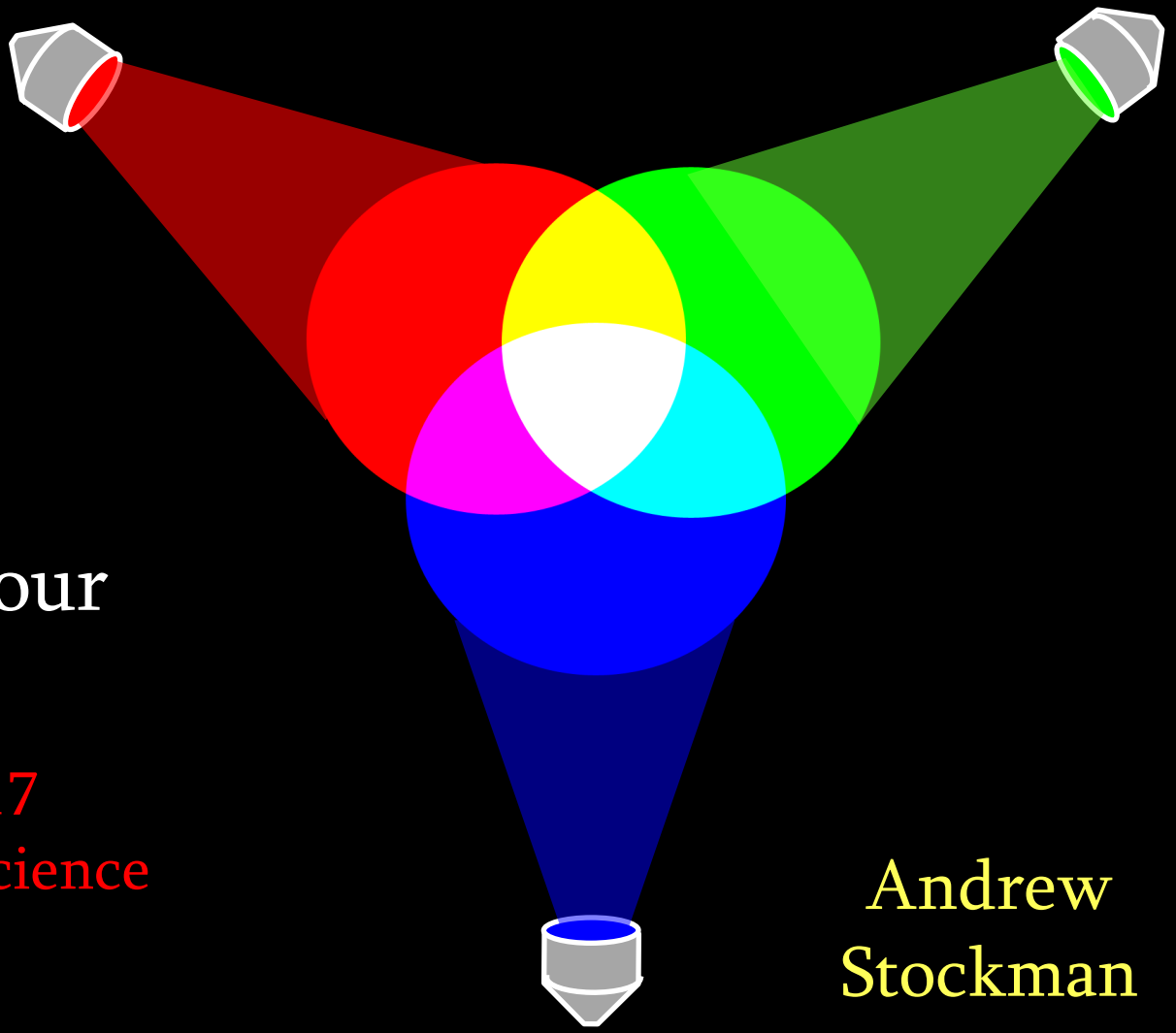


Extra Colour

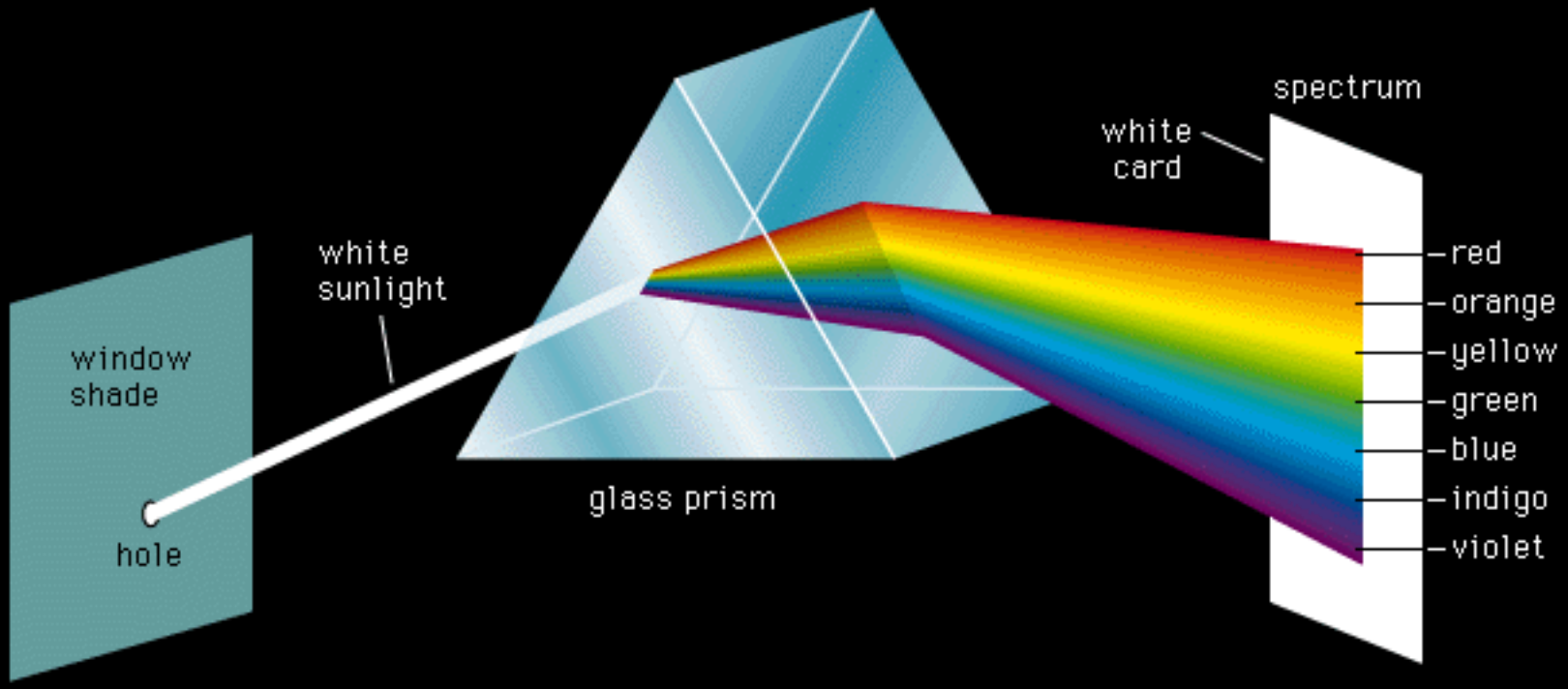
NEUR 0017
Visual Neuroscience

Andrew
Stockman

INTRODUCTION

Light

400 - 700 nm is important for vision



How dependent are
we on colour?

No colour…

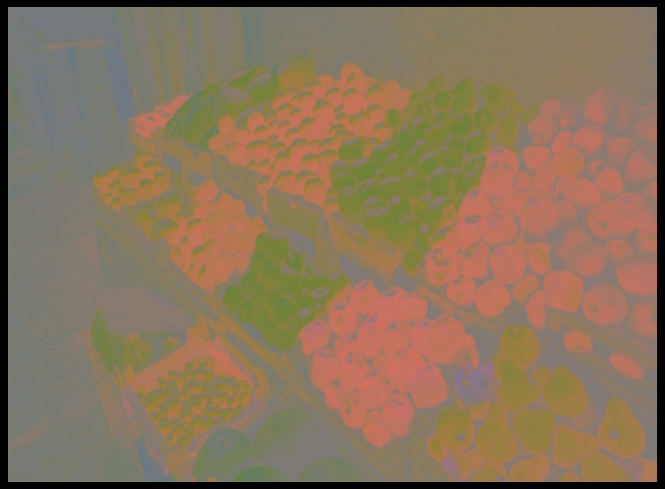
Colour…

But just how
important is colour?

