Data Visualization Principles: Color

CSC444

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

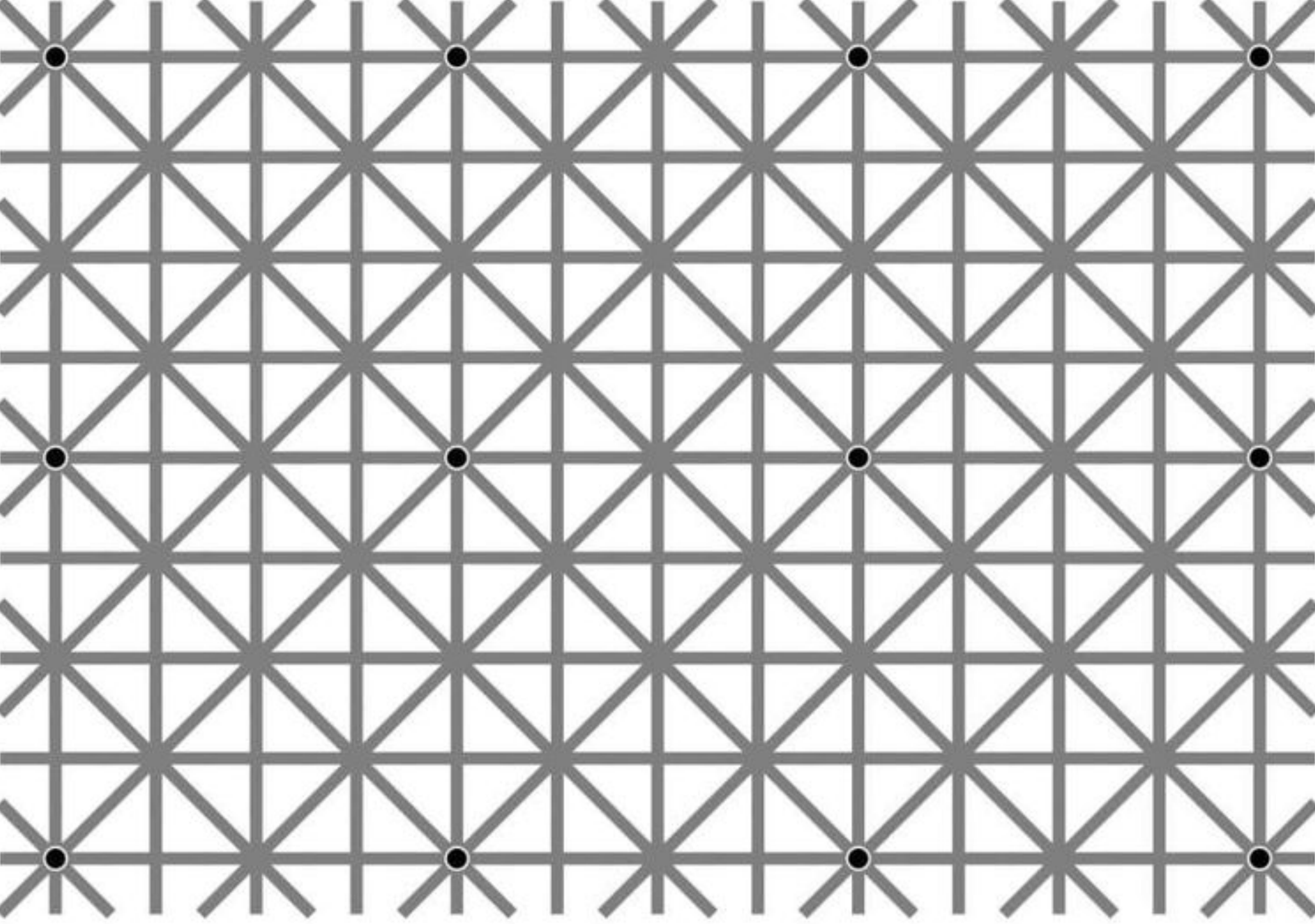
Outlook

Mechanics

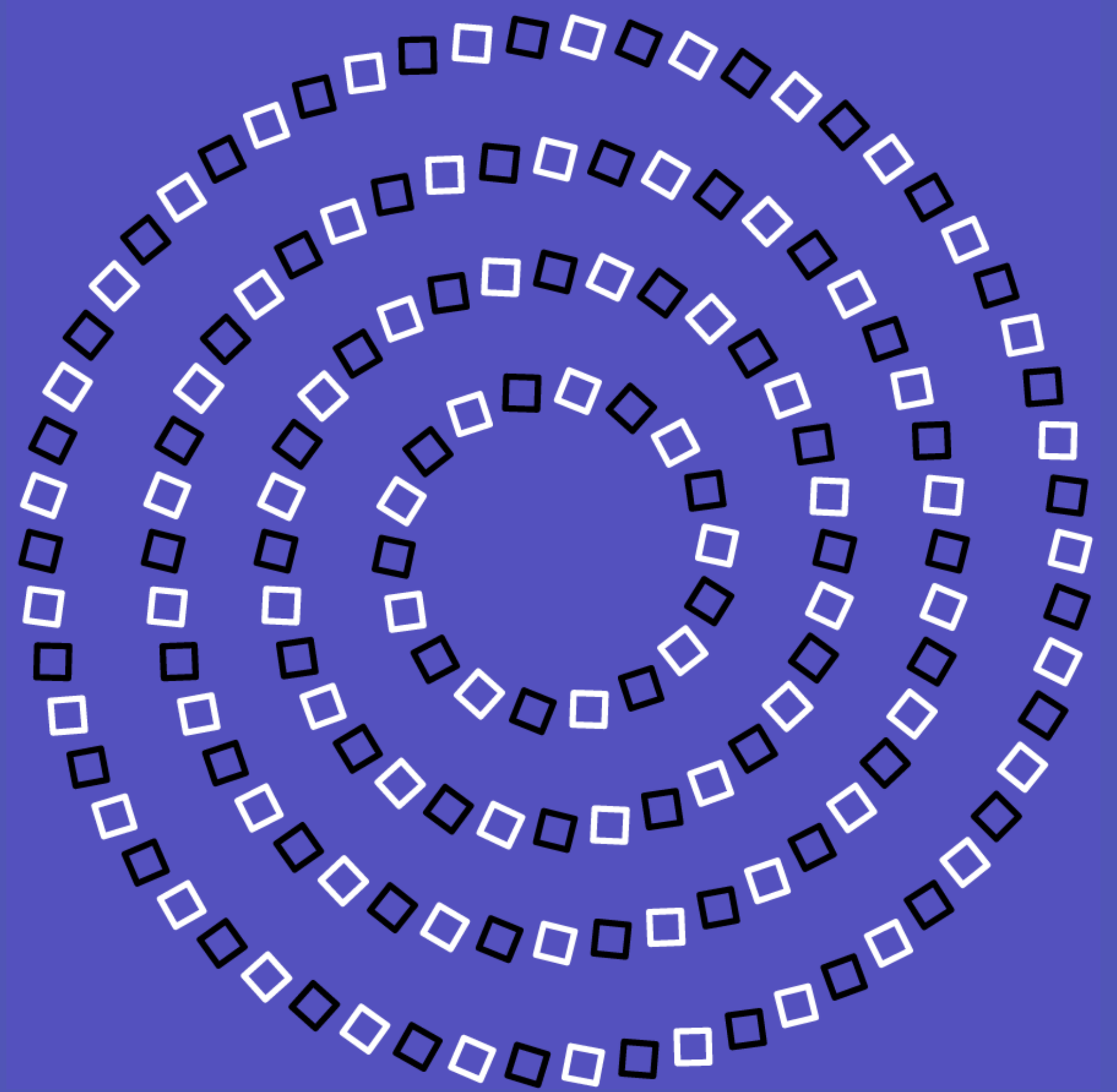
Principles

Techniques

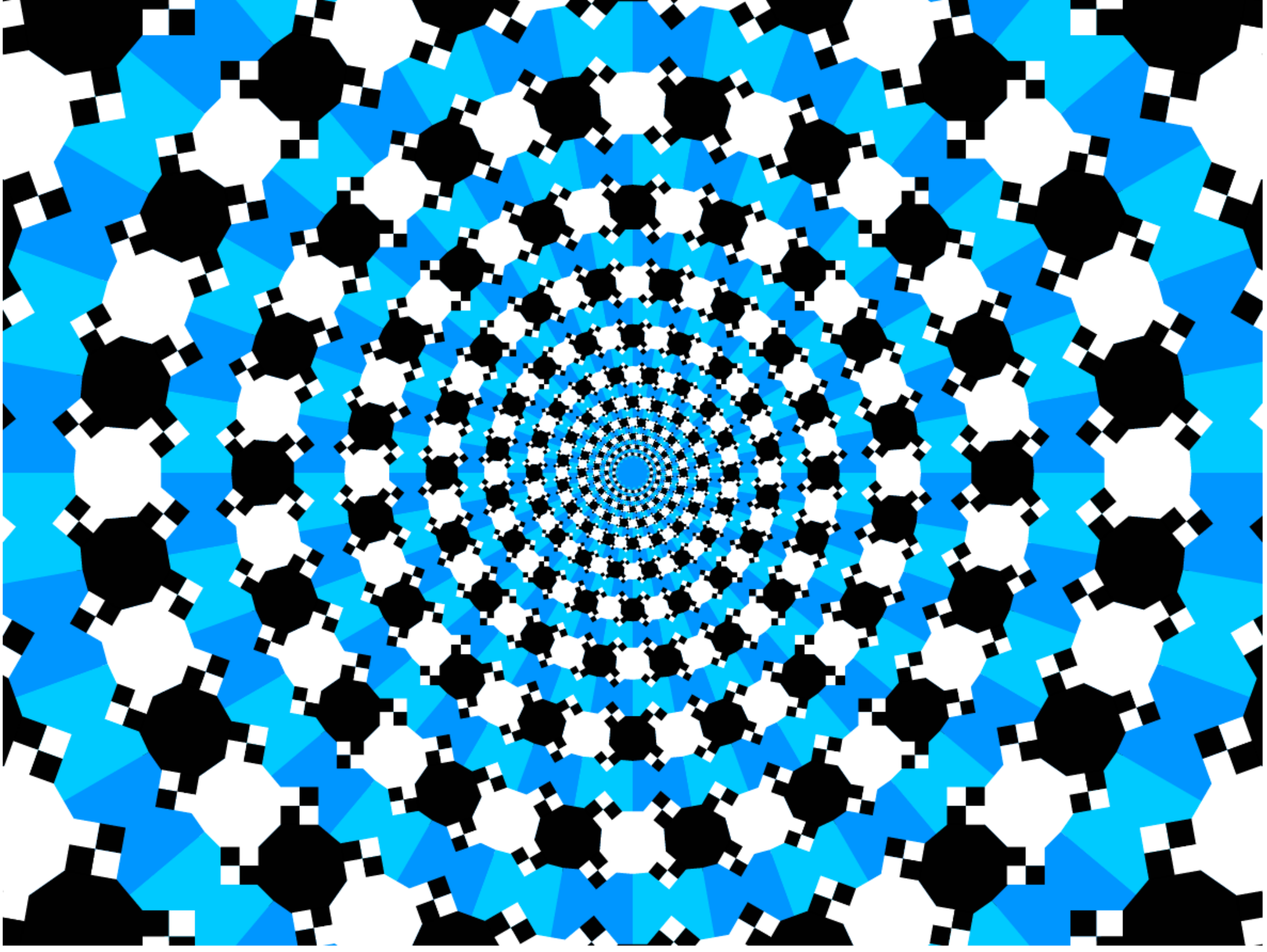
WHY STUDY PRINCIPLES?



Ninio’s extinction illusion



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

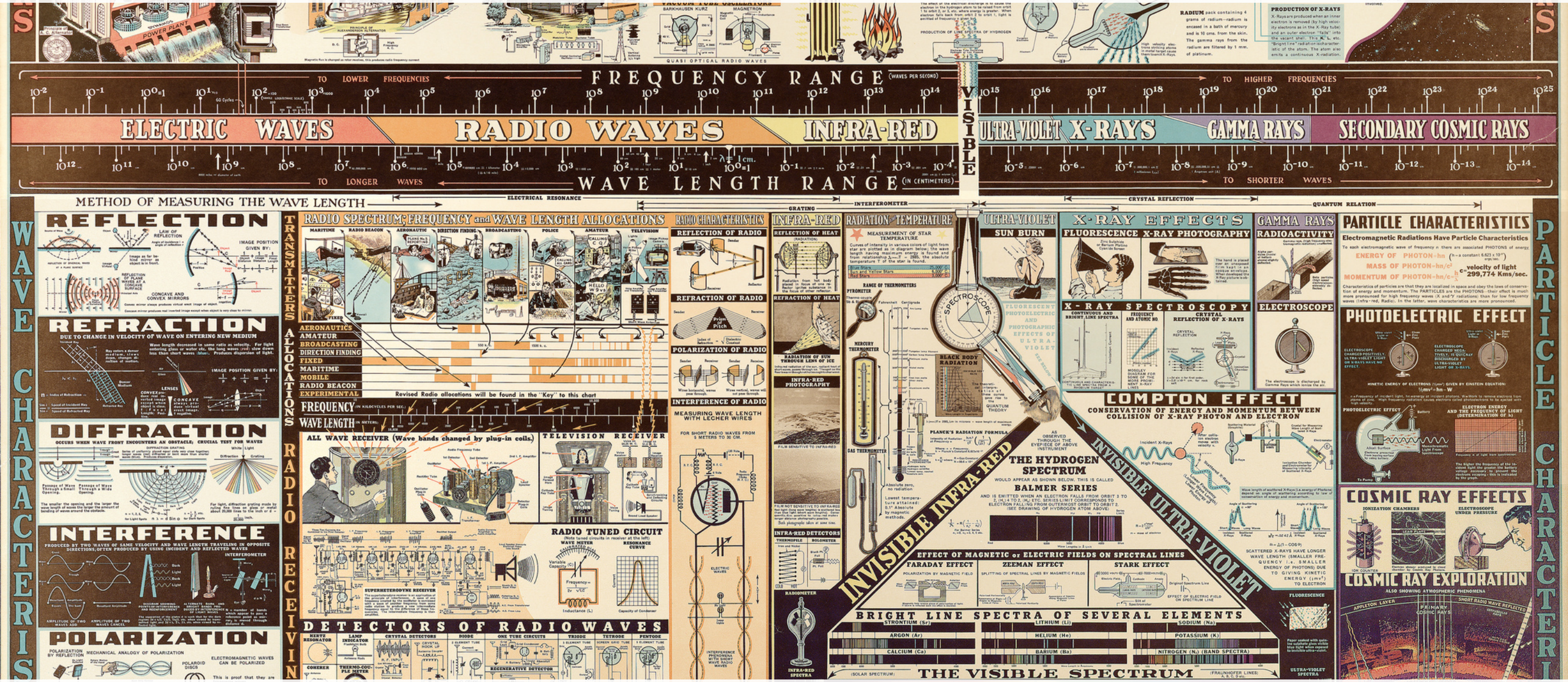
How can it be that your perception of “yellow” from your **laptop display** “is equal” to the yellow from the **sun**, and that from a **painting**?

