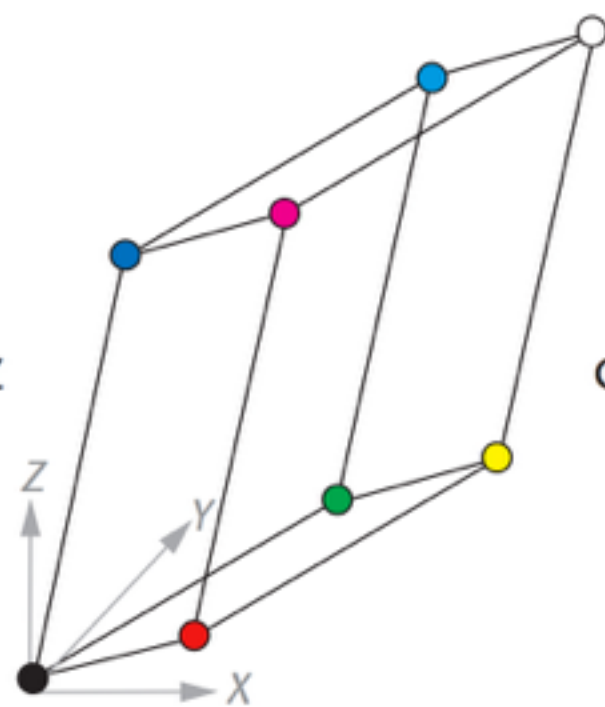
# METAMERISM





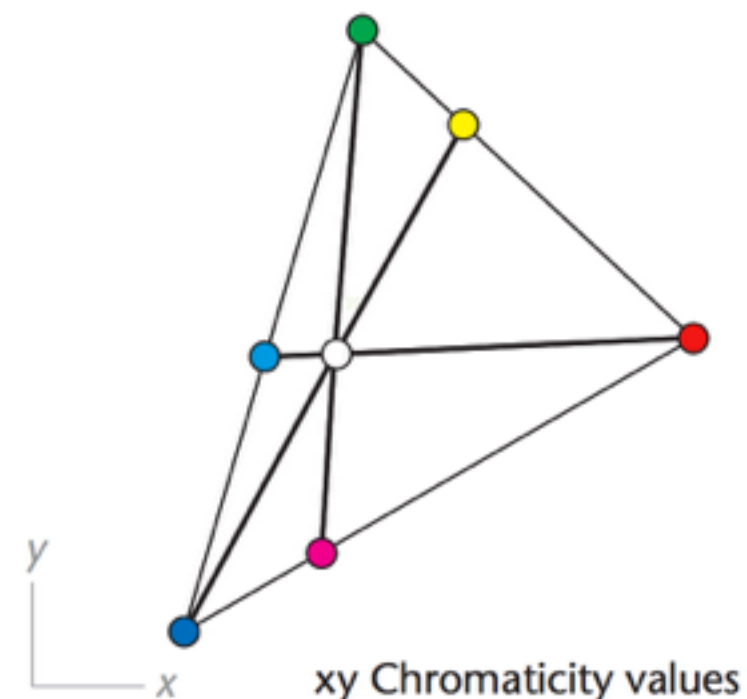
RGB intensity values  