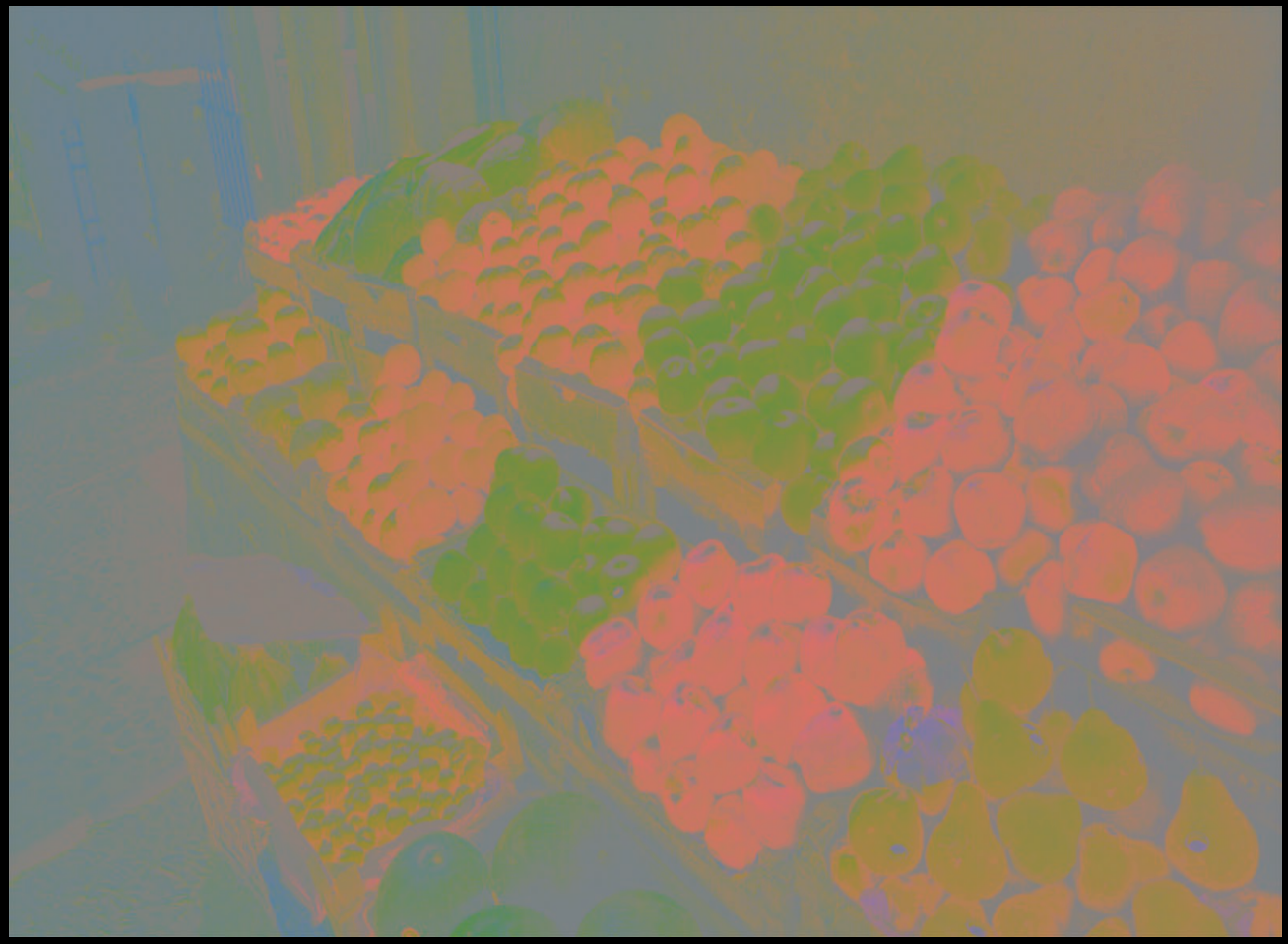
Split the image into...

ACHROMATIC COMPONENTS

CHROMATIC COMPONENTS



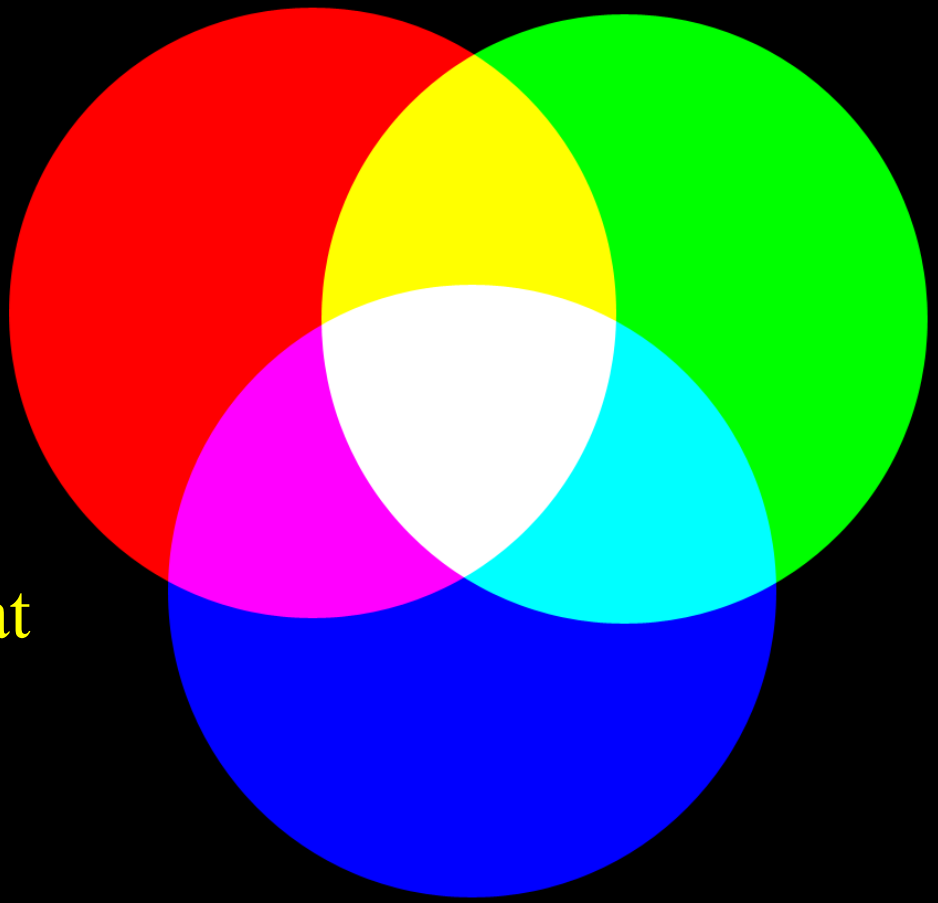
CHROMATIC COMPONENTS



Chromatic information *by itself* provides relatively limited information…

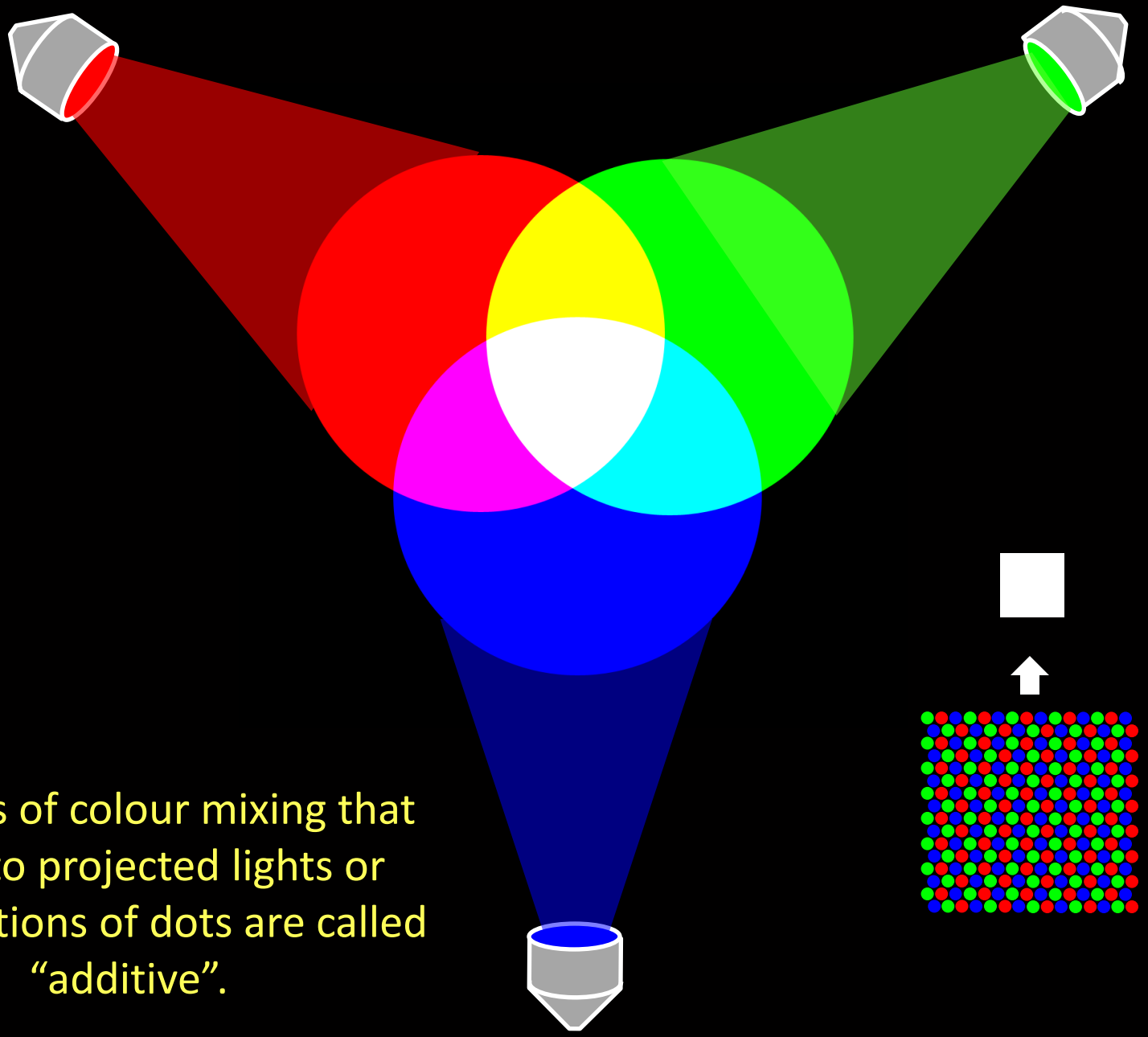
ACHROMATIC COMPONENTS

Achromatic information is important for fine detail …



Trichromacy means that colour vision is relatively simple.

It is a 3 variable system…



The laws of colour mixing that apply to projected lights or combinations of dots are called “additive”.

But what about mixing paints?