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

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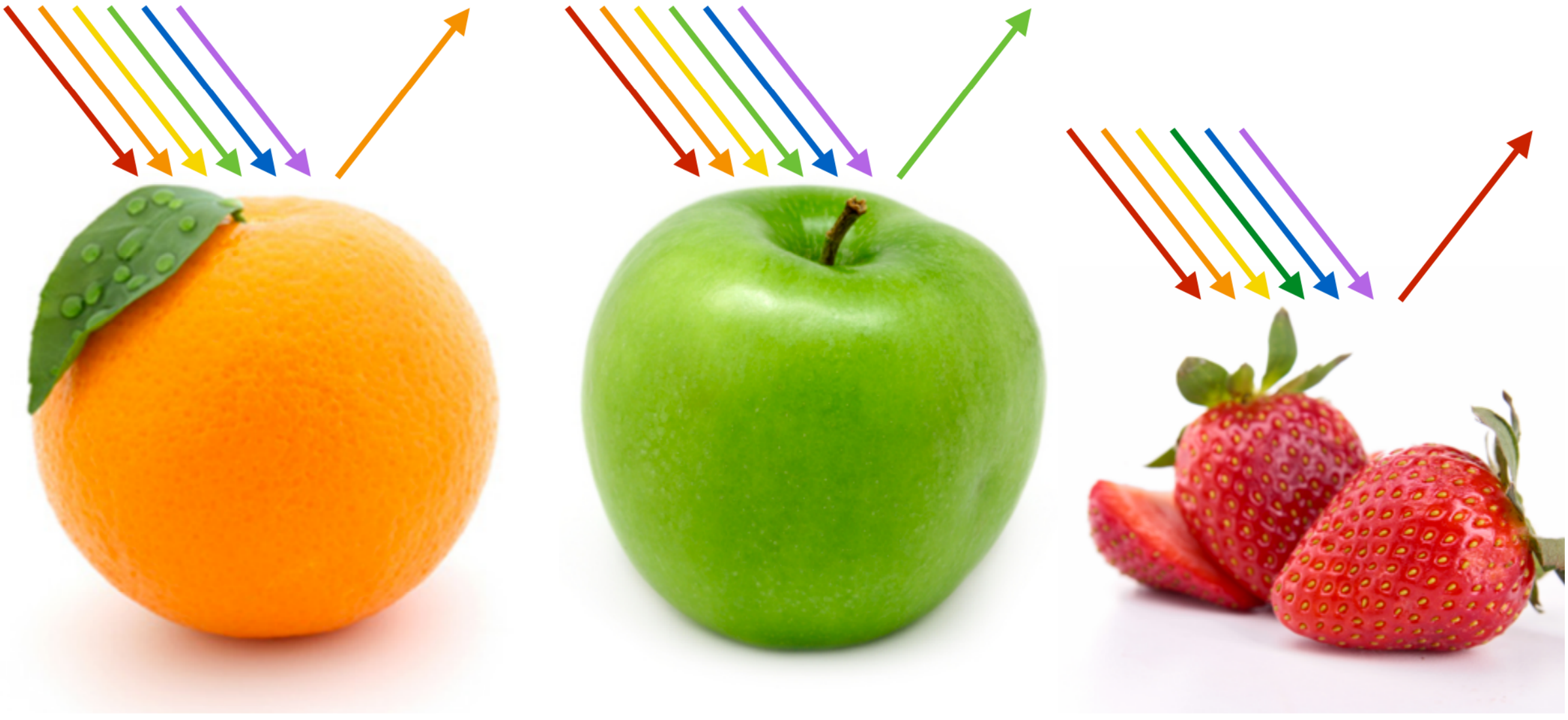
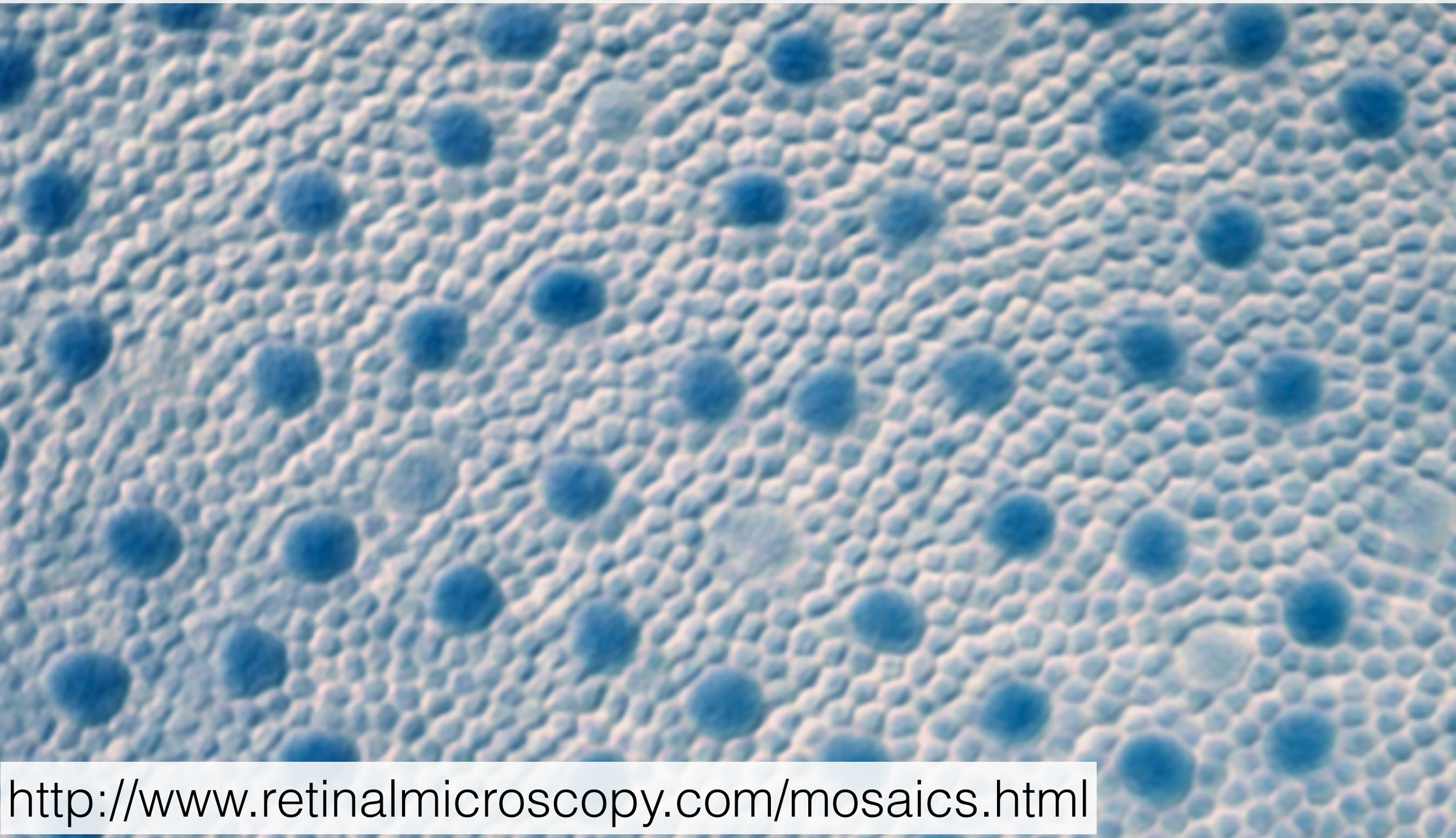


How does your eye work?



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

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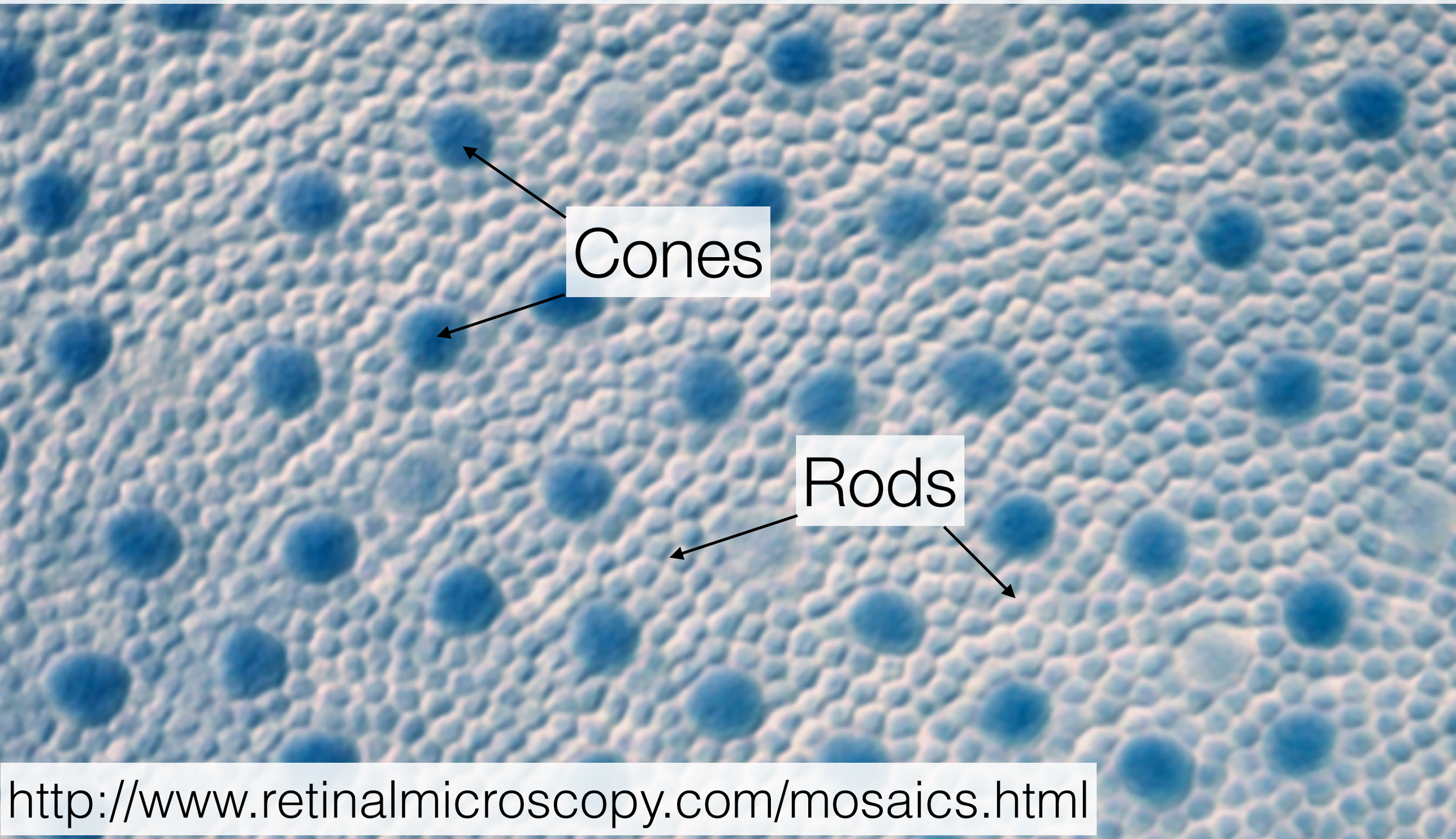