**(a)**

RGB to CIE XYZ  
3 x 3 matrix

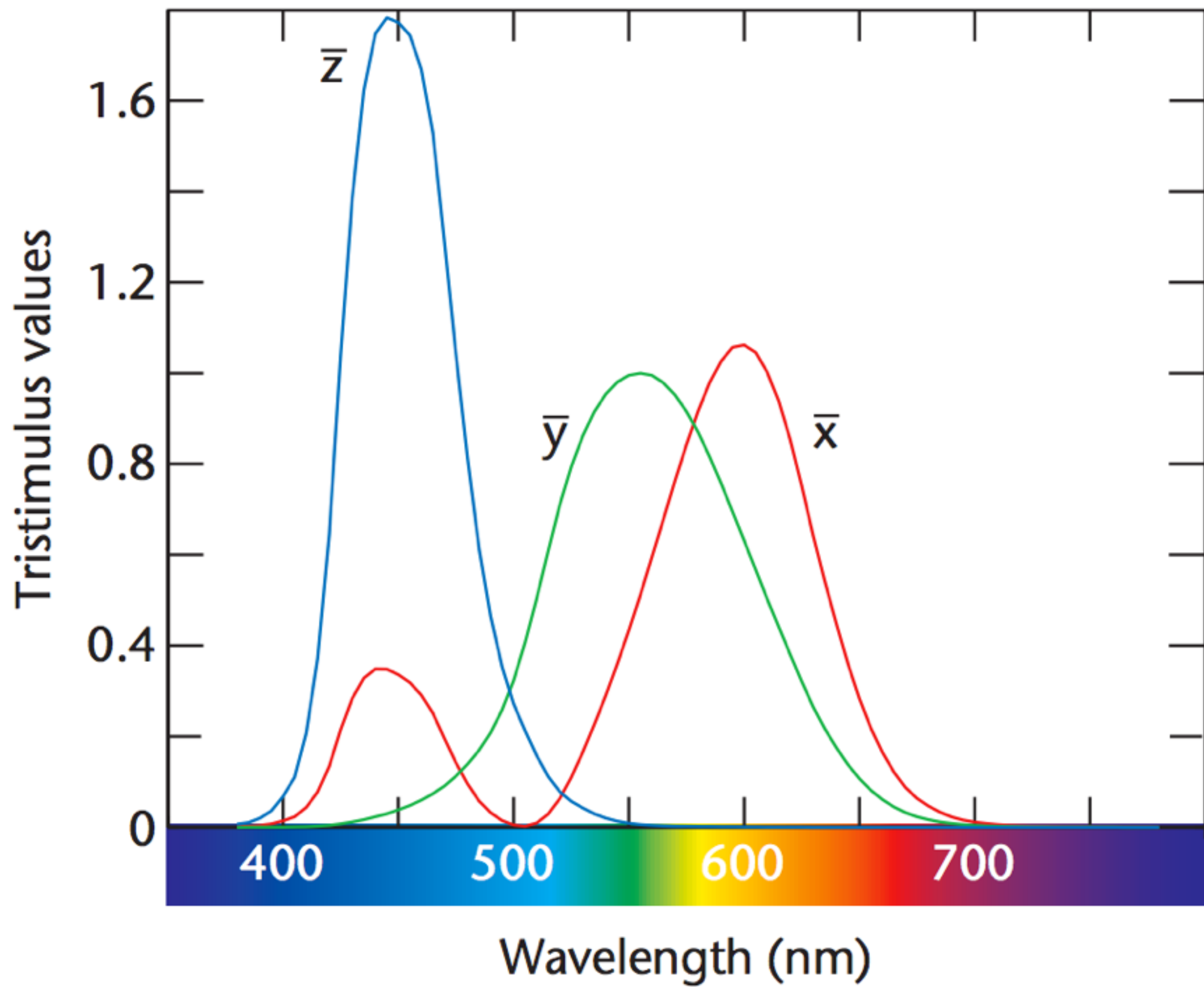


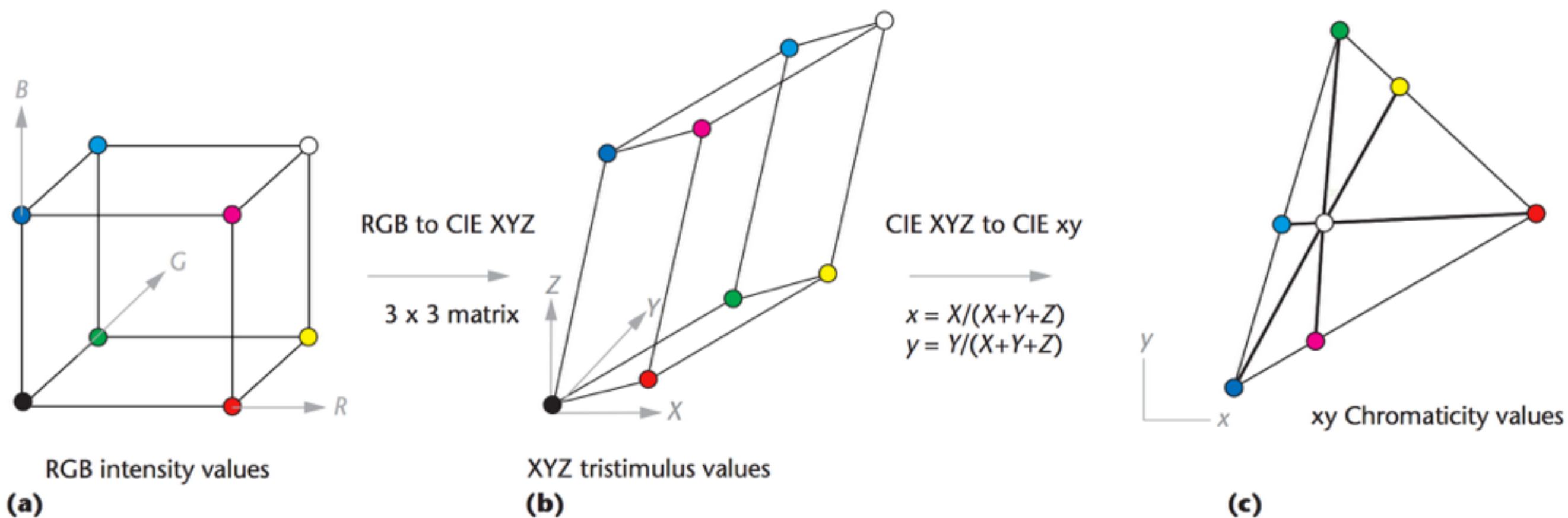