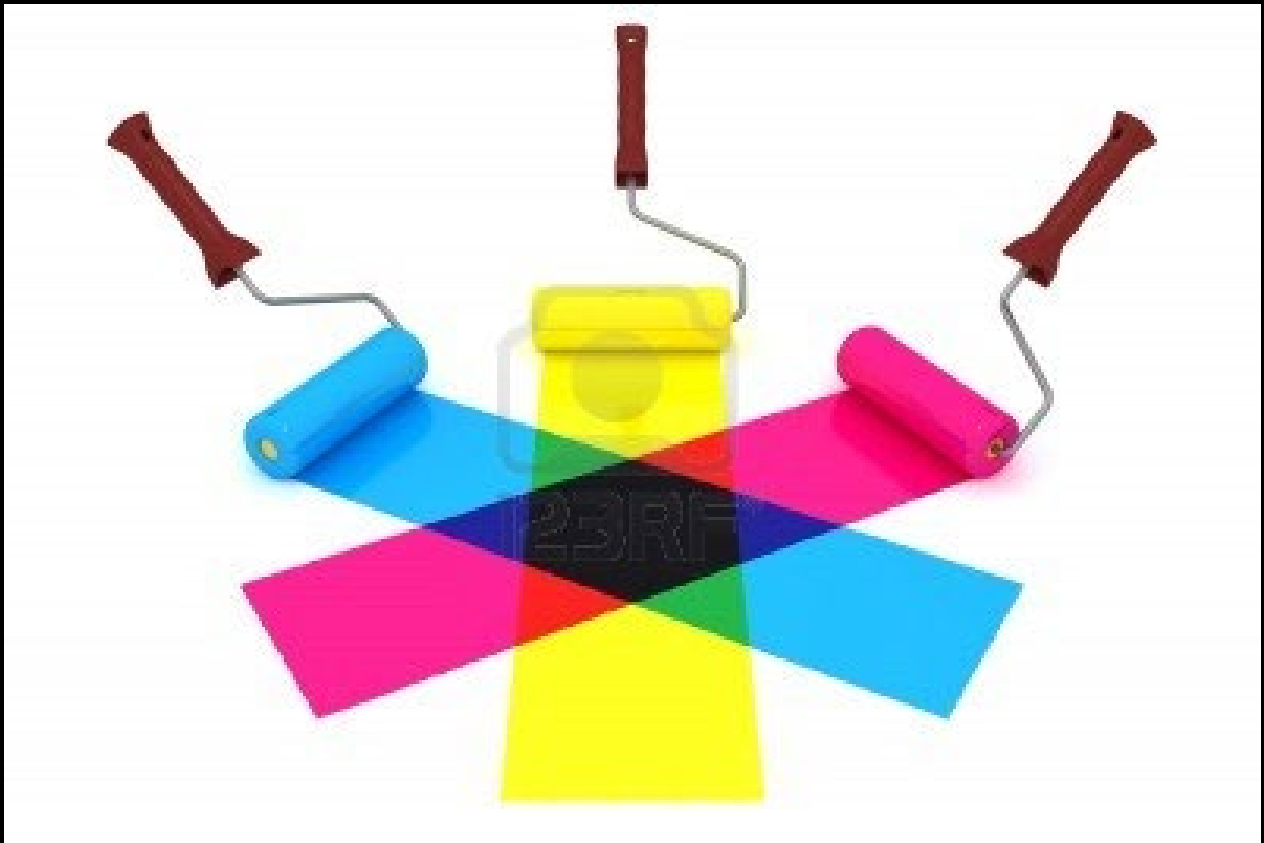
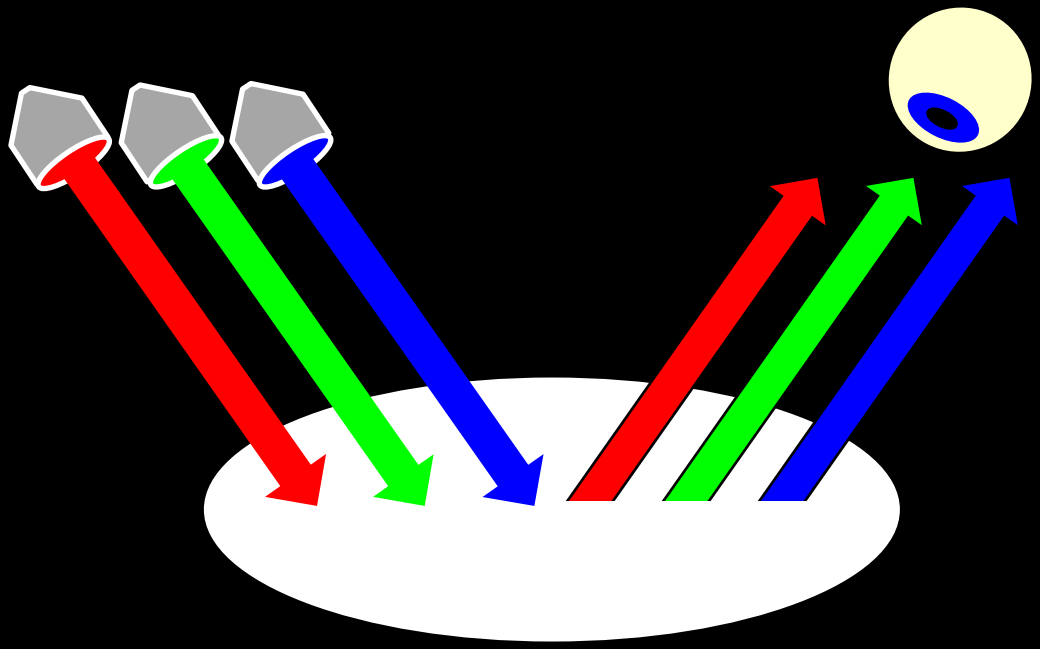
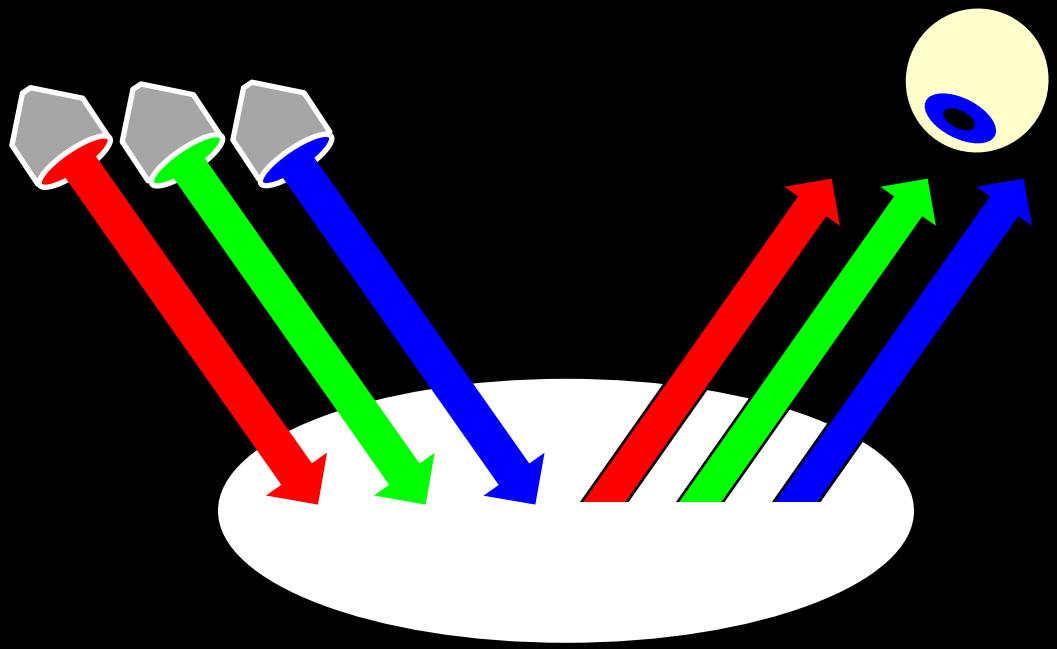


Photo: Jozsef Szasz-Fabian

The laws of colour mixing that apply to pigments or paints are different because they depend on what is absorbed or "subtracted" from the reflected light by the pigment.