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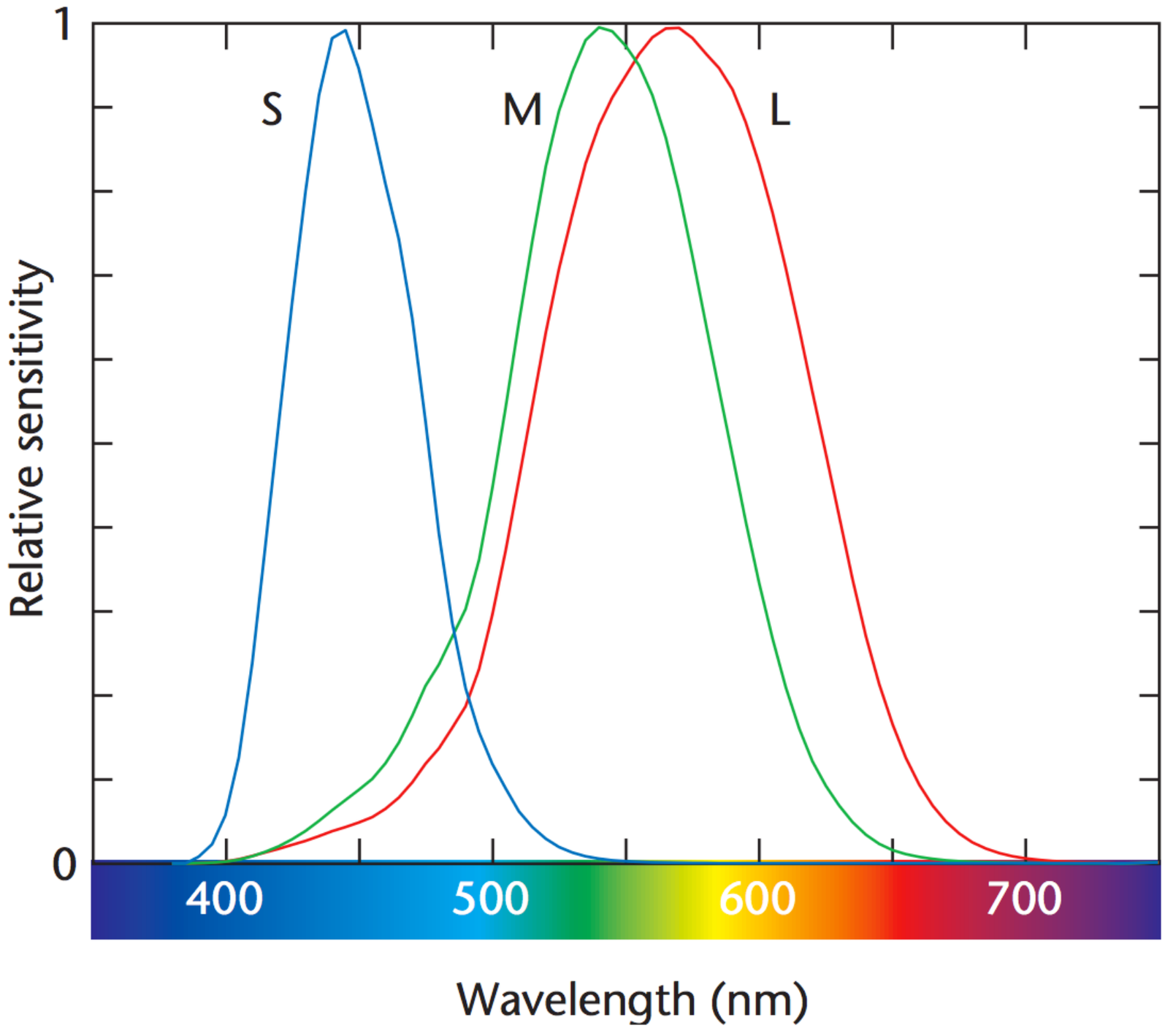
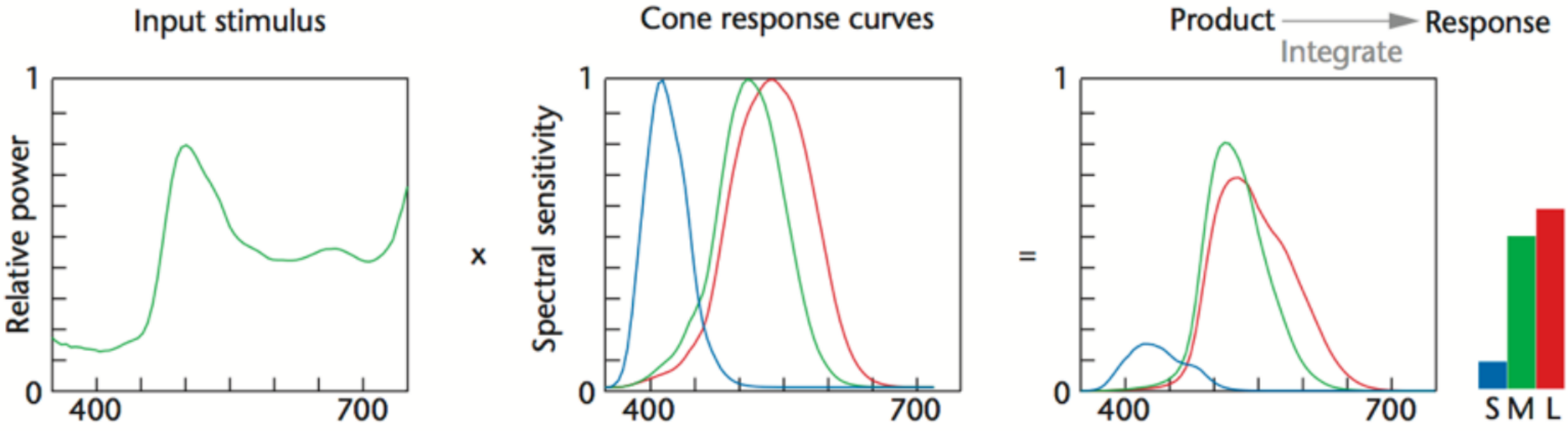
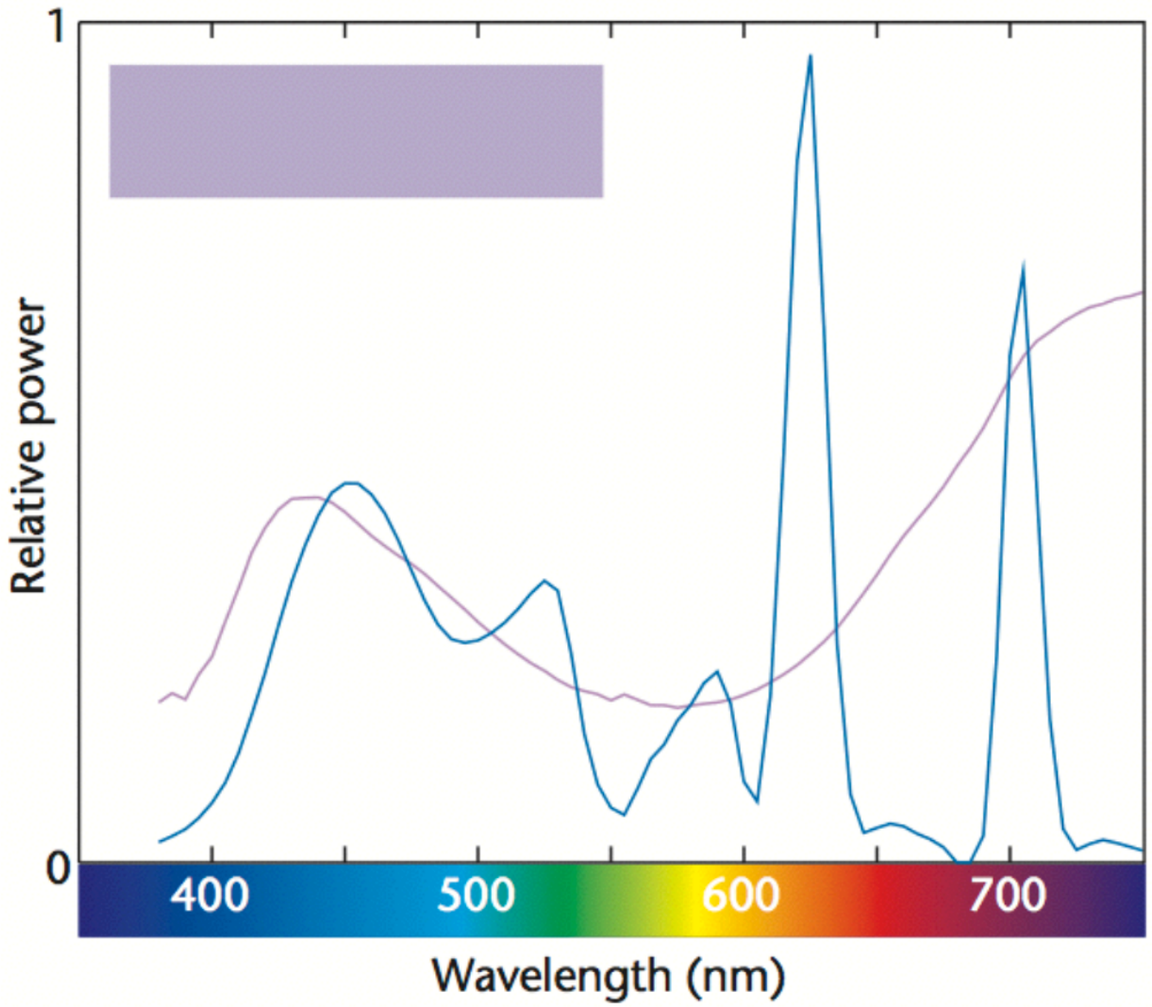


TRICHROMACY

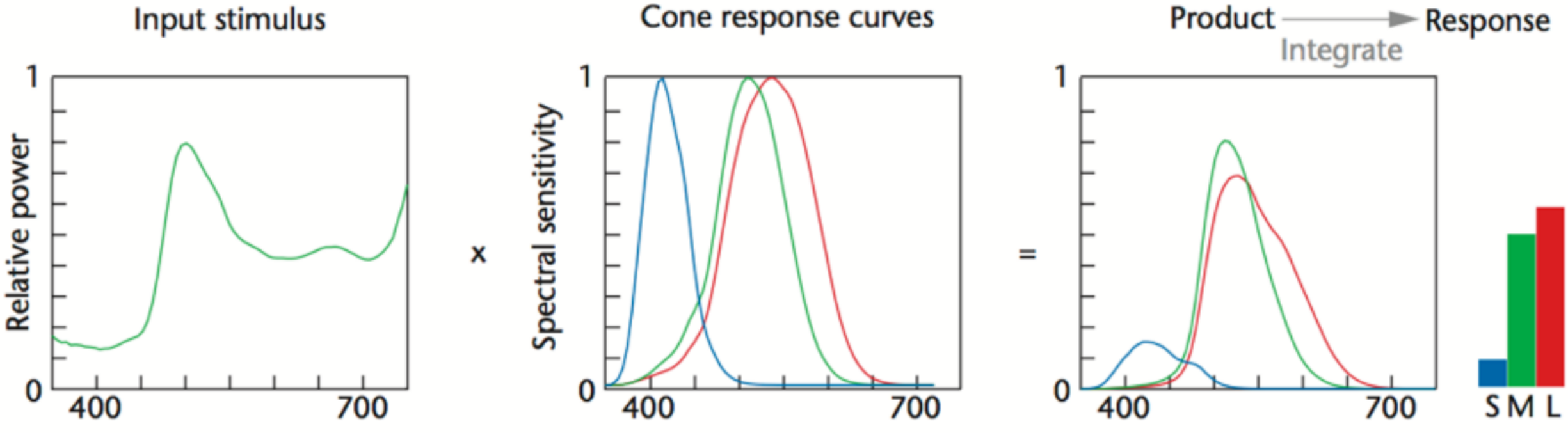


Three numbers!