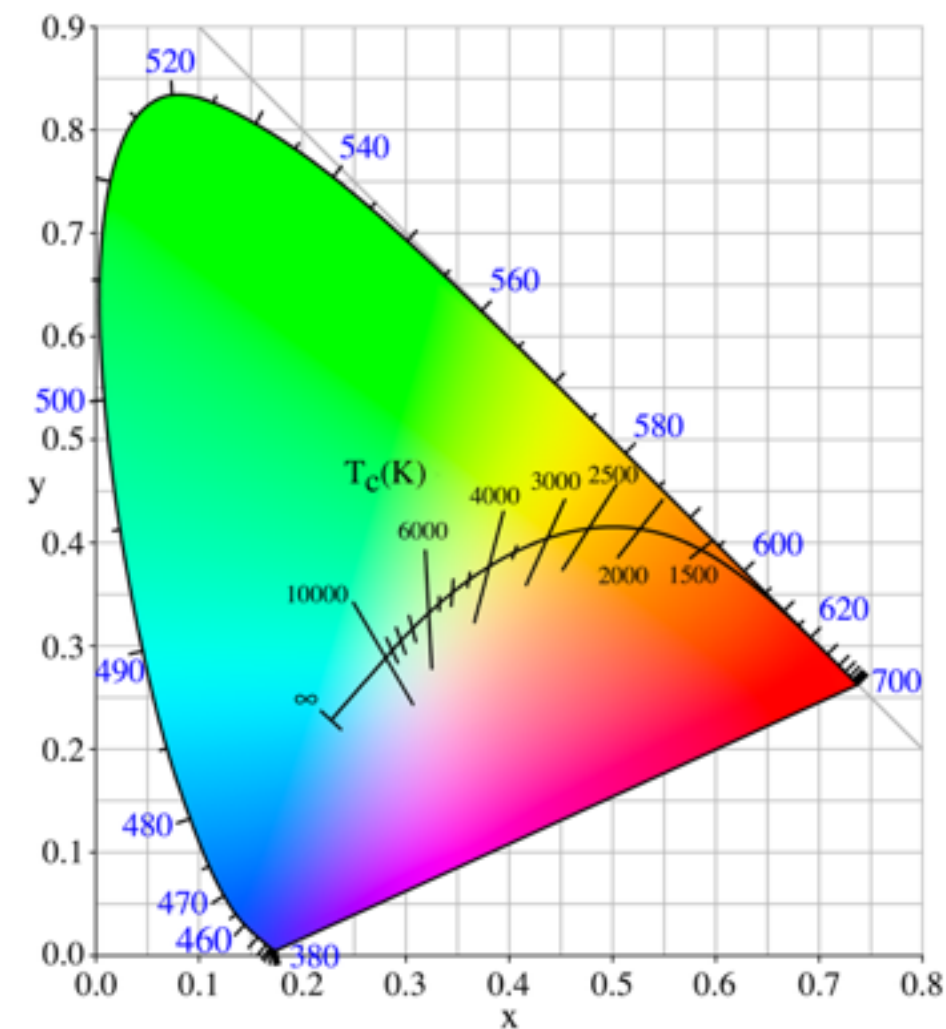
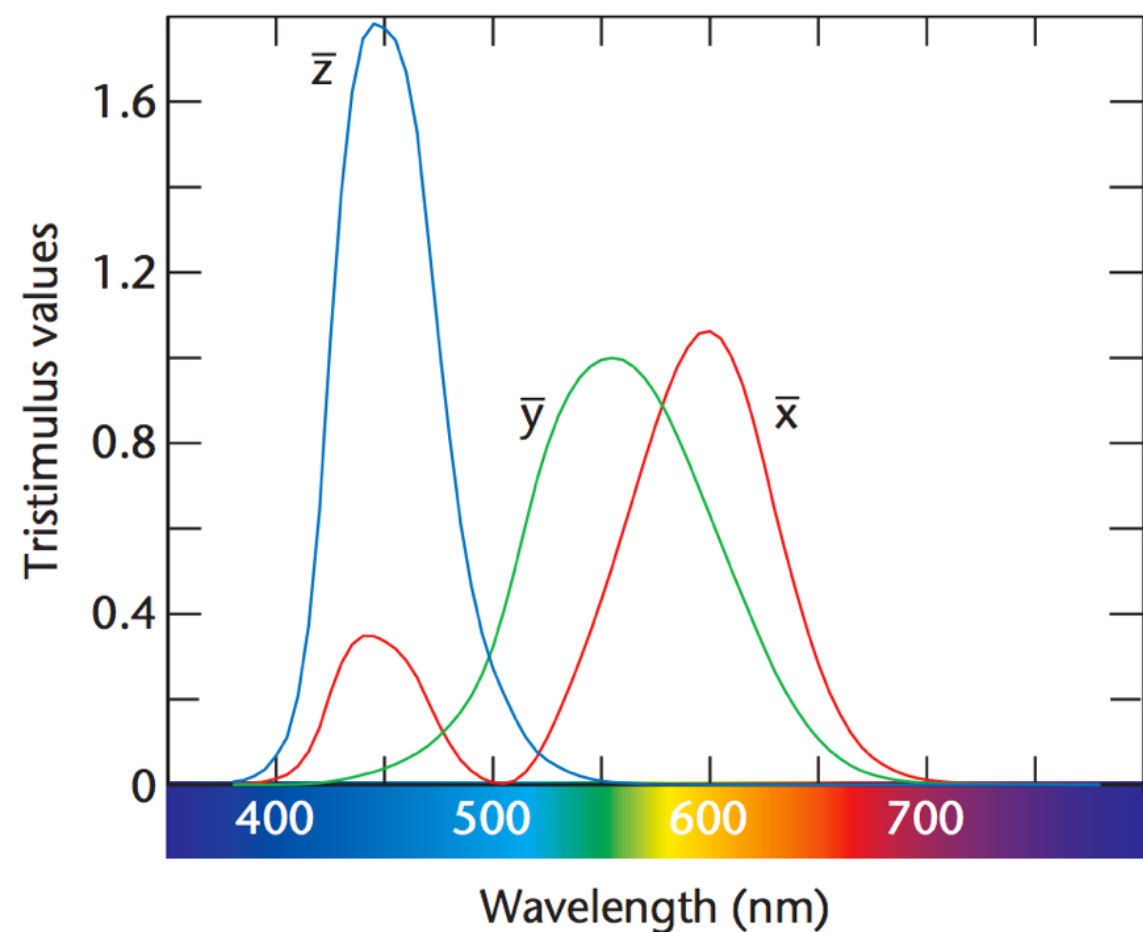
XYZ tristimulus values  
**(b)**