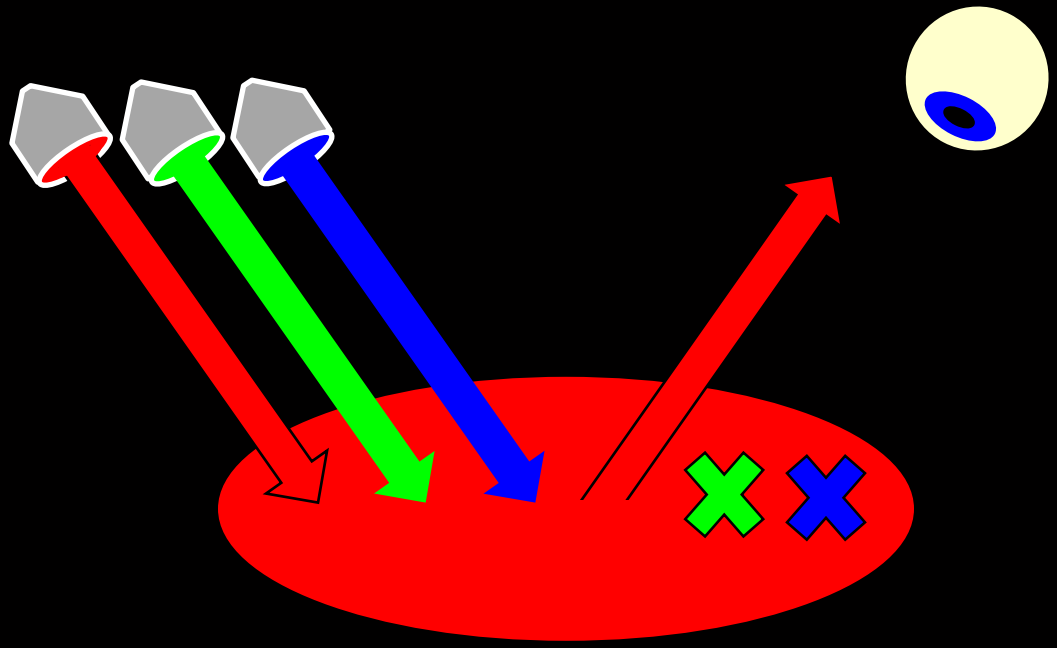


WHITE PIGMENT

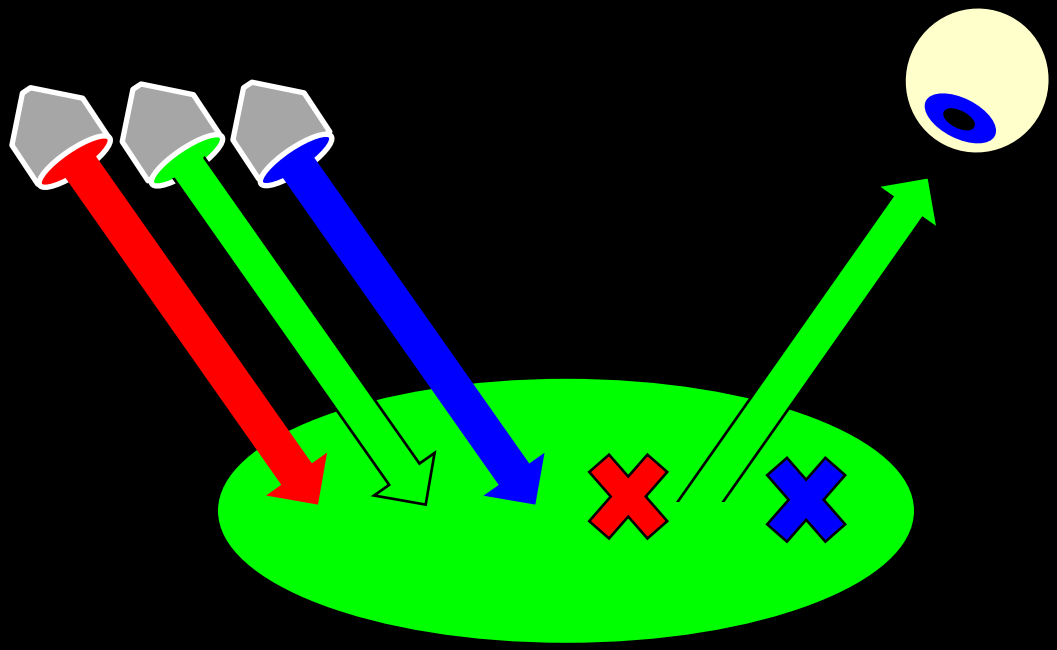


WHITE PIGMENT

A white pigment reflects red, green and blue lights.

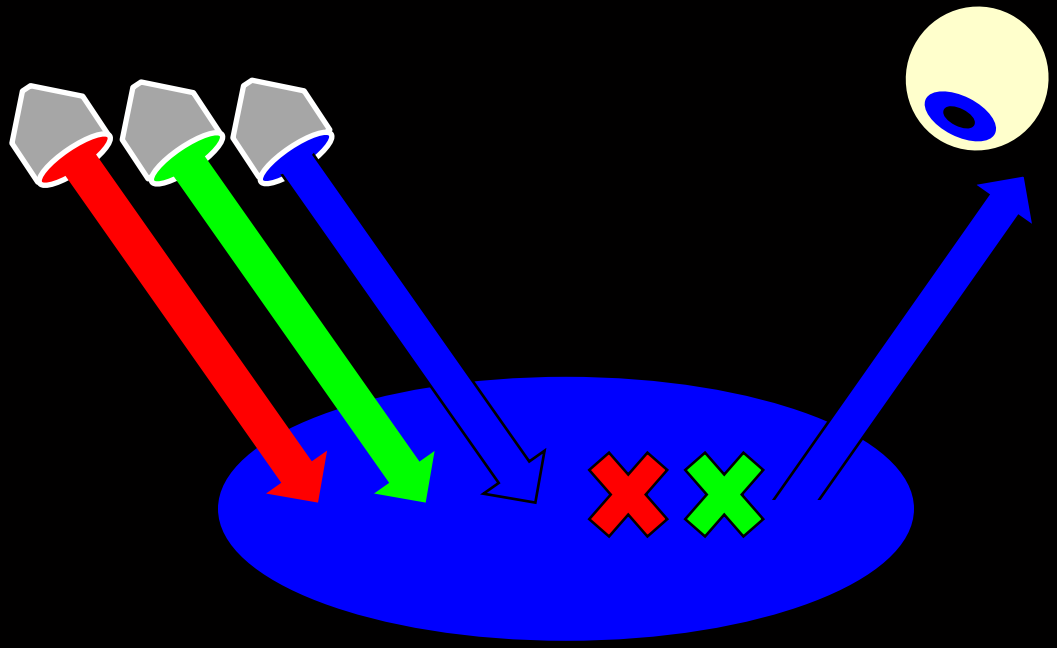


A red pigment subtracts green and blue and reflects red.



GREEN PIGMENT

A green pigment subtracts red and blue and reflects green.

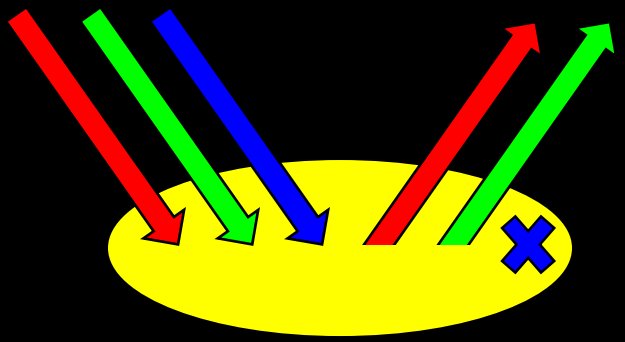


BLUE PIGMENT

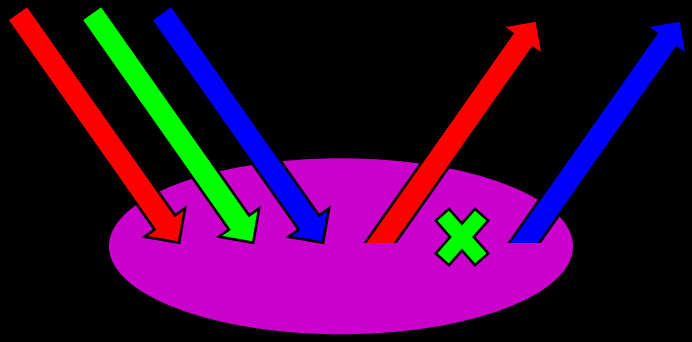
A blue pigment subtracts red and green and reflects blue.

Laws of subtractive colour mixing
(of paints or pigments)

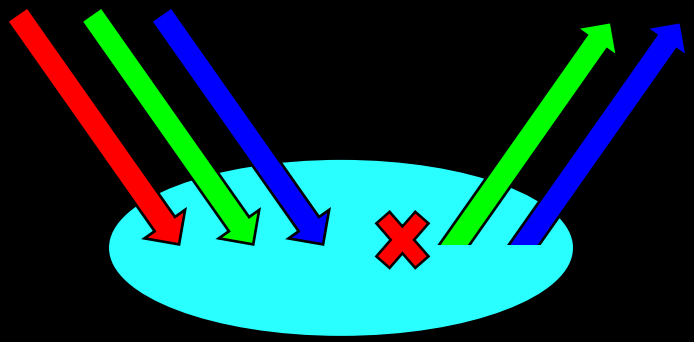
Subtractive colour mixing (of paints or pigments)