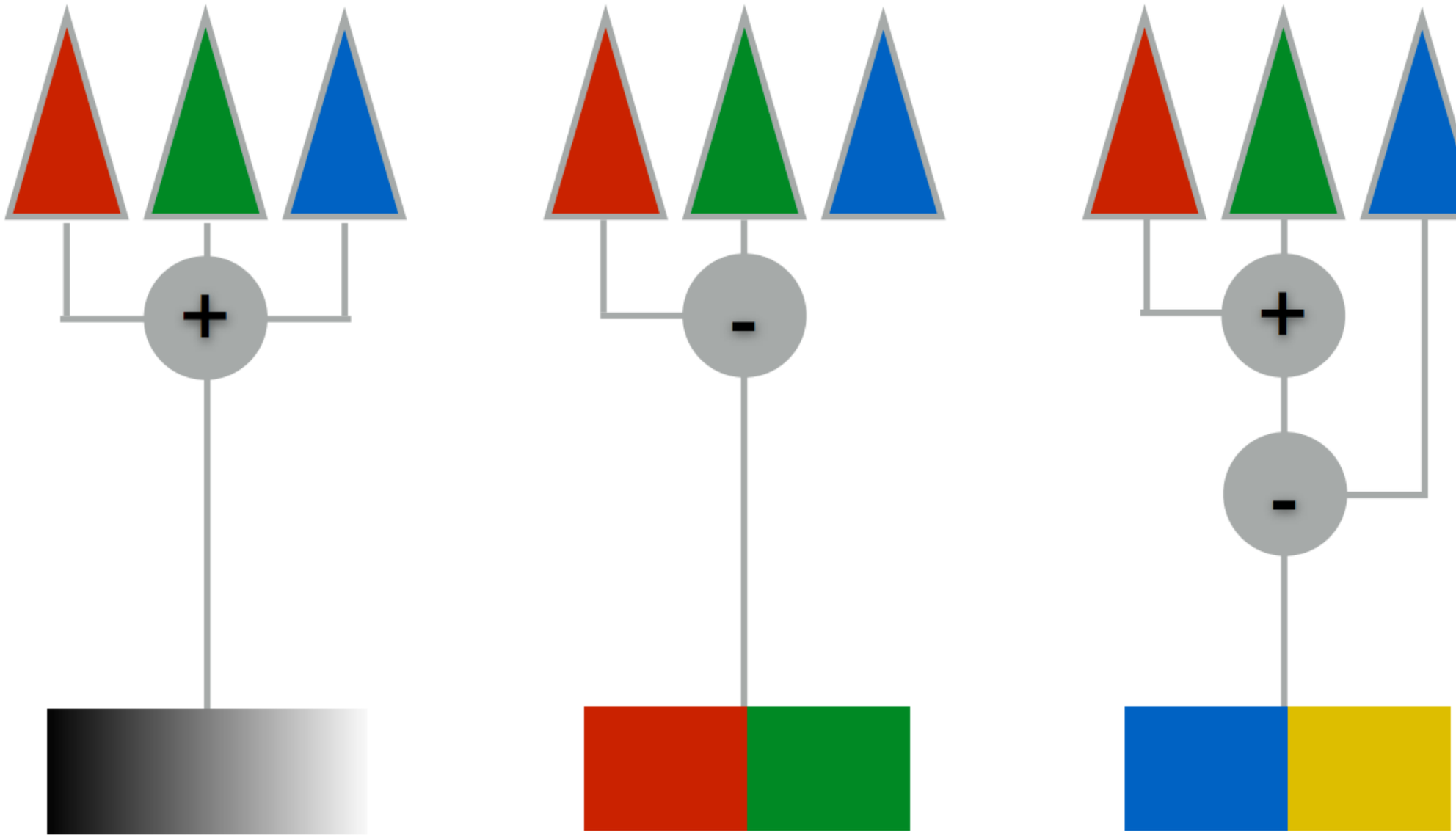


same three numbers,
same impression

METAMERISM

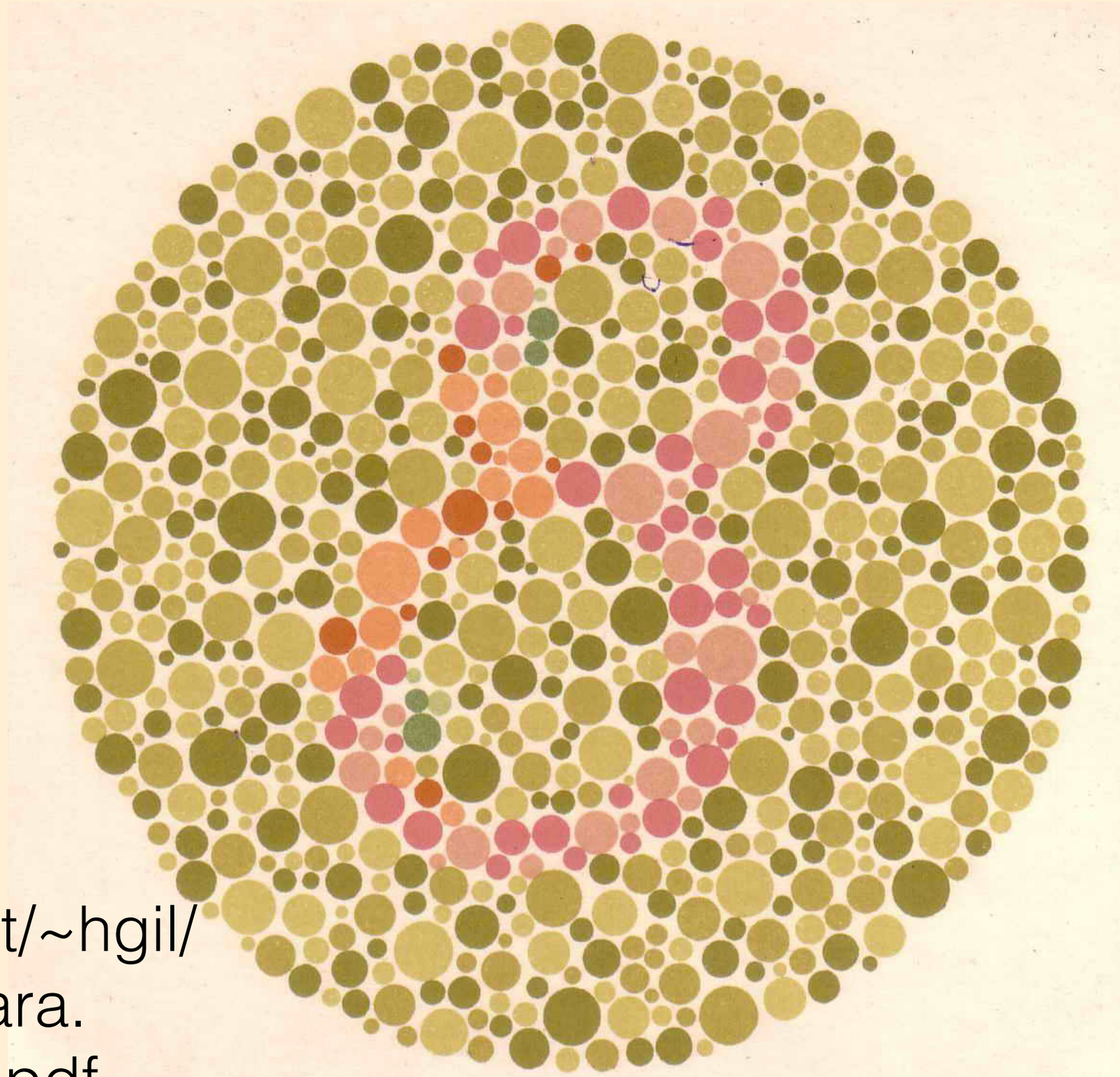


OPPONENT PROCESS MODEL



COLOR VISION DEFICIENCIES

Ishihara Plates



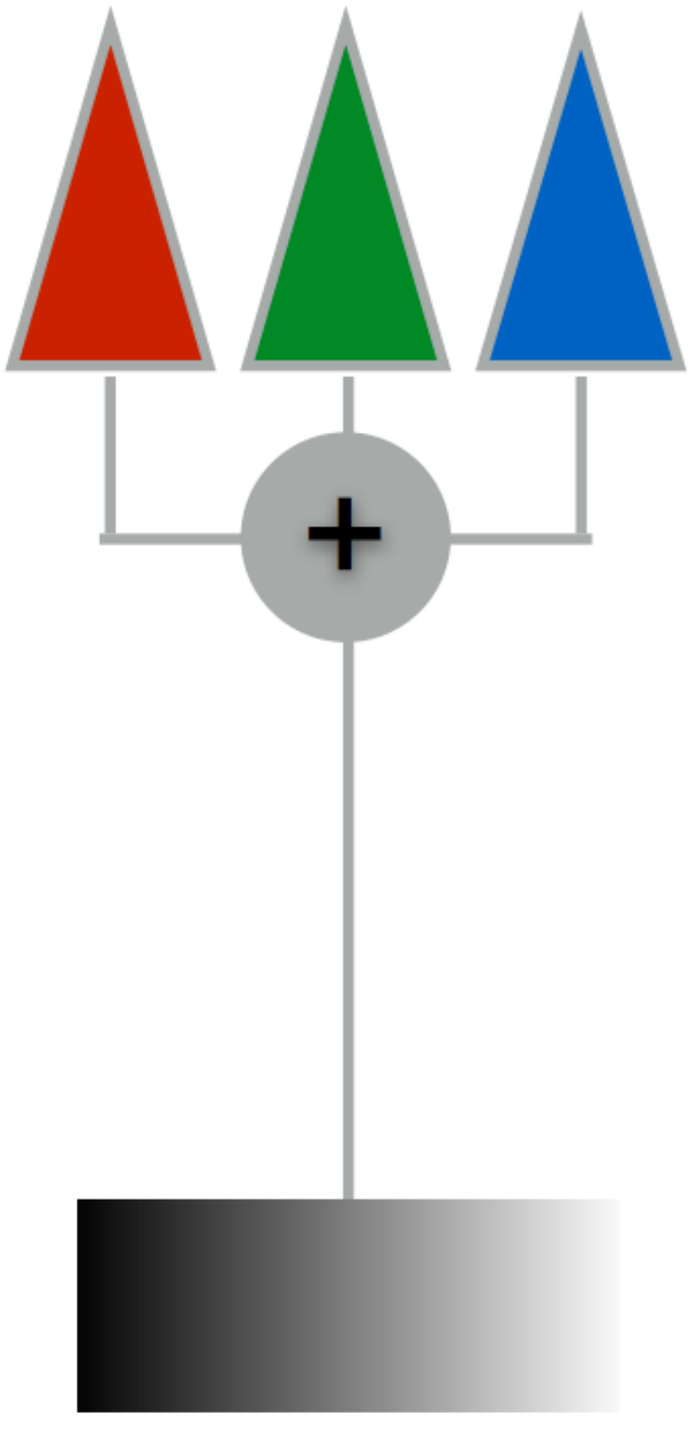
http://www.dfisica.ubi.pt/~hgil/p.v.2/Ishihara/Ishihara.24.Plate.TEST.Book.pdf

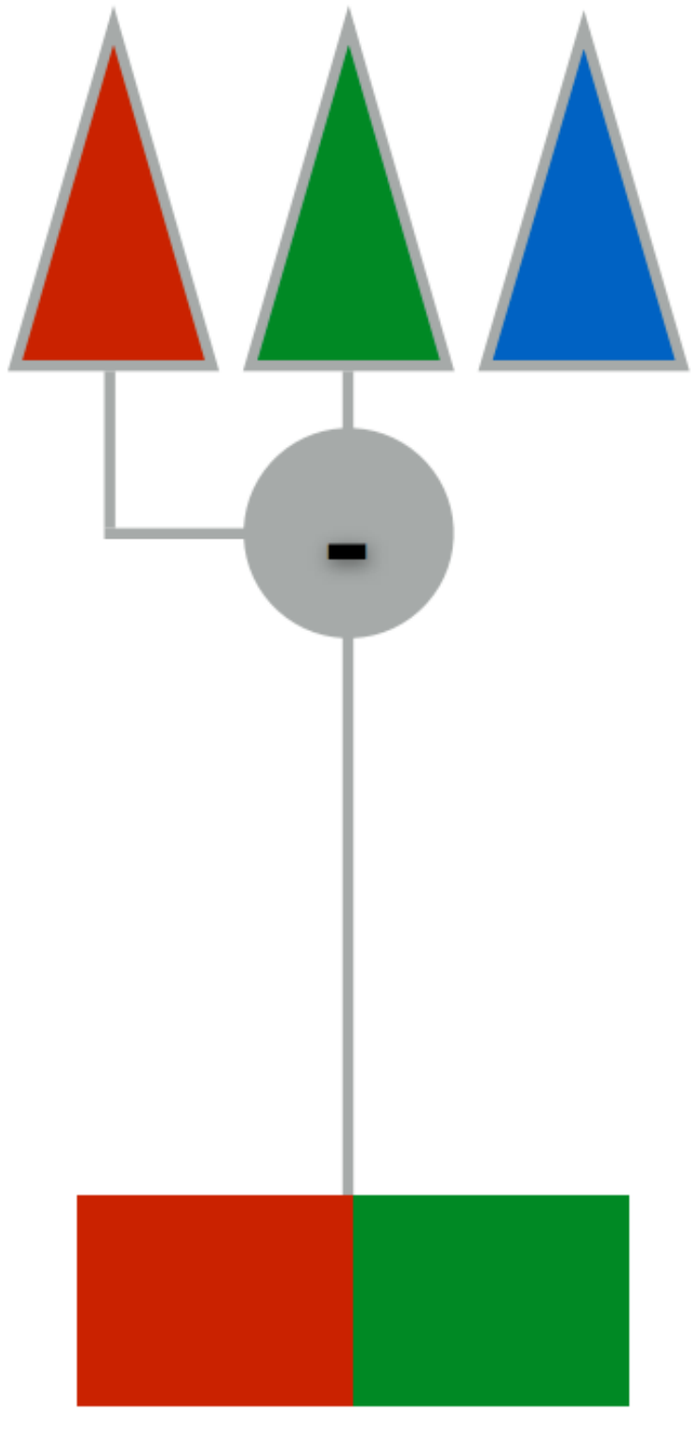
What goes wrong?

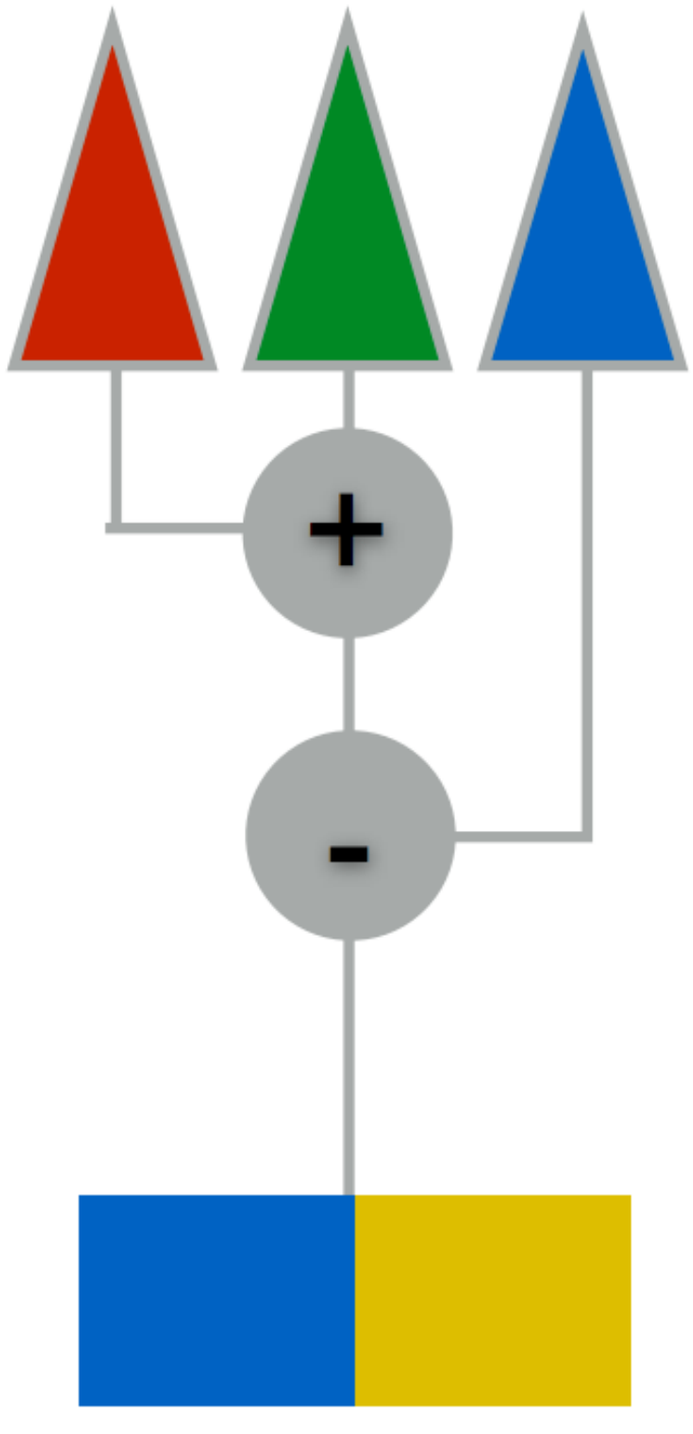
- Two broad classes of problems:
  - Only some types of cones present in the eye (rare)
    - red-green dichromacy, blue-yellow dichromacy
  - Two types of cones with abnormally close response curves
    - relatively common for red-green

How do the “color blind glasses” work?

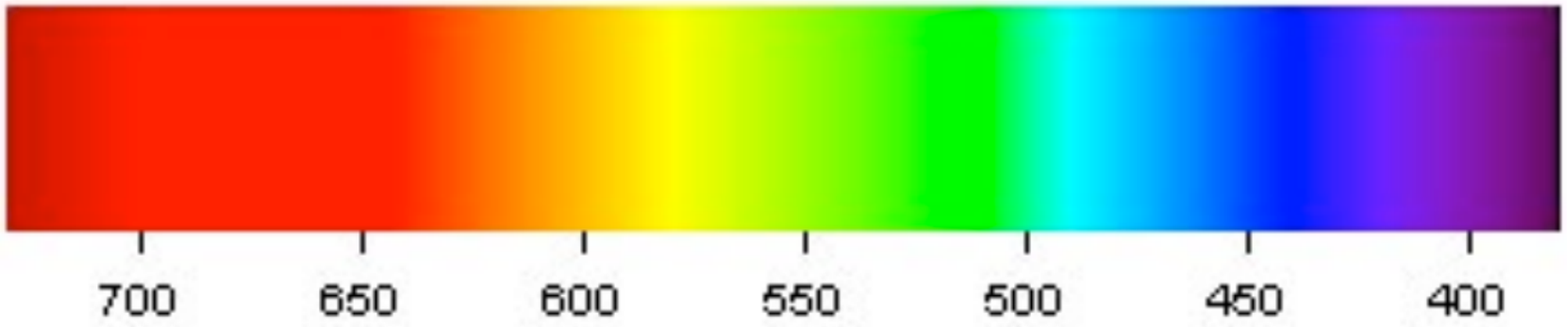
What goes wrong?