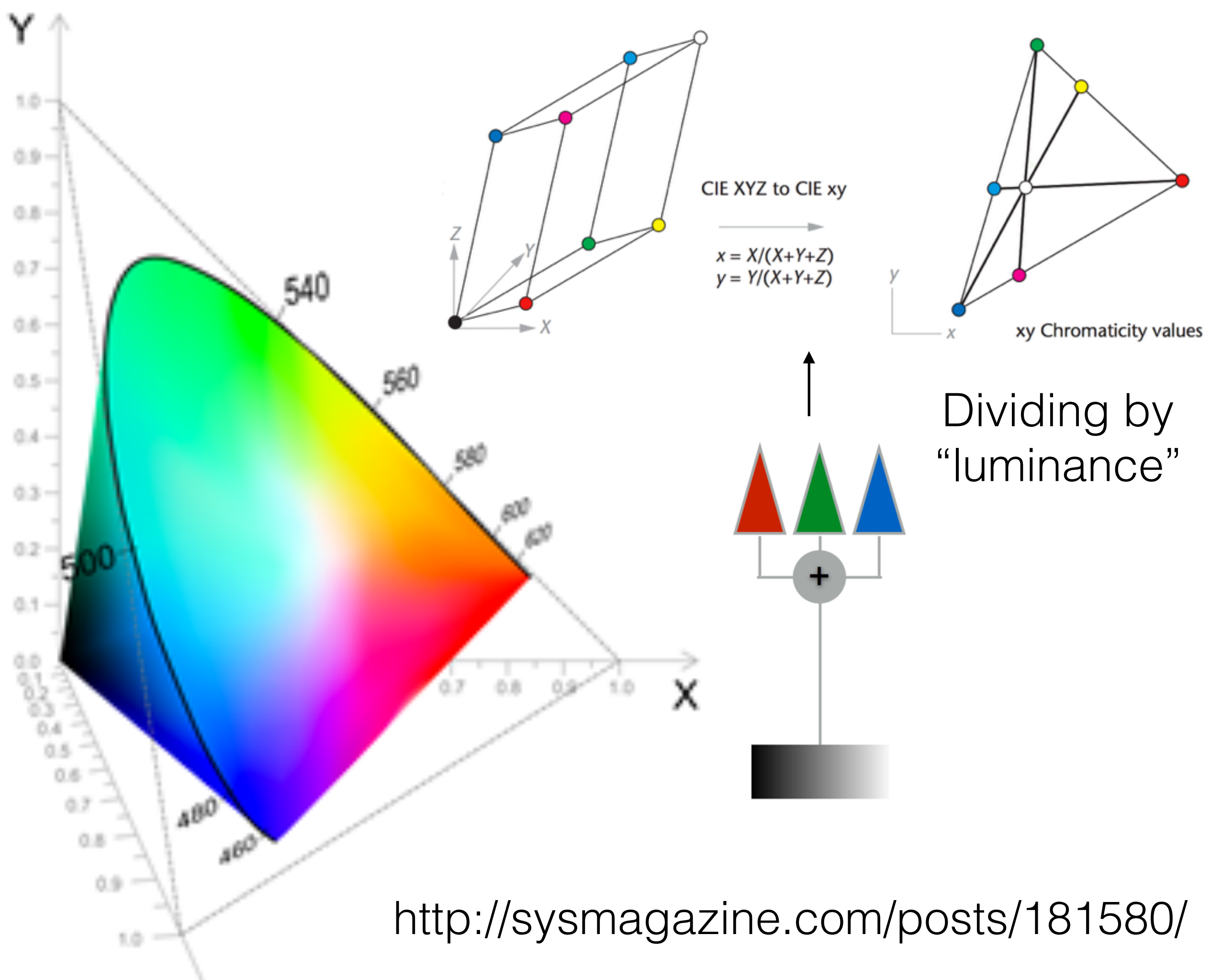
CIE XYZ to CIE xy  
 $x = X/(X+Y+Z)$   
 $y = Y/(X+Y+Z)$