YELLOW PIGMENT

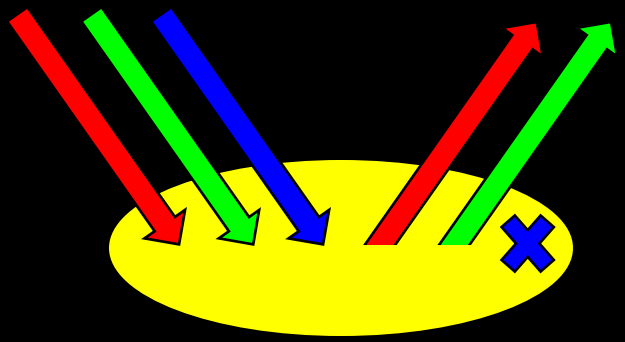


MAGENTA PIGMENT



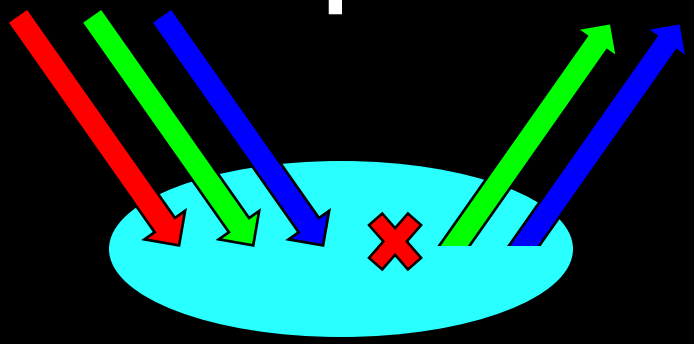
CYAN PIGMENT

Subtractive colour mixing



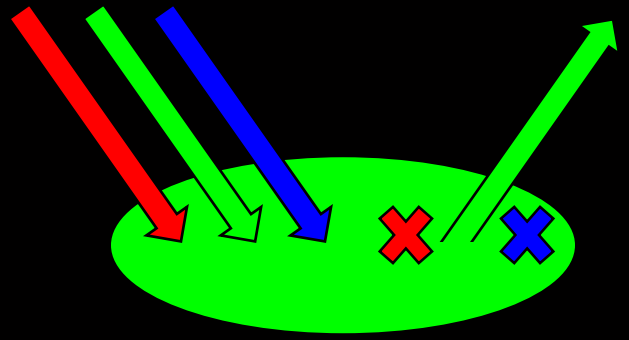
YELLOW PIGMENT

+



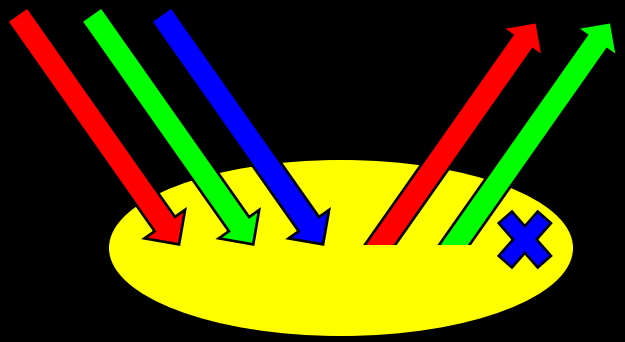
CYAN PIGMENT

=



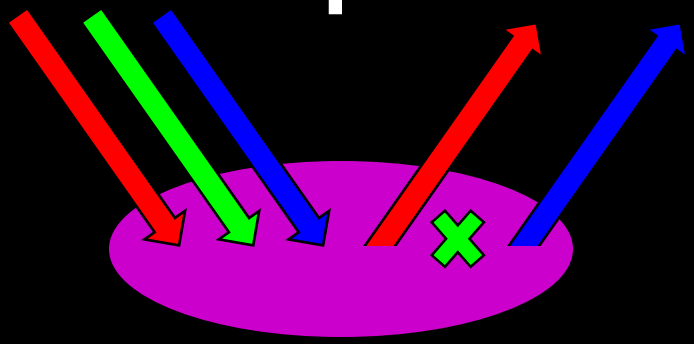
GREEN PIGMENT

Subtractive colour mixing



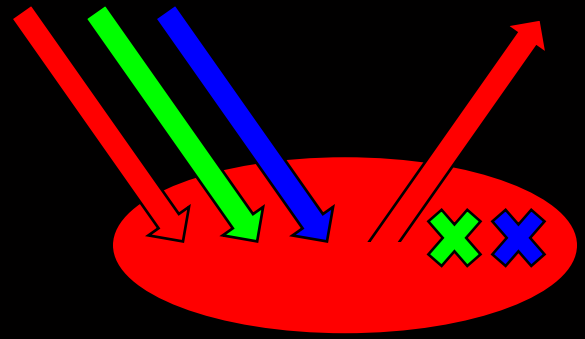
YELLOW PIGMENT

+



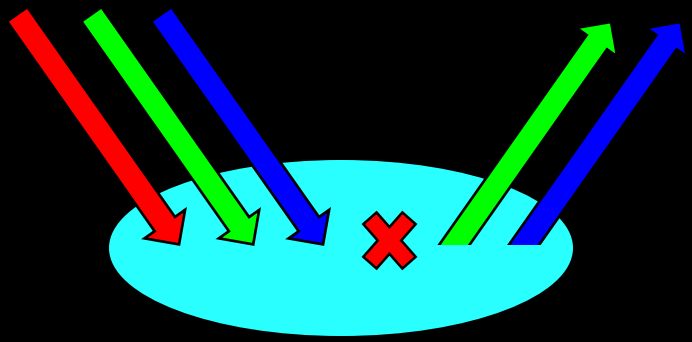
MAGENTA PIGMENT

=



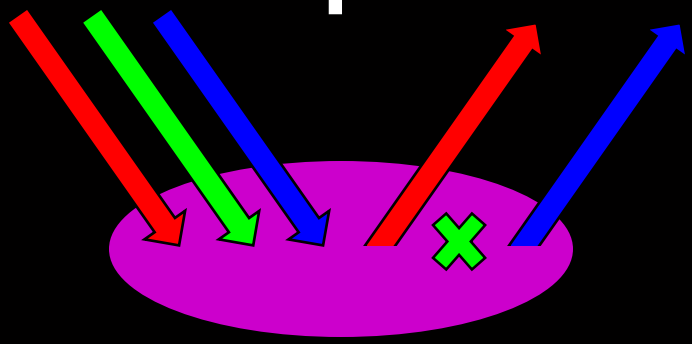
RED PIGMENT

Subtractive colour mixing



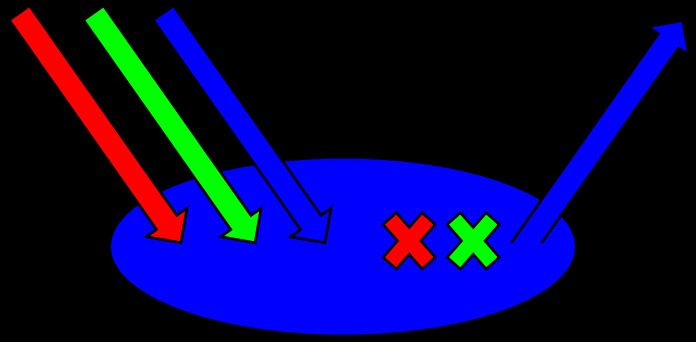
CYAN PIGMENT

+



MAGENTA PIGMENT

=



BLUE PIGMENT

SUBTRACTIVE COLOUR MIXING

SUBTRACTIVE
COLOUR MIXING

ADDITIVE
COLOUR MIXING

NOTE THAT THESE MIXING “LAWS” ARE BOTH CONSISTENT WITH HUMAN COLOUR VISION BEING A TRICHROMAT, THREE VARIABLE SYSTEM.

SUBTRACTIVE
COLOUR MIXING

ADDITIVE
COLOUR MIXING

But, why is normal human vision a trichromatic, three variable system?

COLOUR VISION AND MOLECULAR GENETICS

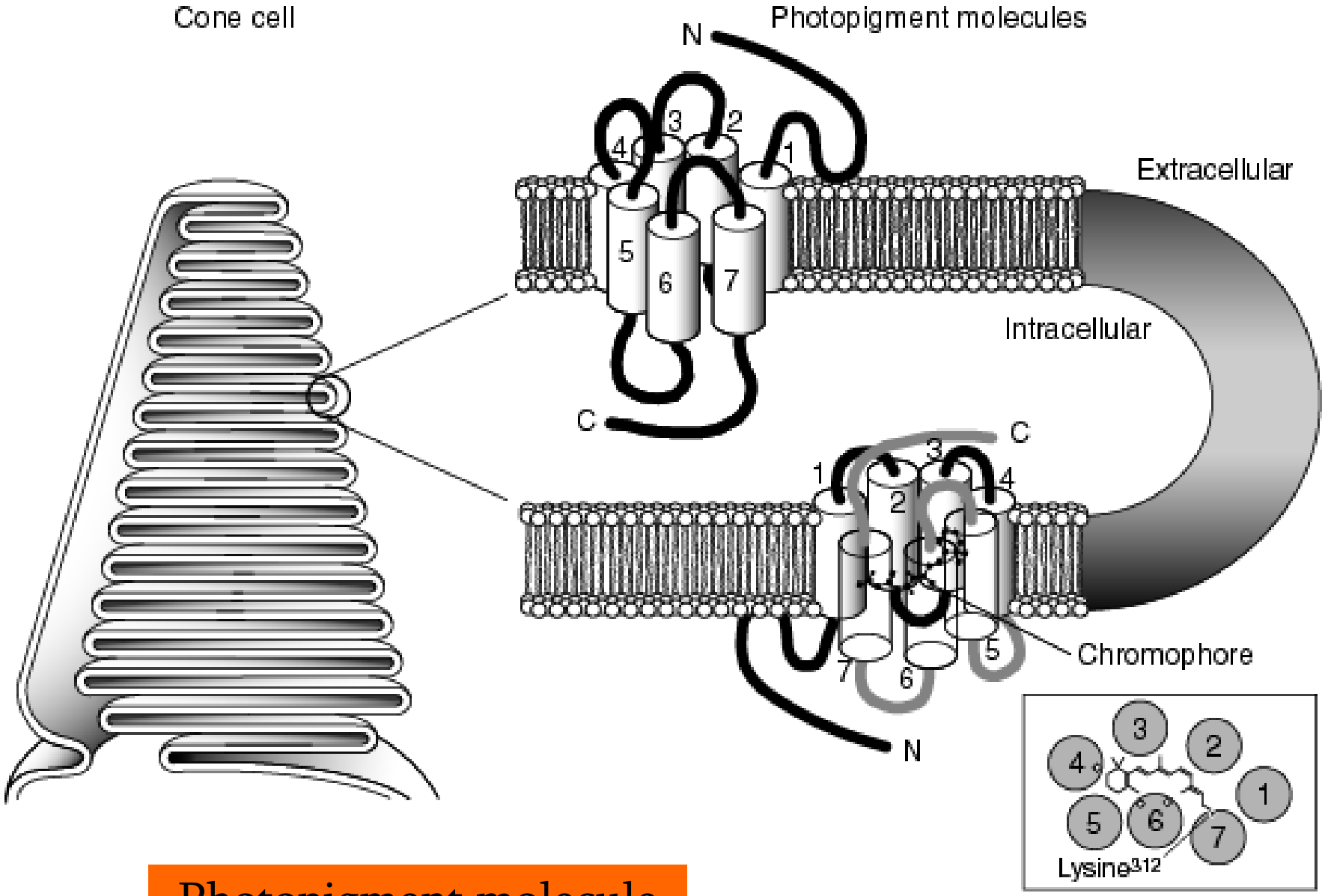
Normal

Deuteranope

Protanope

How do red-green colour vision deficiencies arise?