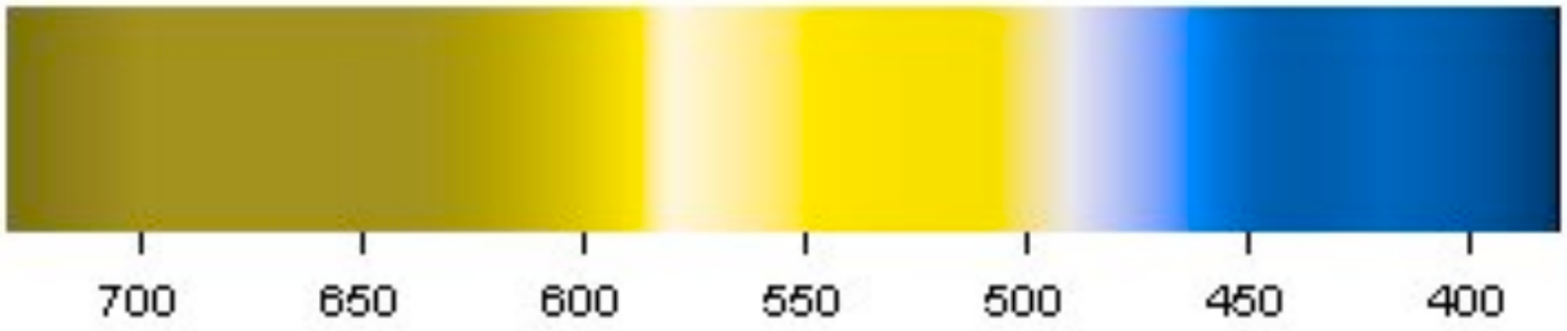




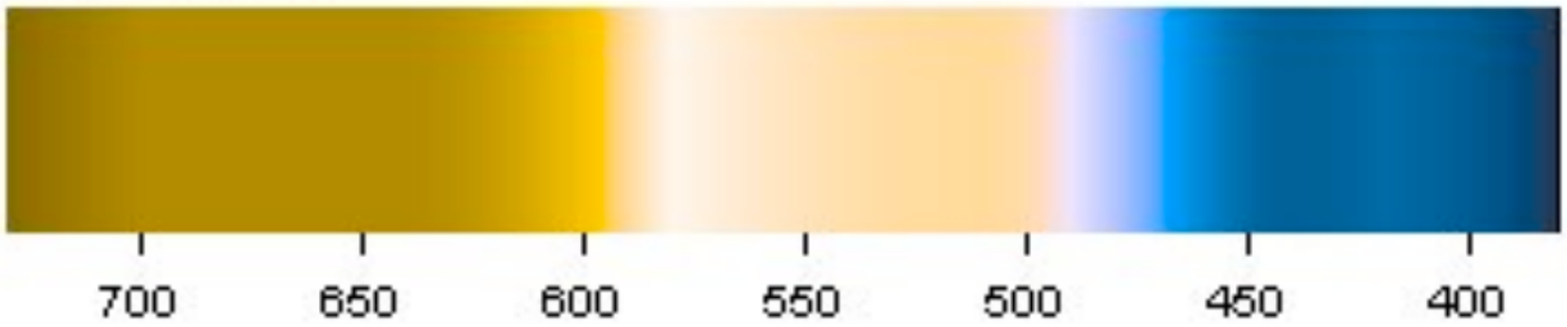
Normal



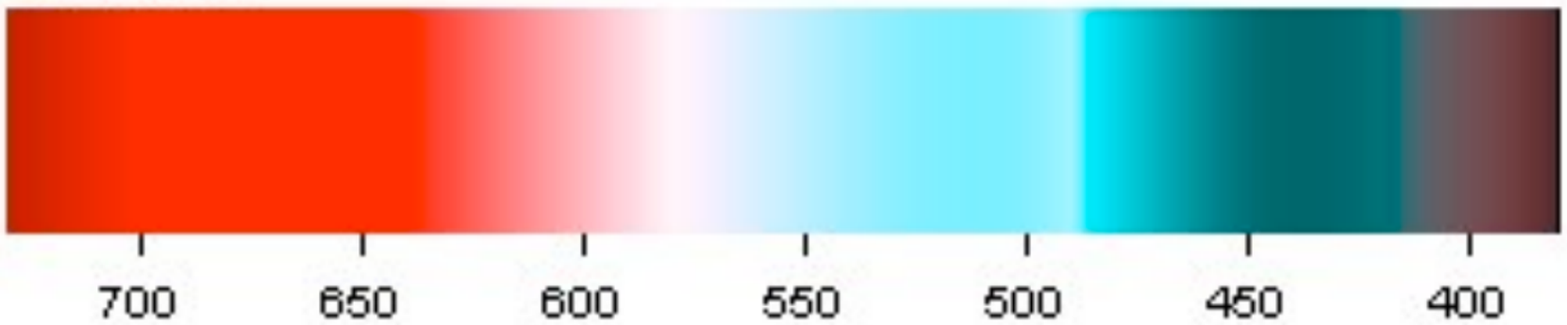
Protanopia



Deuteranopia



Tritanopia



WHAT ARE THE PRIMARY COLORS?

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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 (!)

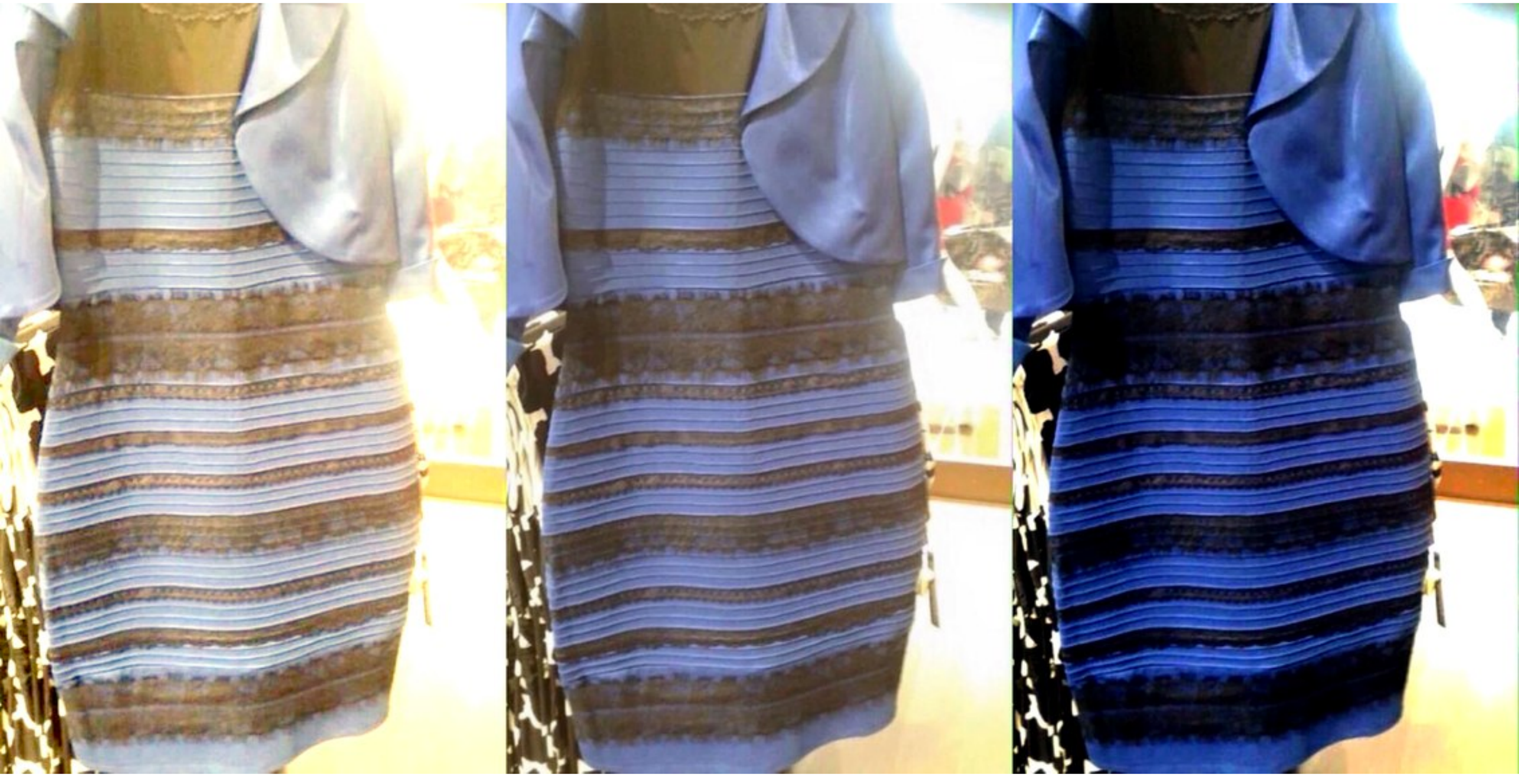
Color to match

Observer

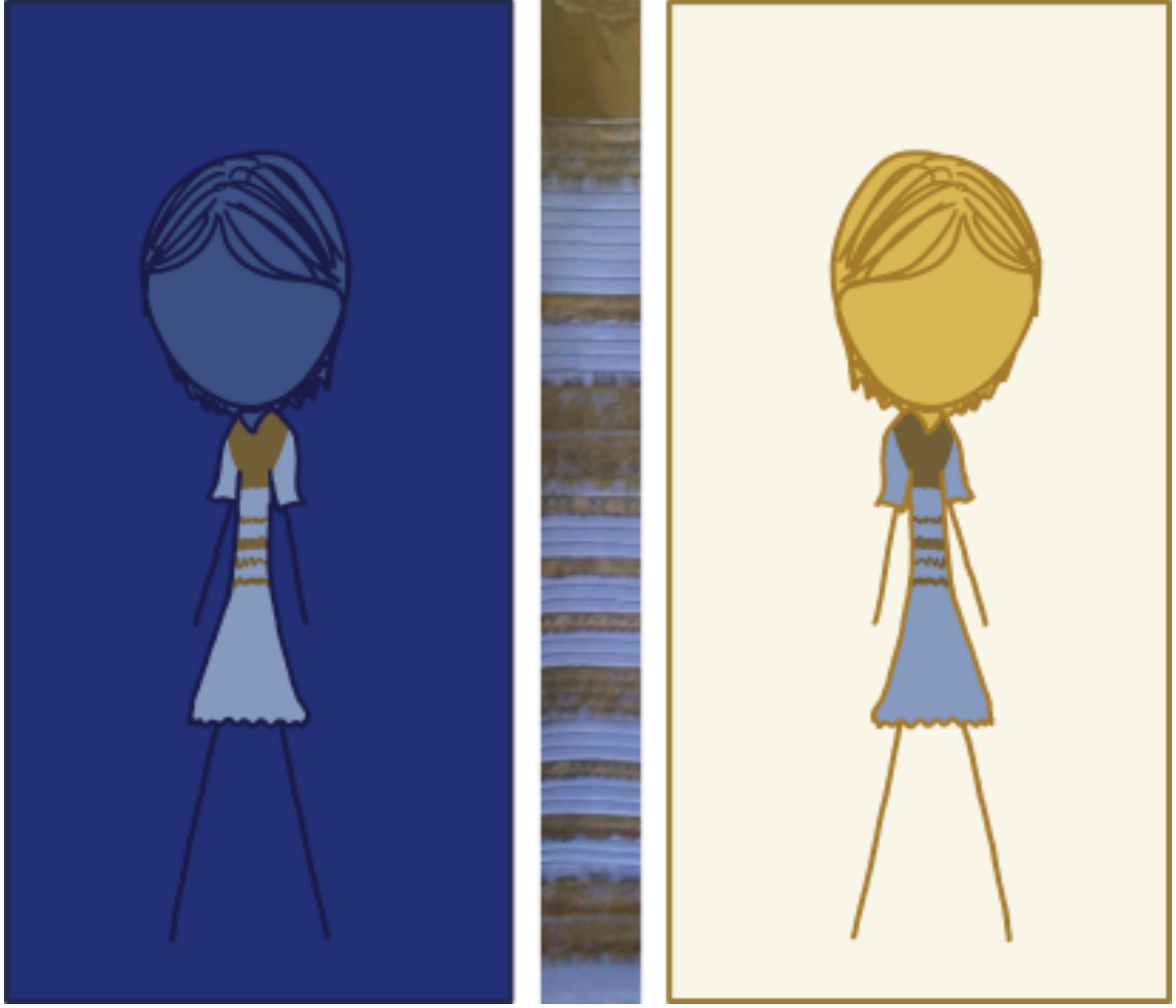
Three adjustable primaries

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

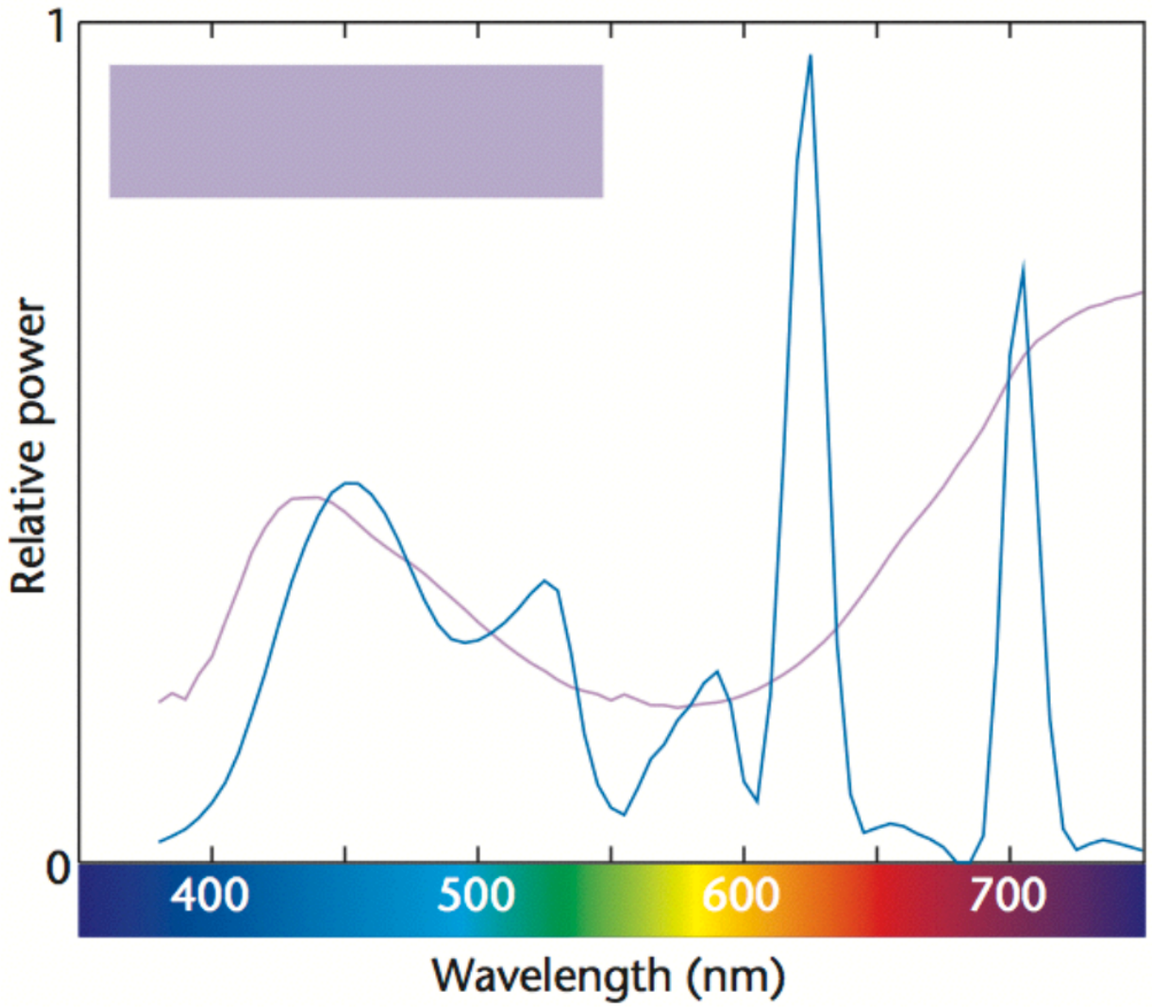
General principle: your visual perception of an object often depends on the **surrounding** objects