**(c)**



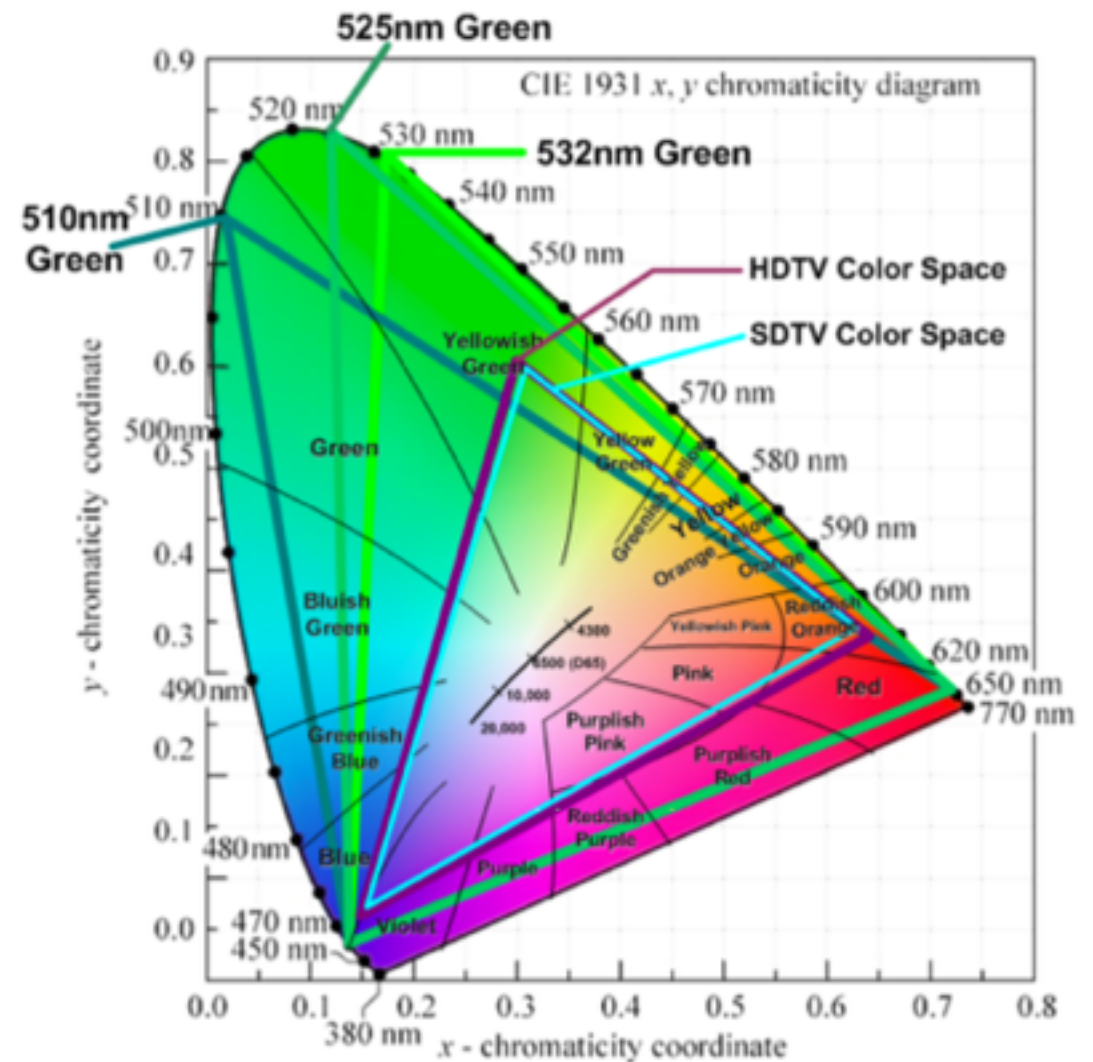
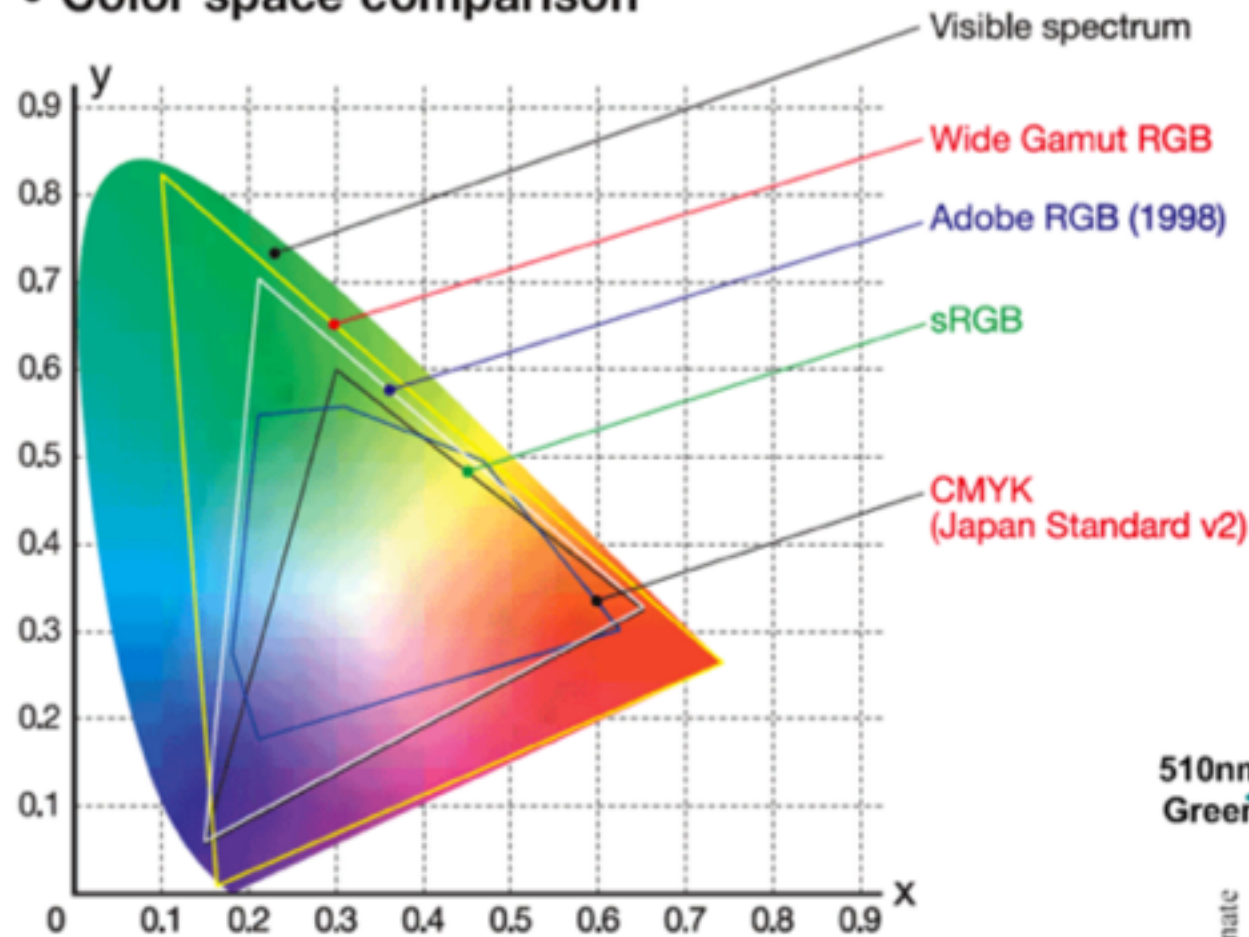