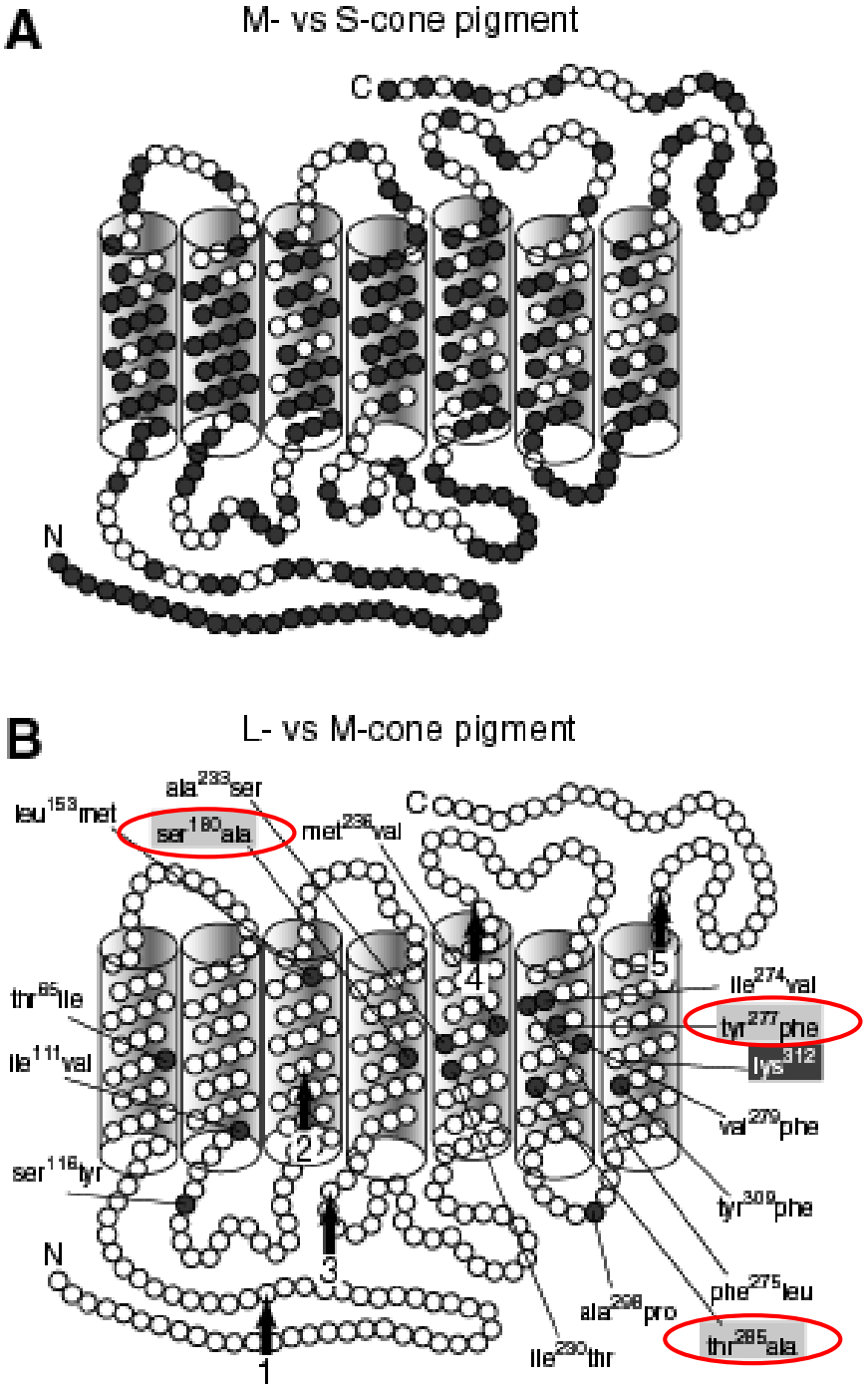
From Sharpe, Stockman, Jägle & Nathans, 1999



Photopigment molecule

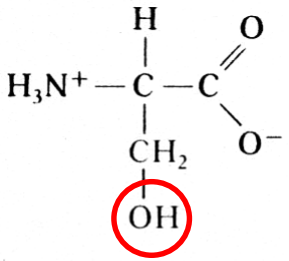
From Sharpe, Stockman, Jägle & Nathans, 1999

Amino acid differences between photopigment opsins

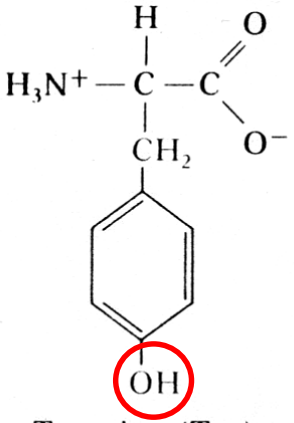


From Sharpe, Stockman, Jägle & Nathans, 1999

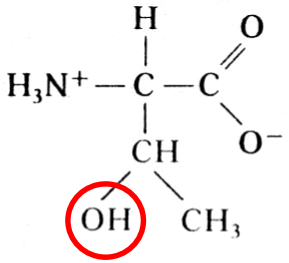
POLAR



Serine (Ser)



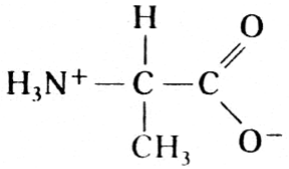
Tyrosine (Tyr)



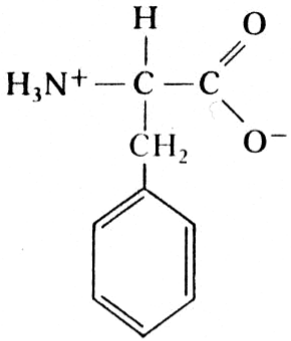
Threonine (Thr)

LWS
all with OH group

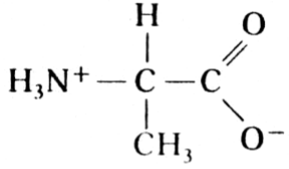
NON-POLAR



Alanine (Ala)



Phenylalanine (Phe)



Alanine (Ala)