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



https://xkcd.com/1492/



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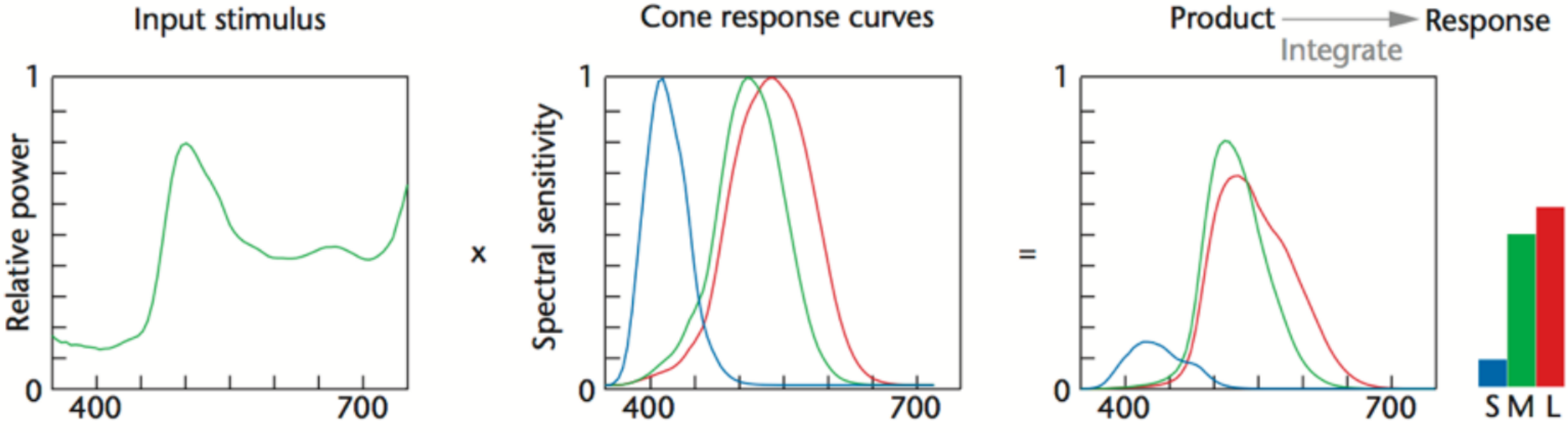
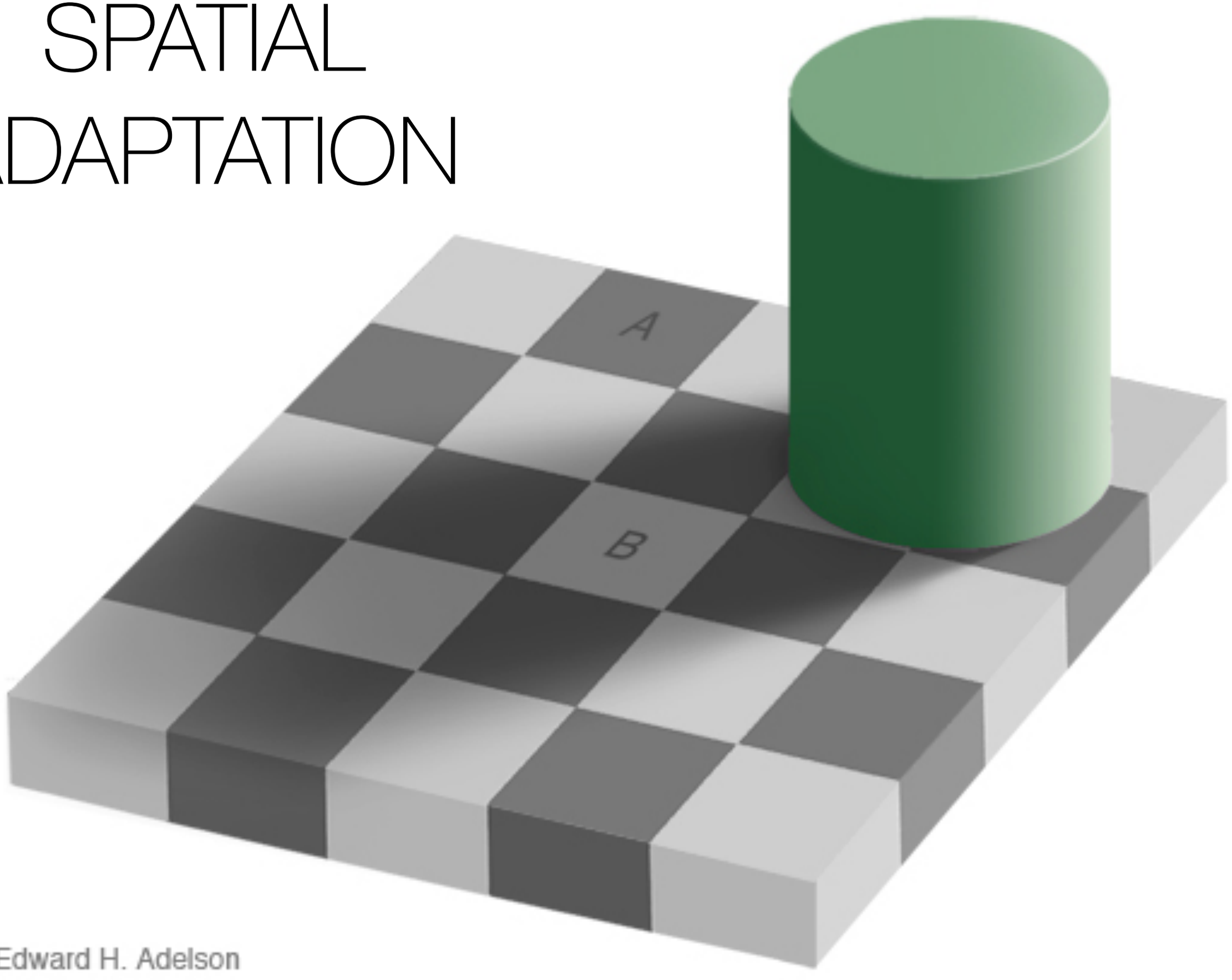