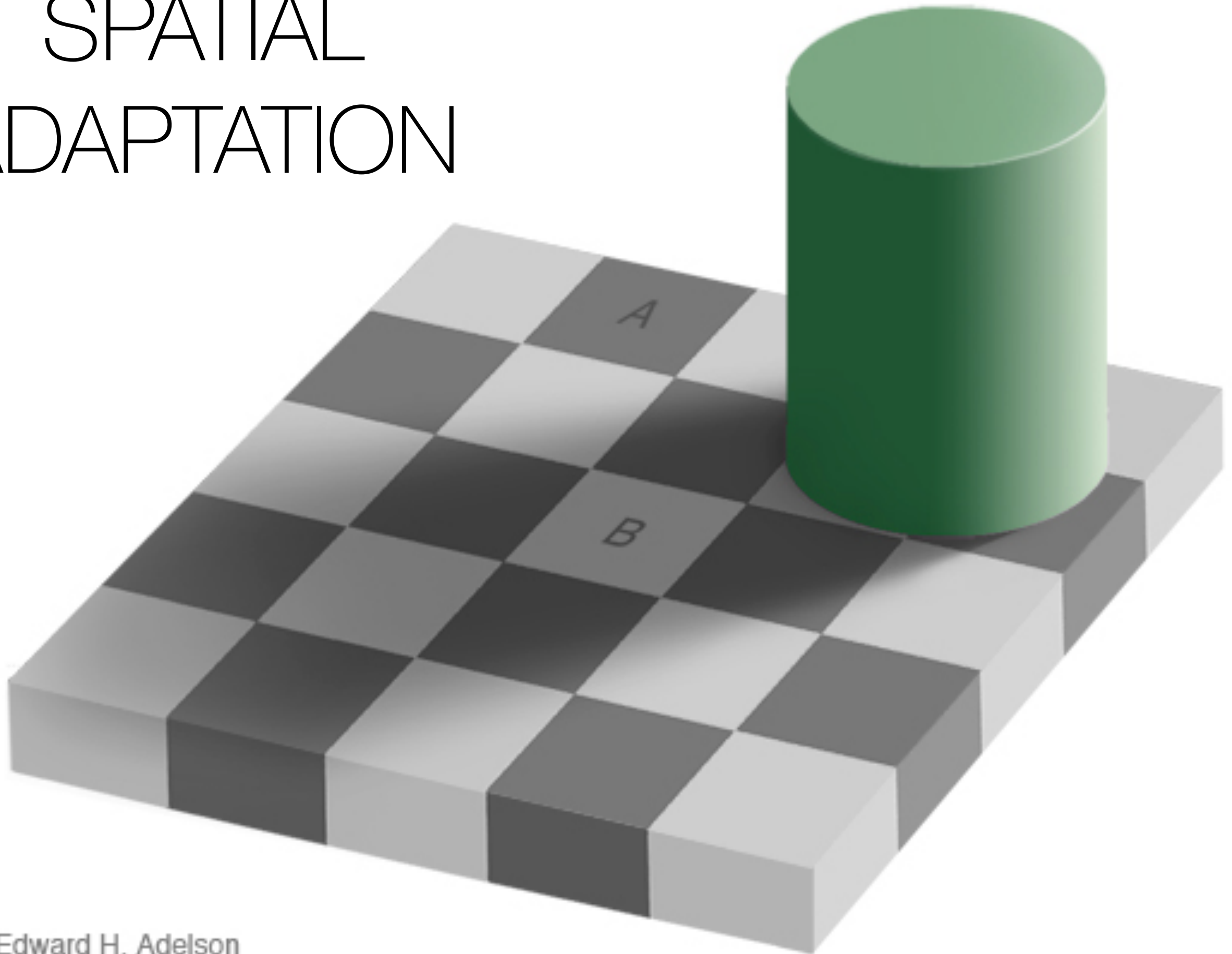
# COLOR GAMUTS

- Color space comparison



# CONSTANCY AND ADAPTATION

# SPATIAL ADAPTATION



Edward H. Adelson

# SPATIAL ADAPTATION

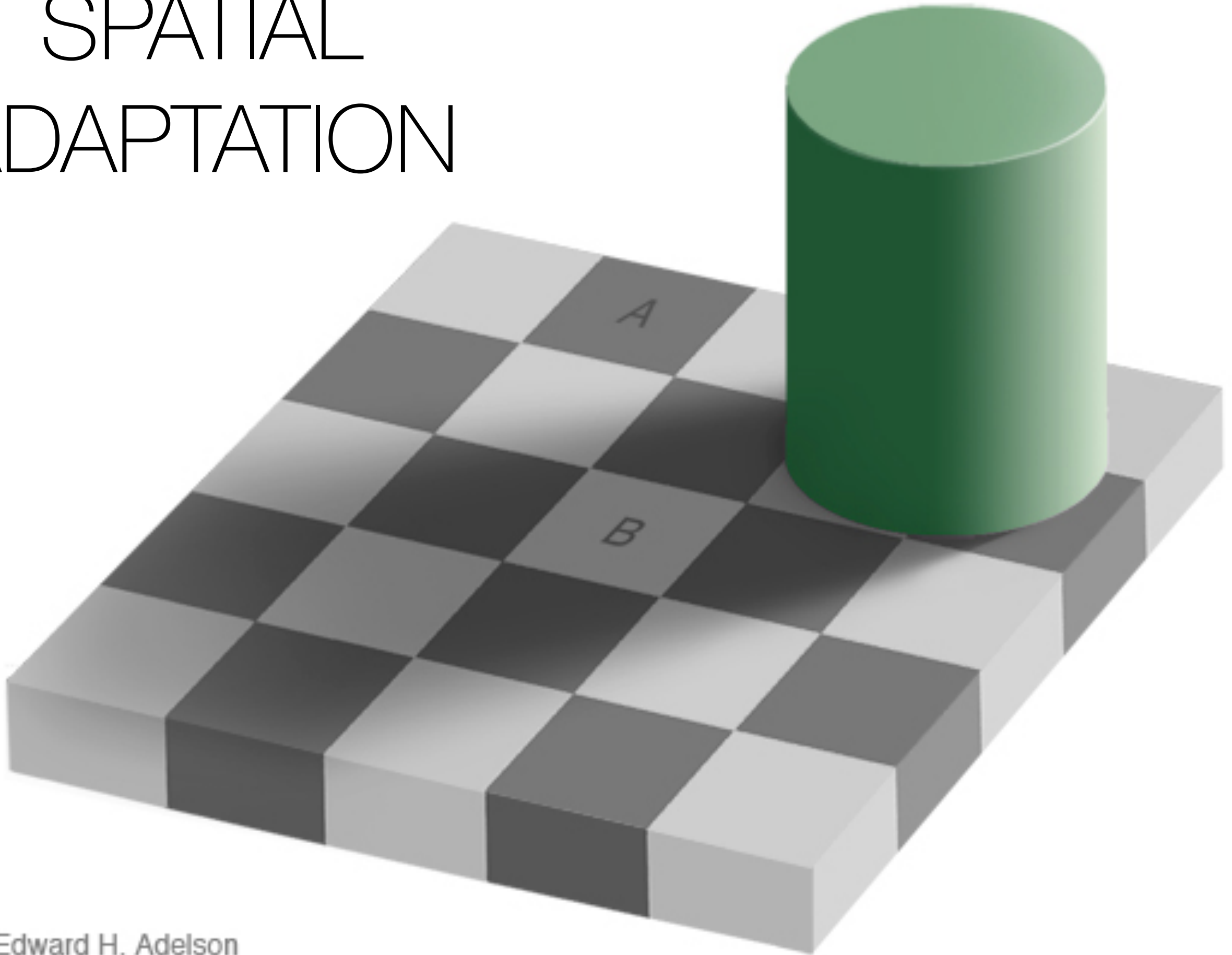


# SPATIAL ADAPTATION



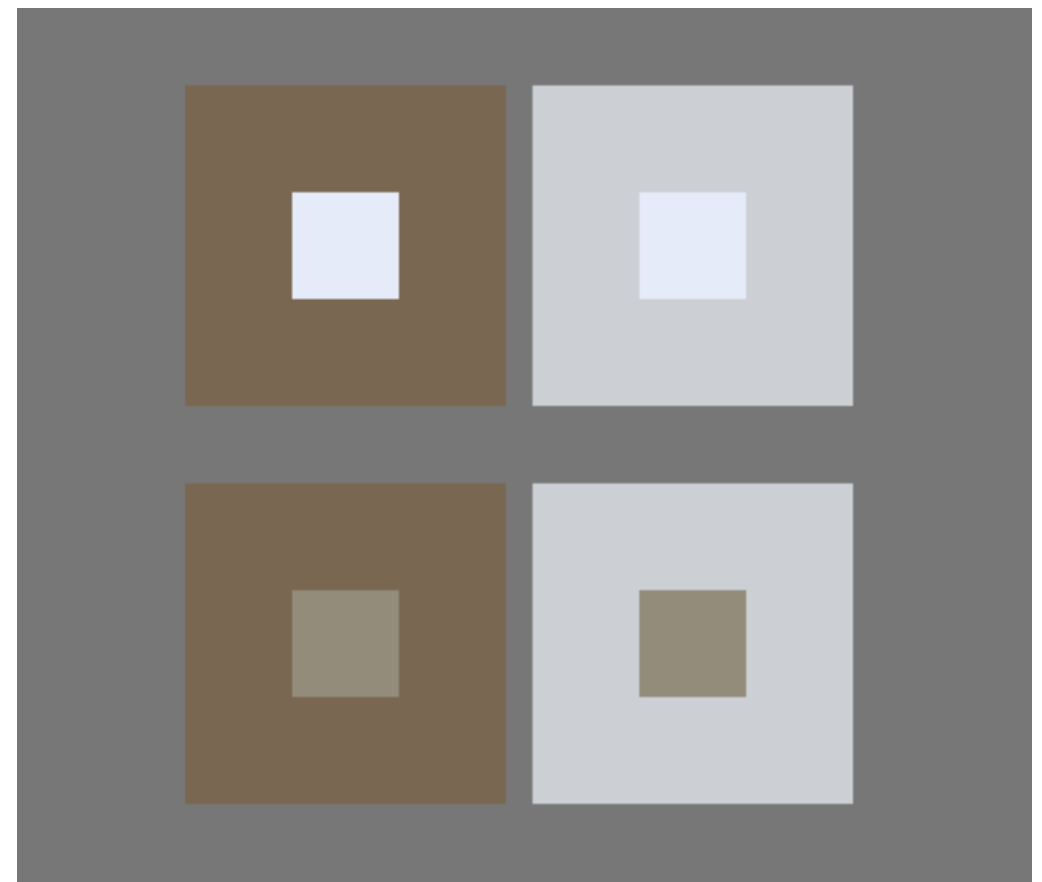


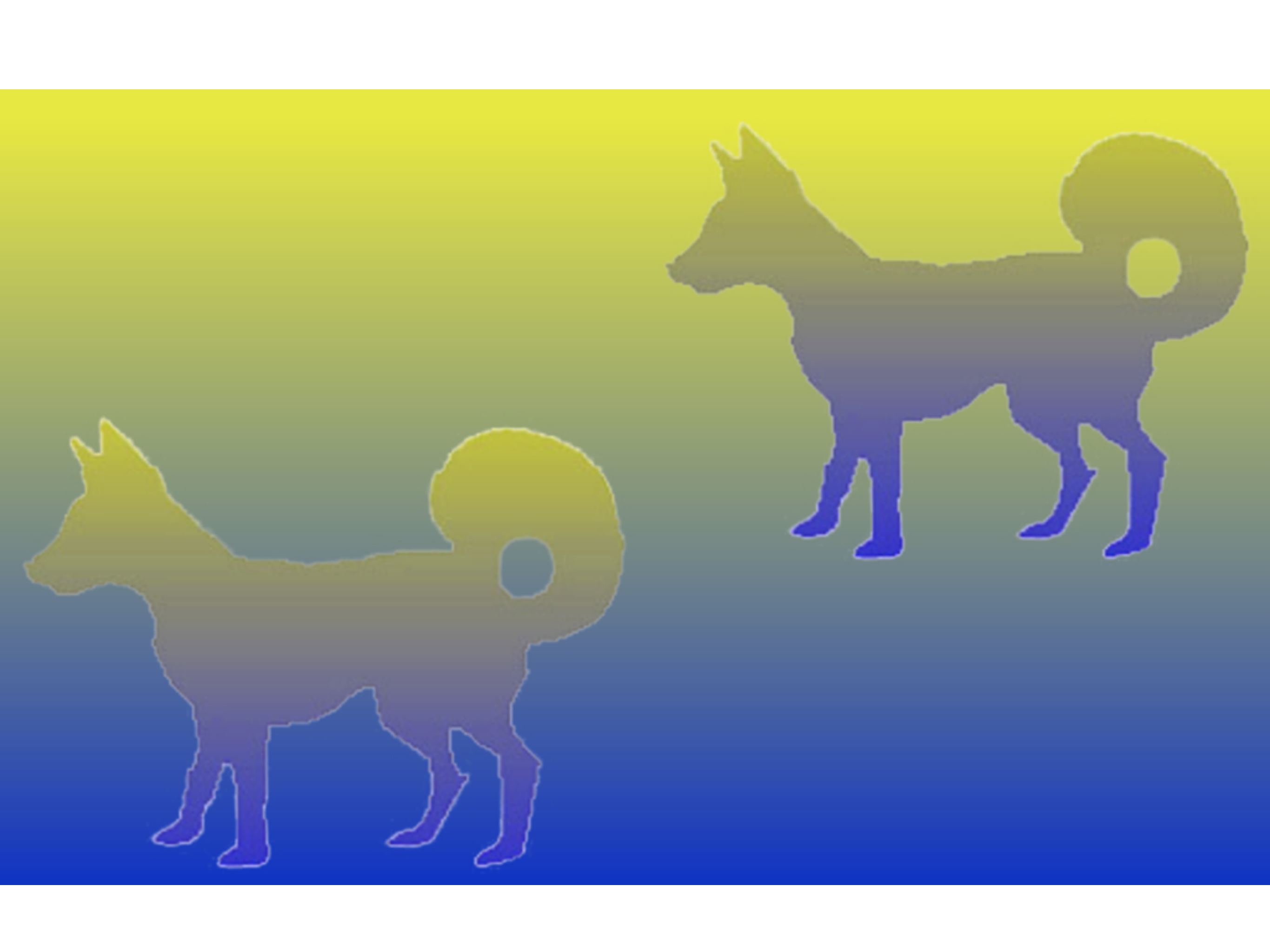
# SPATIAL ADAPTATION



Edward H. Adelson