MWS

180

277

285

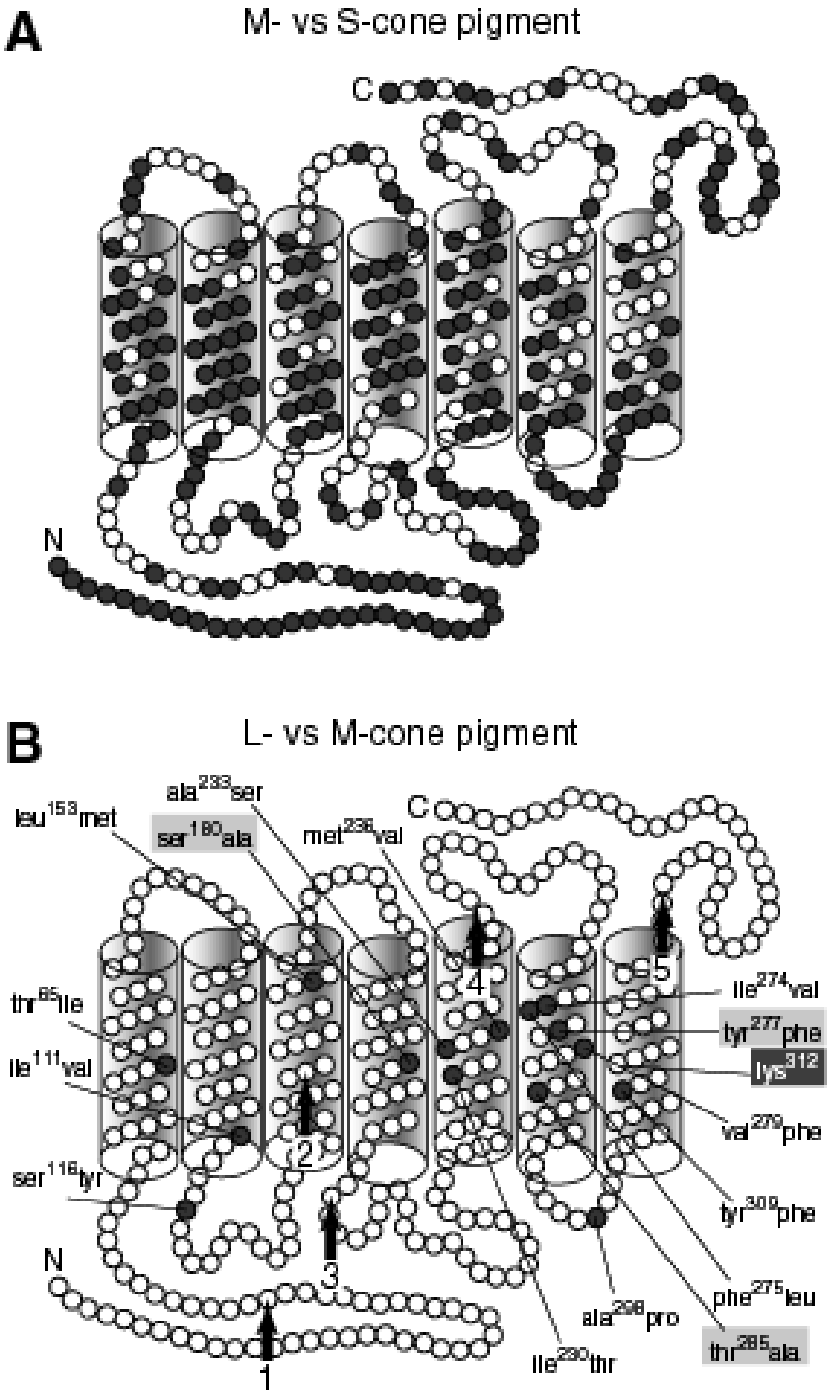
Spectral shifts

~ 5 nm

~ 25 nm

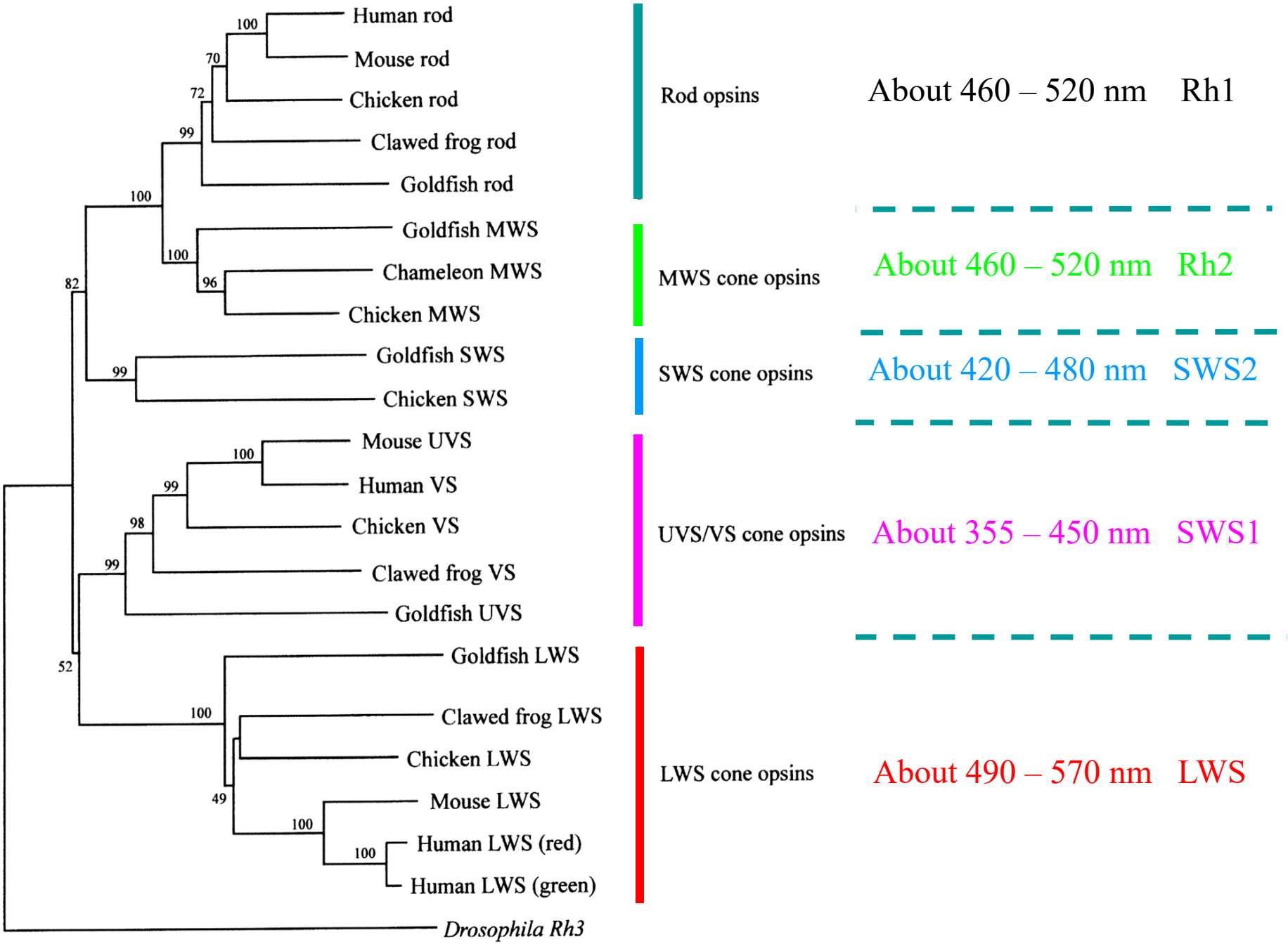
Amino acid differences between photopigment opsins

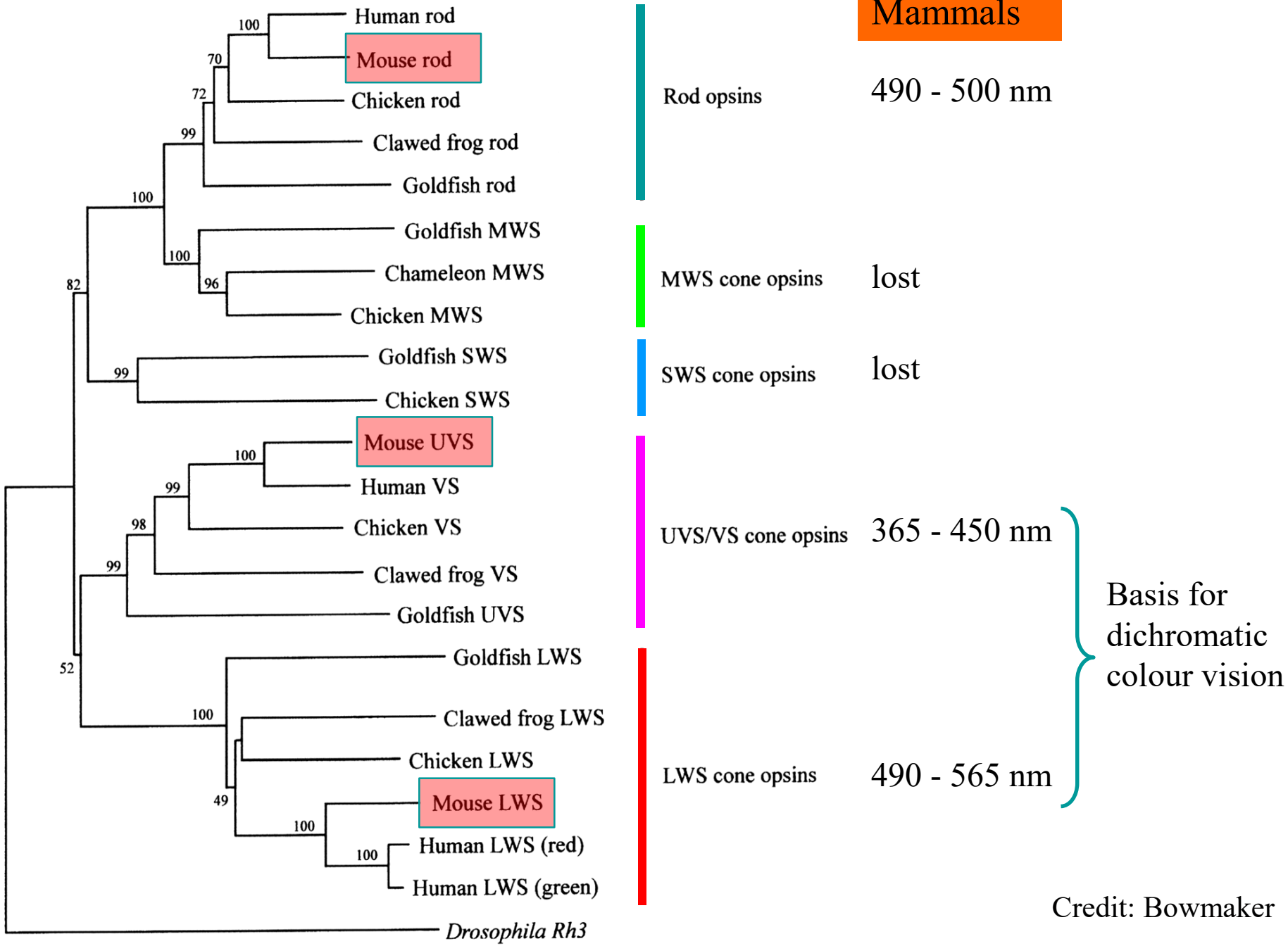
Why are the M- and L-cone opsins so similar?



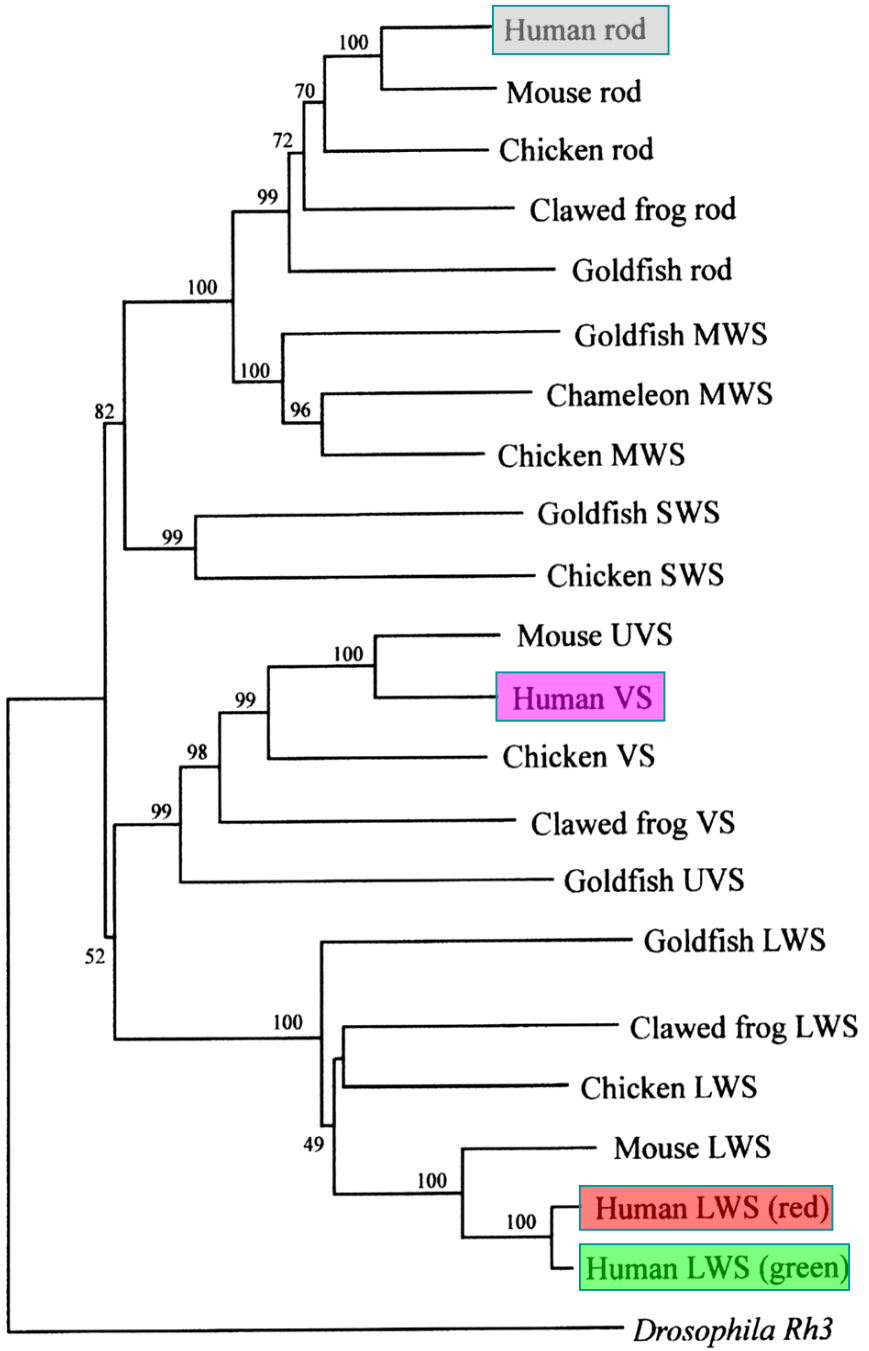
From Sharpe, Stockman, Jägle & Nathans, 1999