CONSTANCY AND ADAPTATION

SPATIAL ADAPTATION



Edward H. Adelson

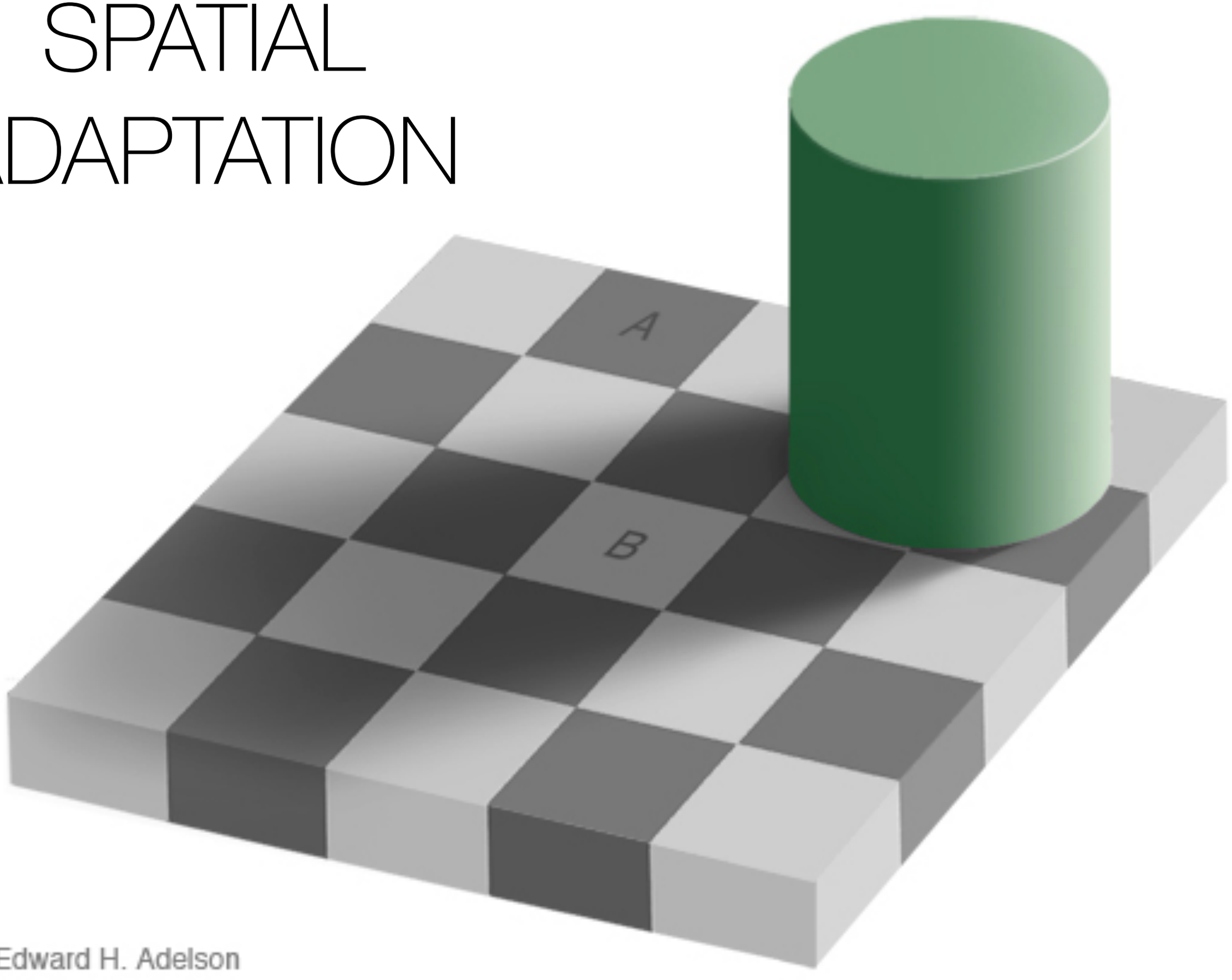
SPATIAL ADAPTATION

SPATIAL ADAPTATION

A

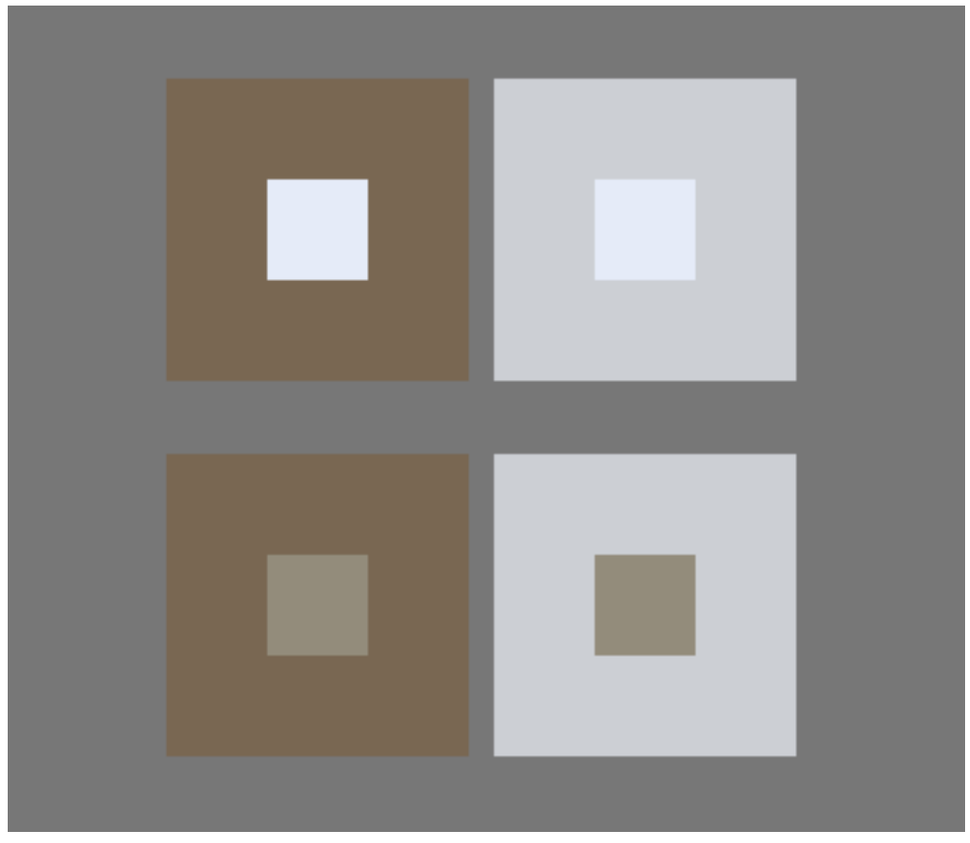
B

SPATIAL ADAPTATION

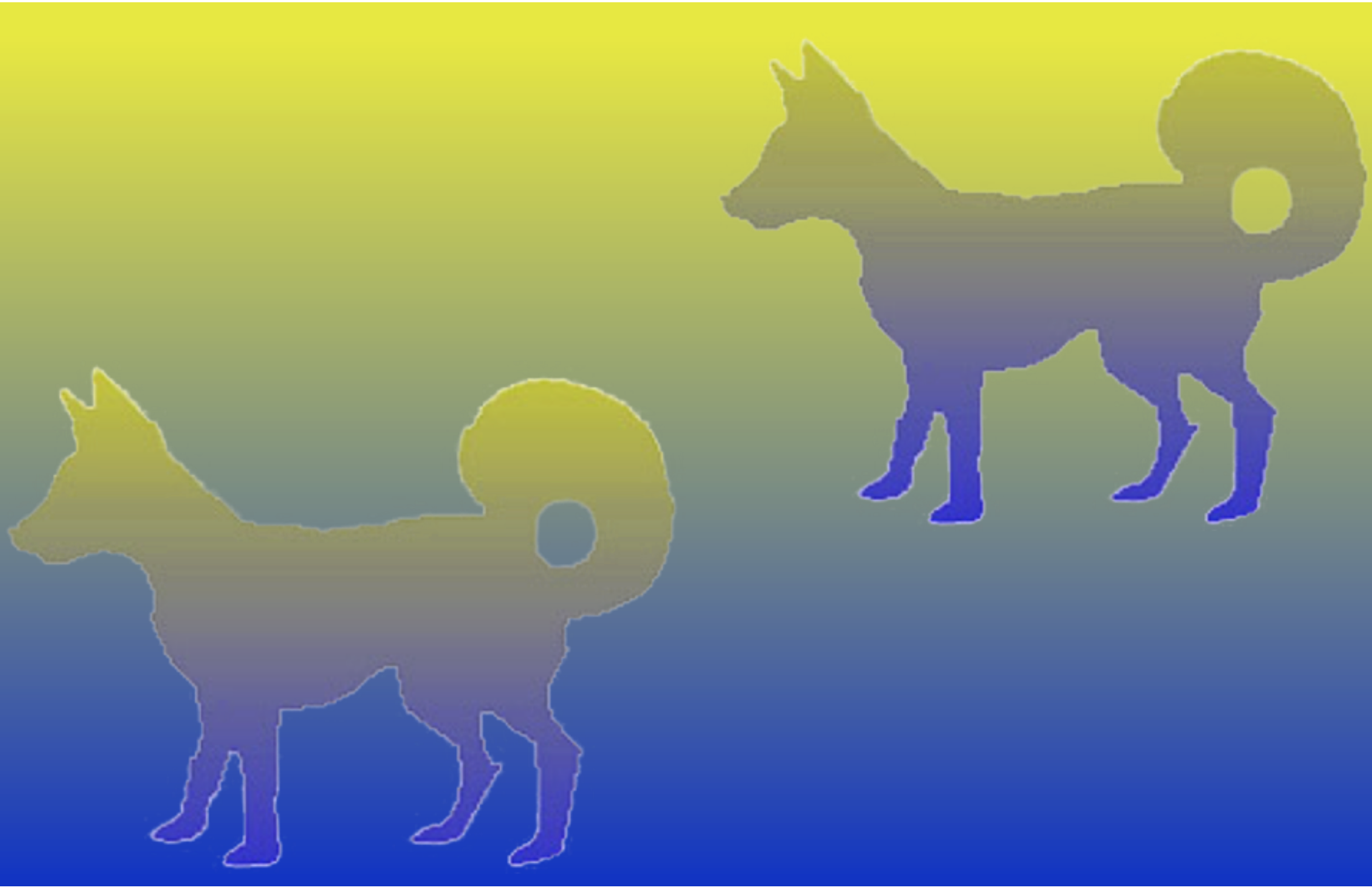


Edward H. Adelson

SIMULTANEOUS CONTRAST



http://www.handprint.com/HP/WCL/tech13.html

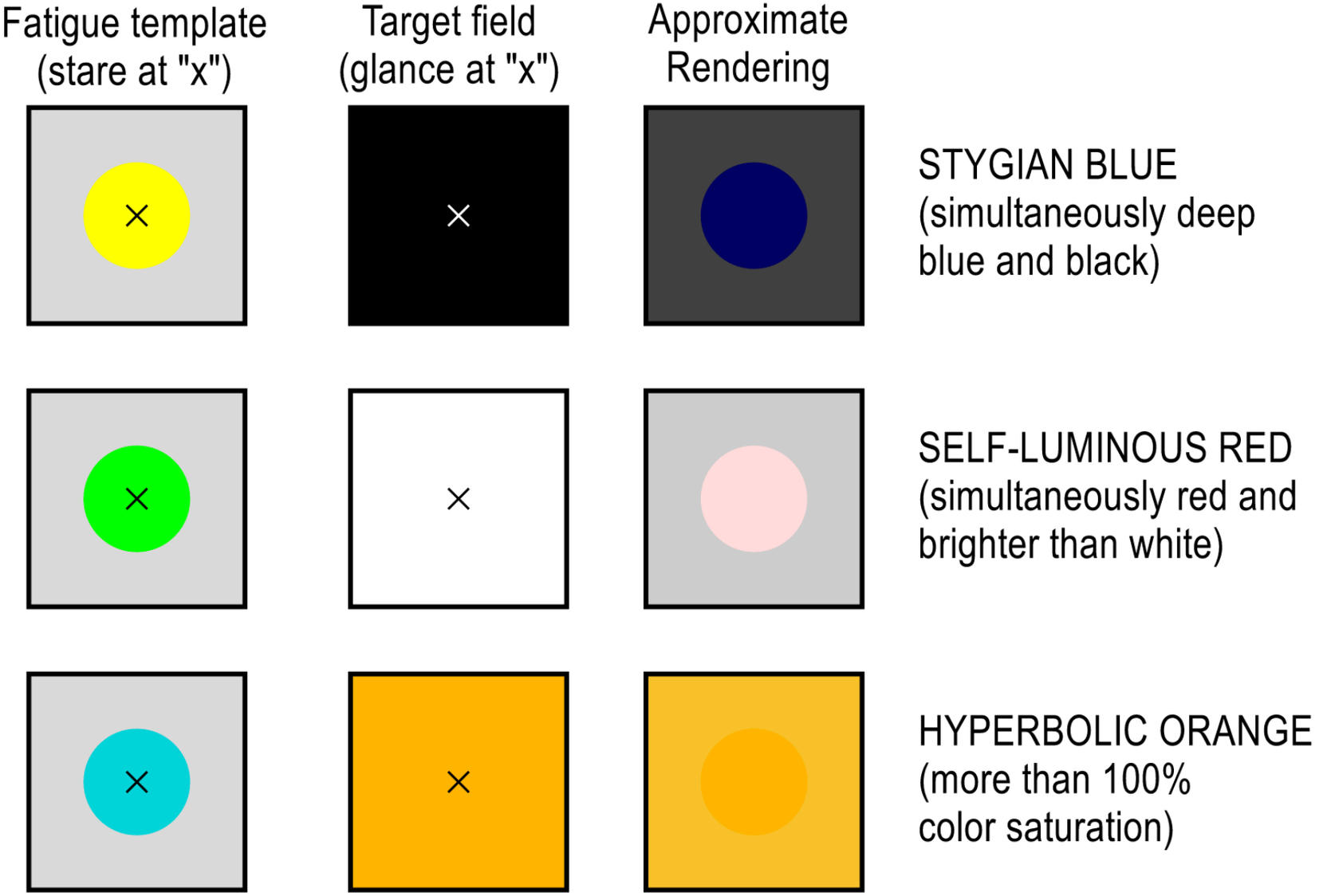


TEMPORAL ADAPTATION

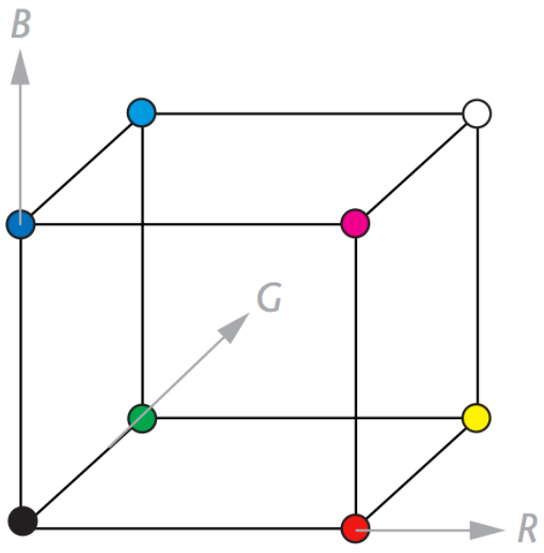
http://www.moillusions.com/black-and-white-in-colour-again.html/13191556xteeocm7

Impossible Colors (!)

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



Extras (stuff we skipped in class)

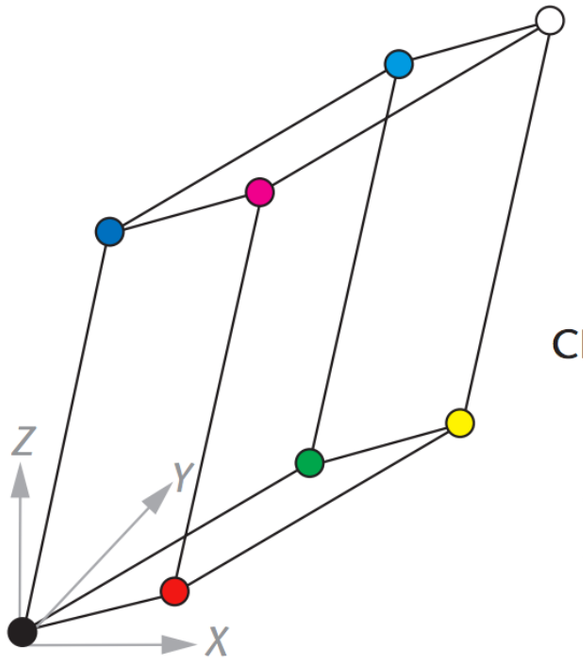


RGB intensity values

(a)

RGB to CIE XYZ

3 x 3 matrix

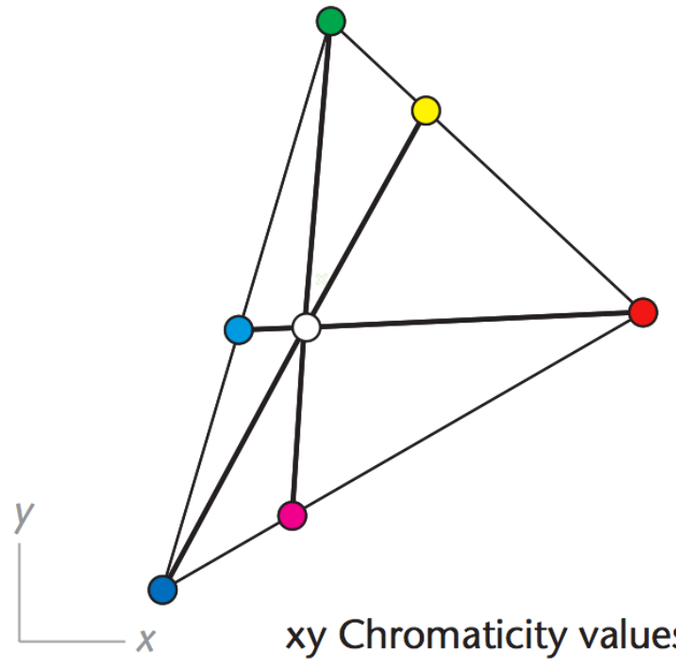


XYZ tristimulus values

(b)