# SIMULTANEOUS CONTRAST







# TEMPORAL ADAPTATION

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

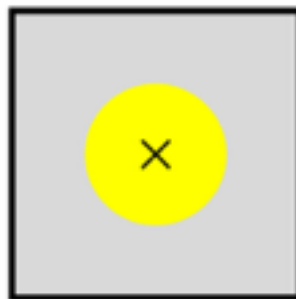


# Impossible Colors (!)

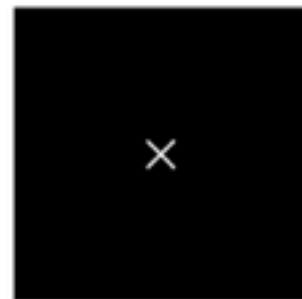
<http://upload.wikimedia.org/wikipedia/commons/5/56/Chimerical-color-demo.svg>  
Chimerical-color-demo.svg

## CHIMERICAL COLOR DEMO TEMPLATES

Fatigue template  
(stare at "x")



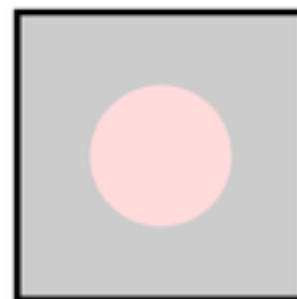