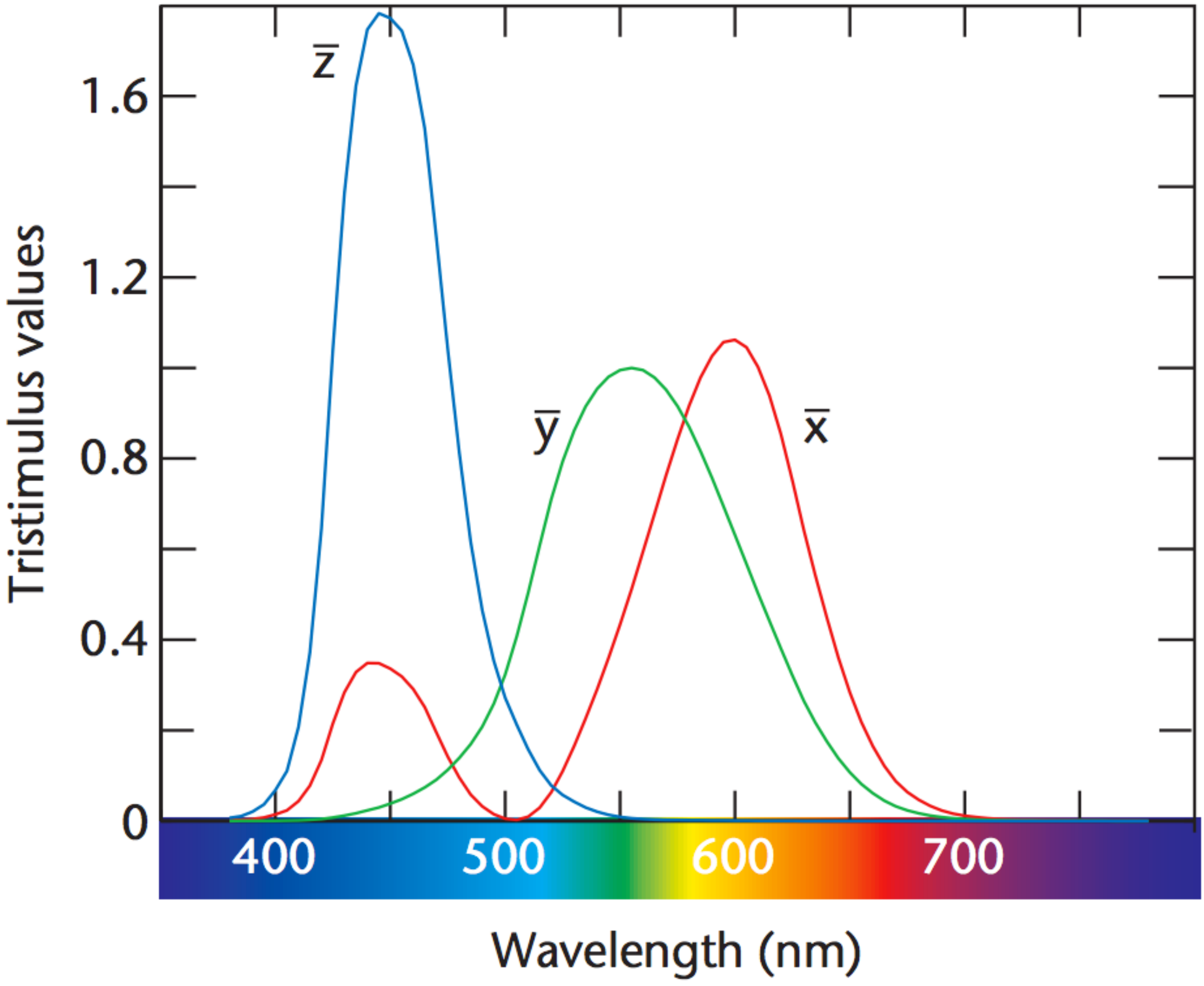
CIE XYZ to CIE xy

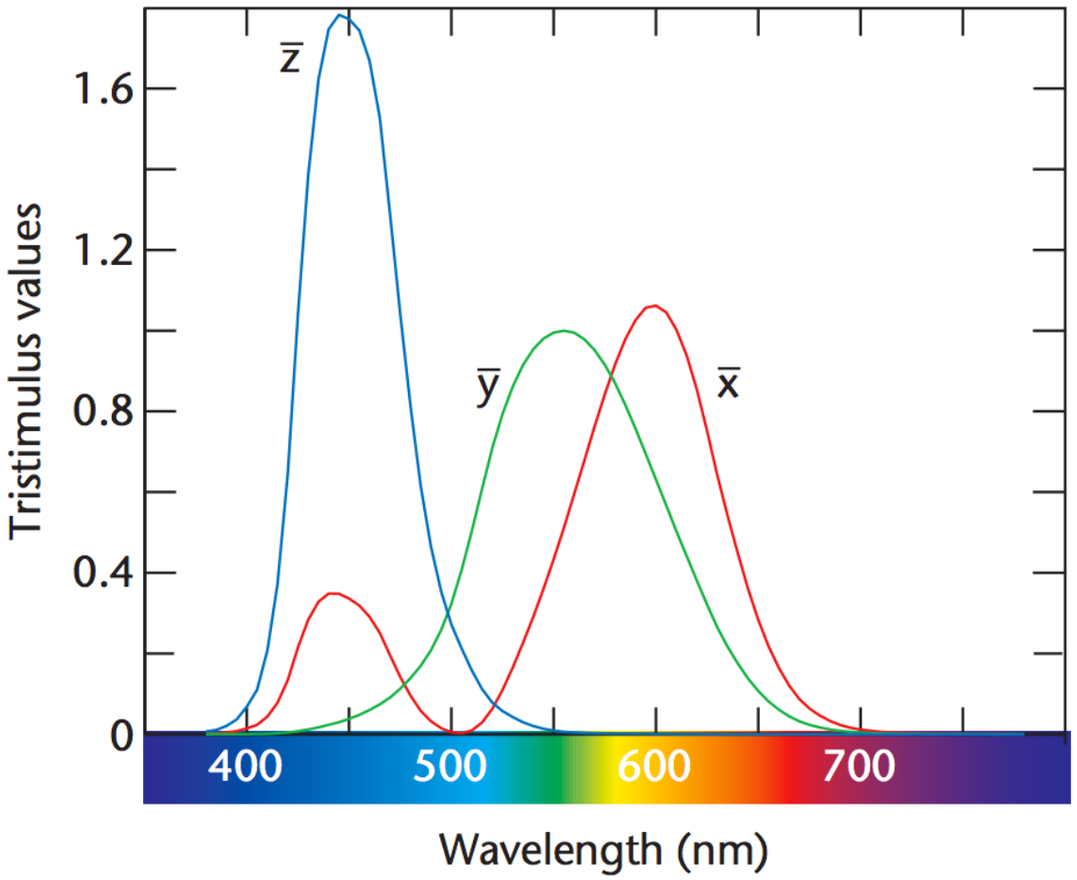
$x = X/(X+Y+Z)$
$y = Y/(X+Y+Z)$

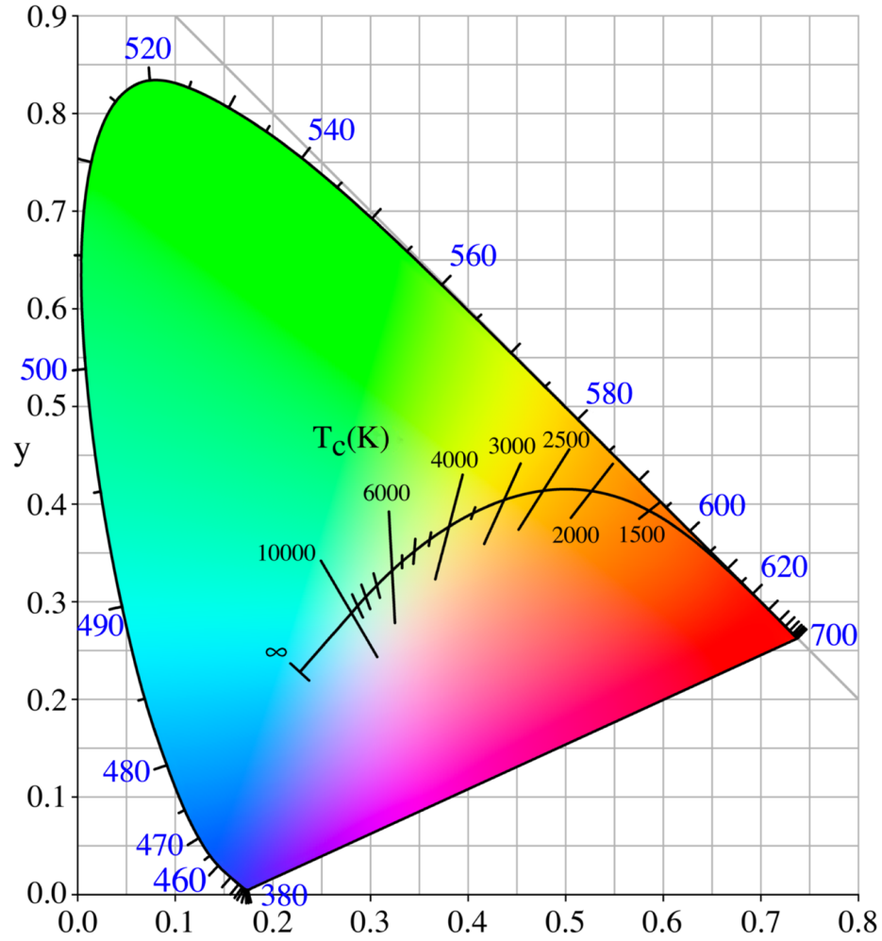


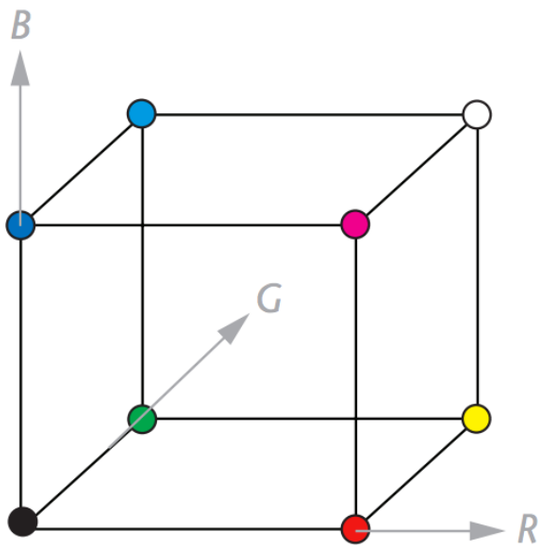
xy Chromaticity values

(c)


Tristimulus values
1.6
1.2
0.8
0.4
0
z̄
ȳ
x̄
400
500
600
700
Wavelength (nm)







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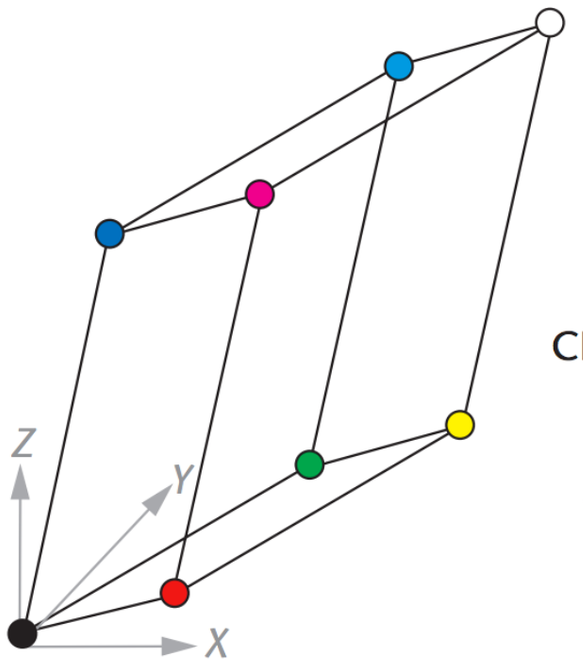

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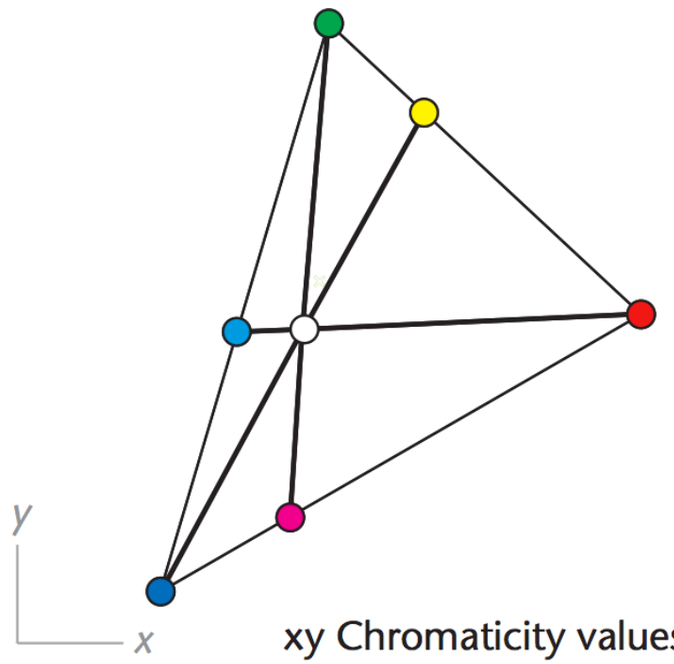
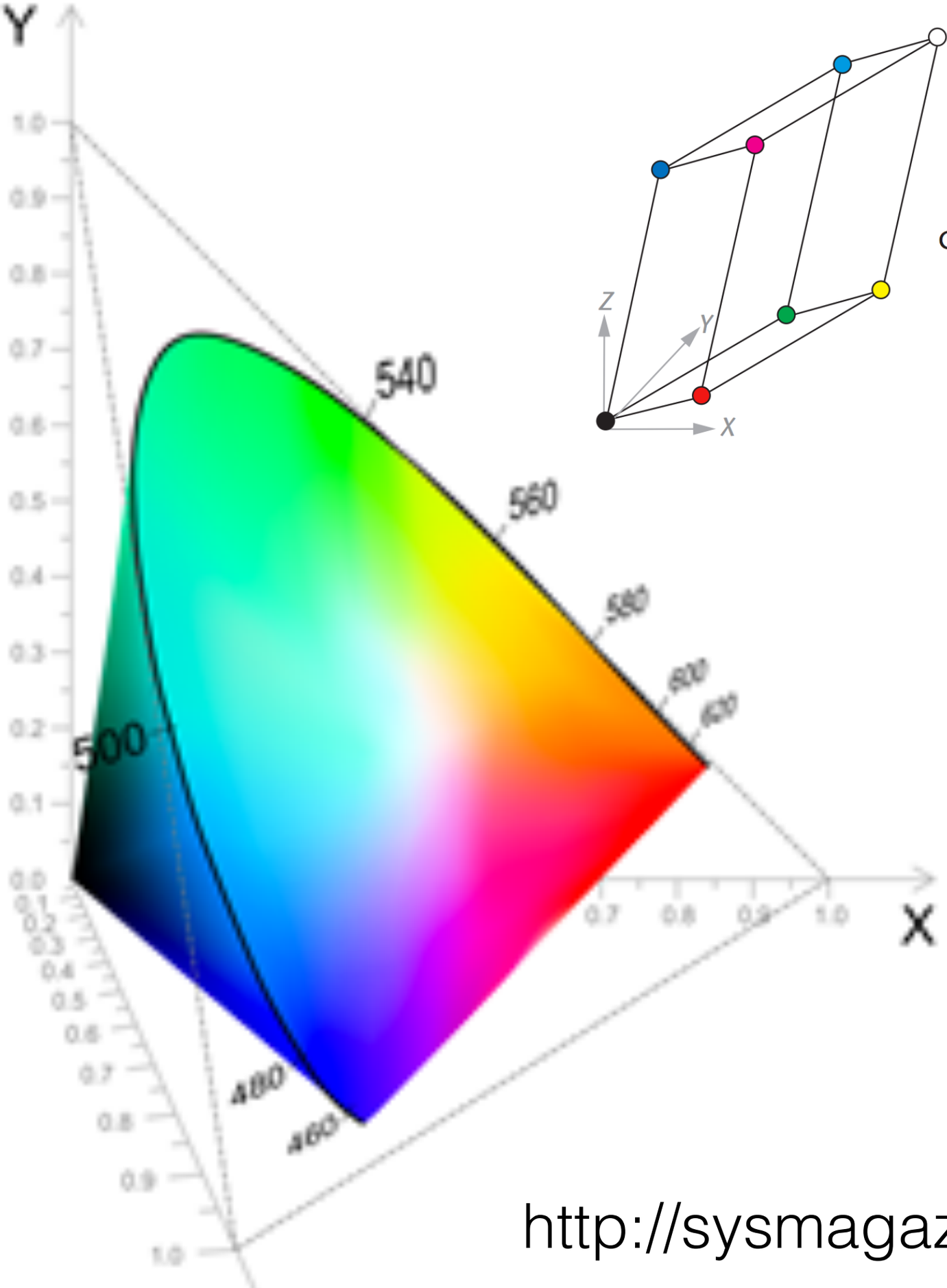


xy Chromaticity values

(c)



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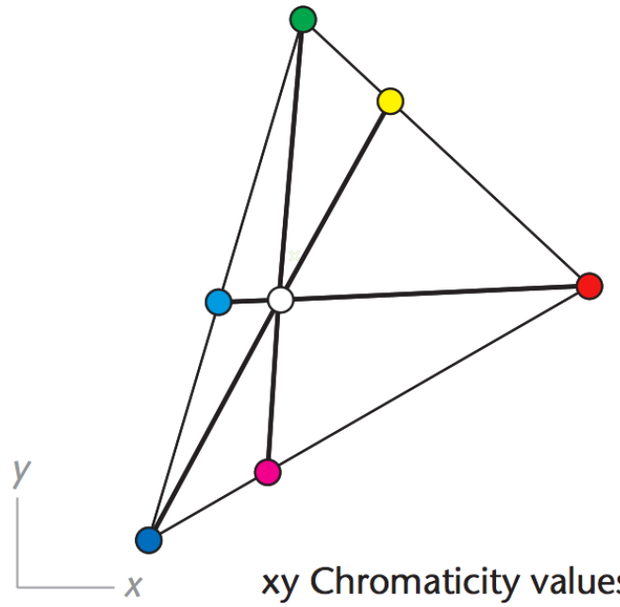

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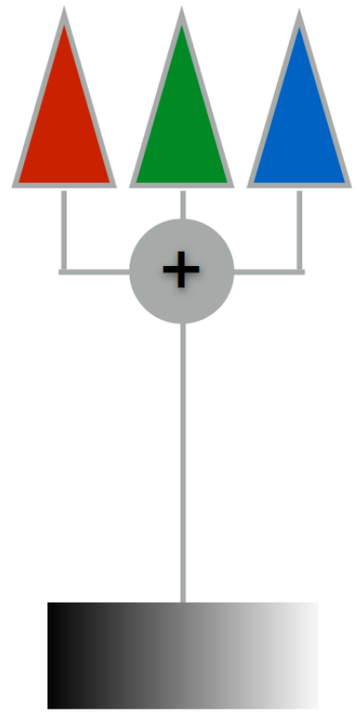

Dividing by “luminance”

http://sysmagazine.com/posts/181580/

COLOR GAMUTS