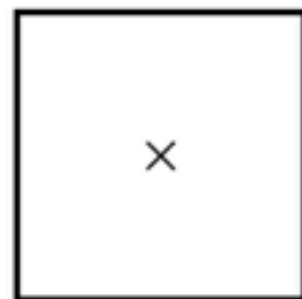
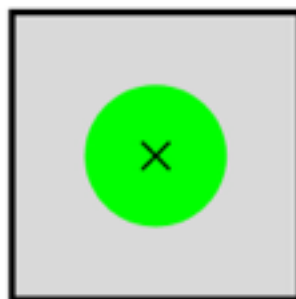
Target field  
(glance at "x")



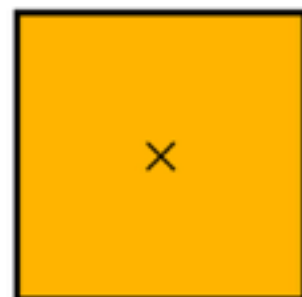
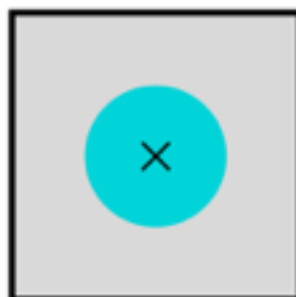
Approximate  
Rendering



STYGIAN BLUE  
(simultaneously deep  
blue and black)



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



HYPERBOLIC ORANGE  
(more than 100%  
color saturation)