Phylogenetic tree of visual pigments





Credit: Bowmaker



Rod opsins

MWS cone opsins

SWS cone opsins

UVS/VS cone opsins

LWS cone opsins

Humans

490 - 500 nm

lost

lost

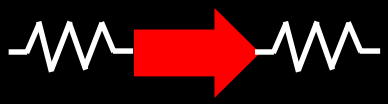
365 - 450 nm

Basis for trichromatic colour vision

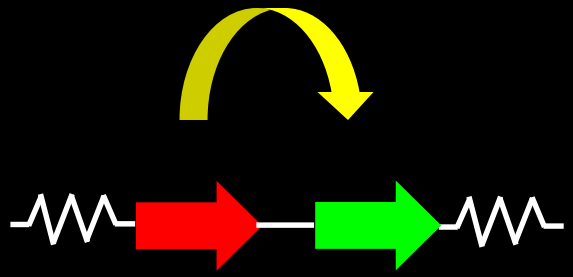
Gene duplication

Credit: Bowmaker

Gene duplication on the X-chromosome



Mammal

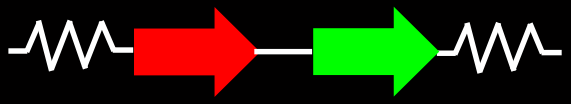


L-cone photopigment opsin gene

M-cone photopigment opsin gene

Human/ Old world primate

Because these two genes are in a tandem array, and are very similar…

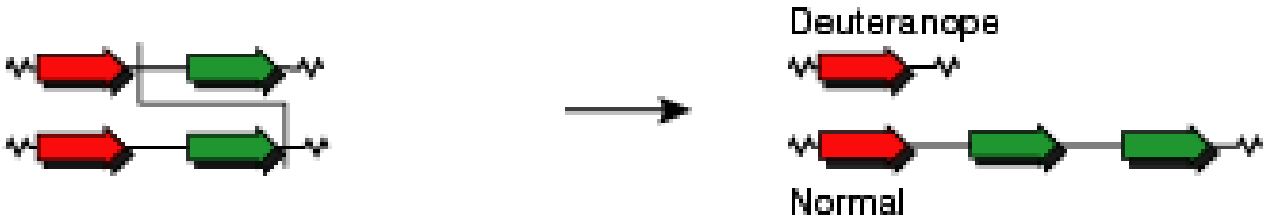


L-cone photopigment opsin gene

M-cone photopigment opsin gene

Crossovers during meiosis are common:

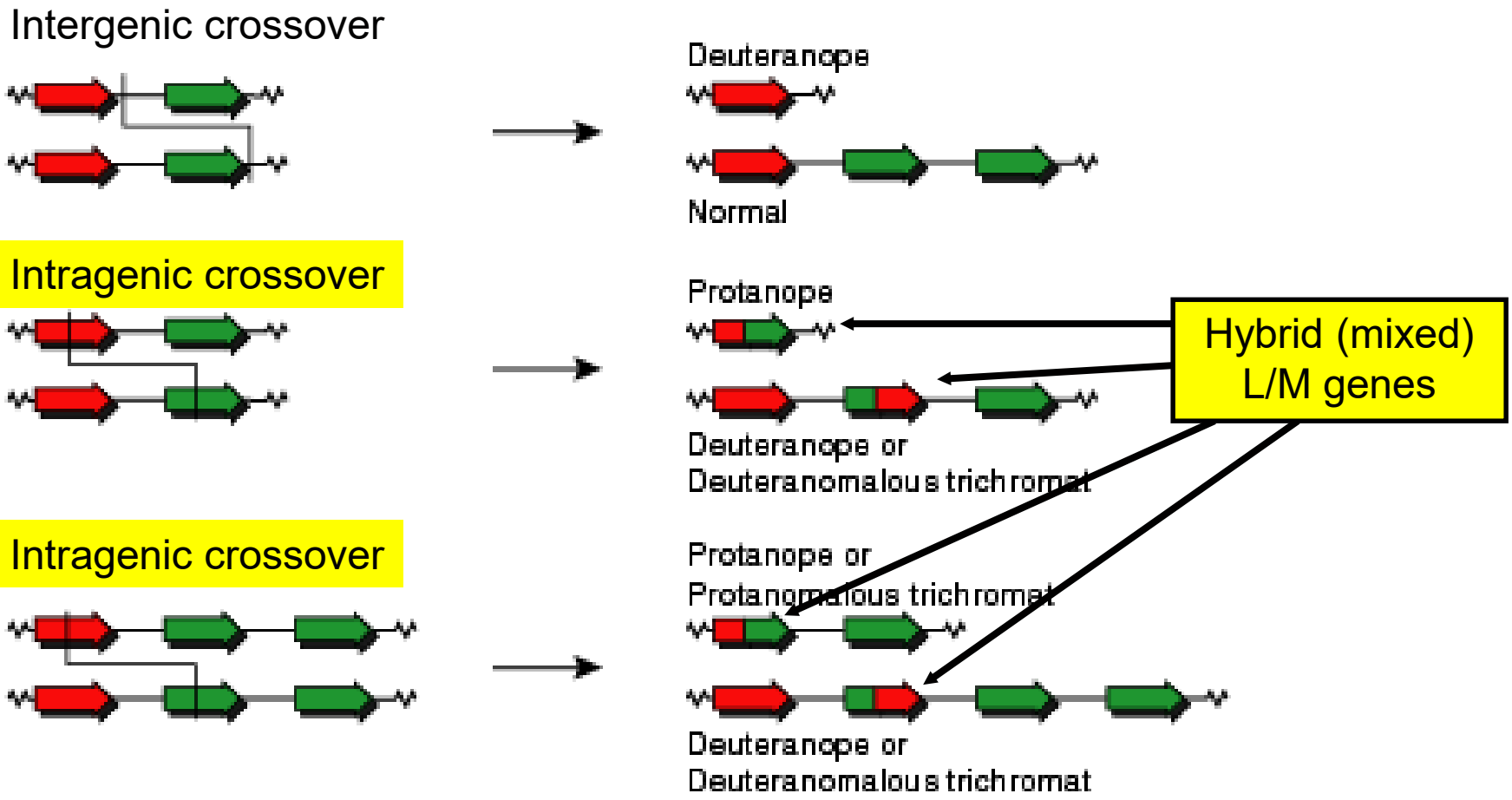
Intergenic crossover



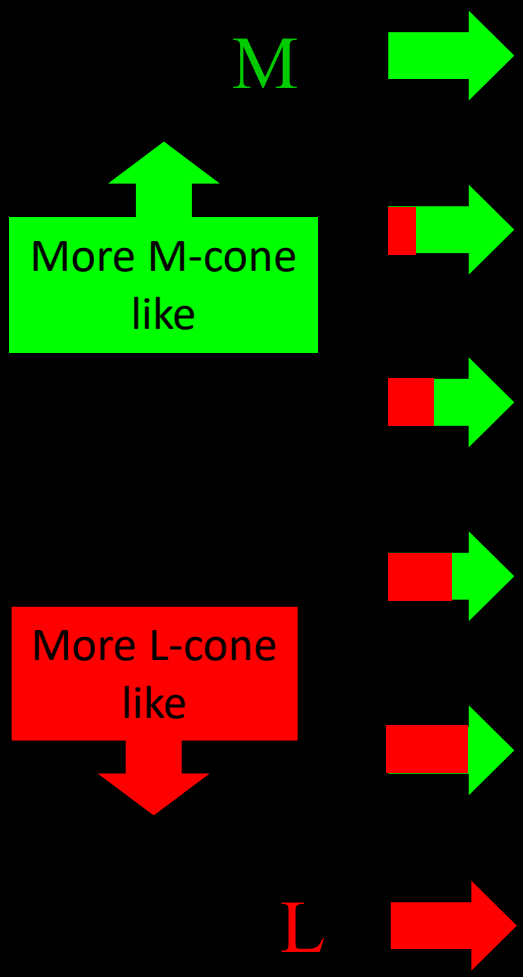
Intergenic crossovers produce more or less L and M-cone genes on each X chromosome

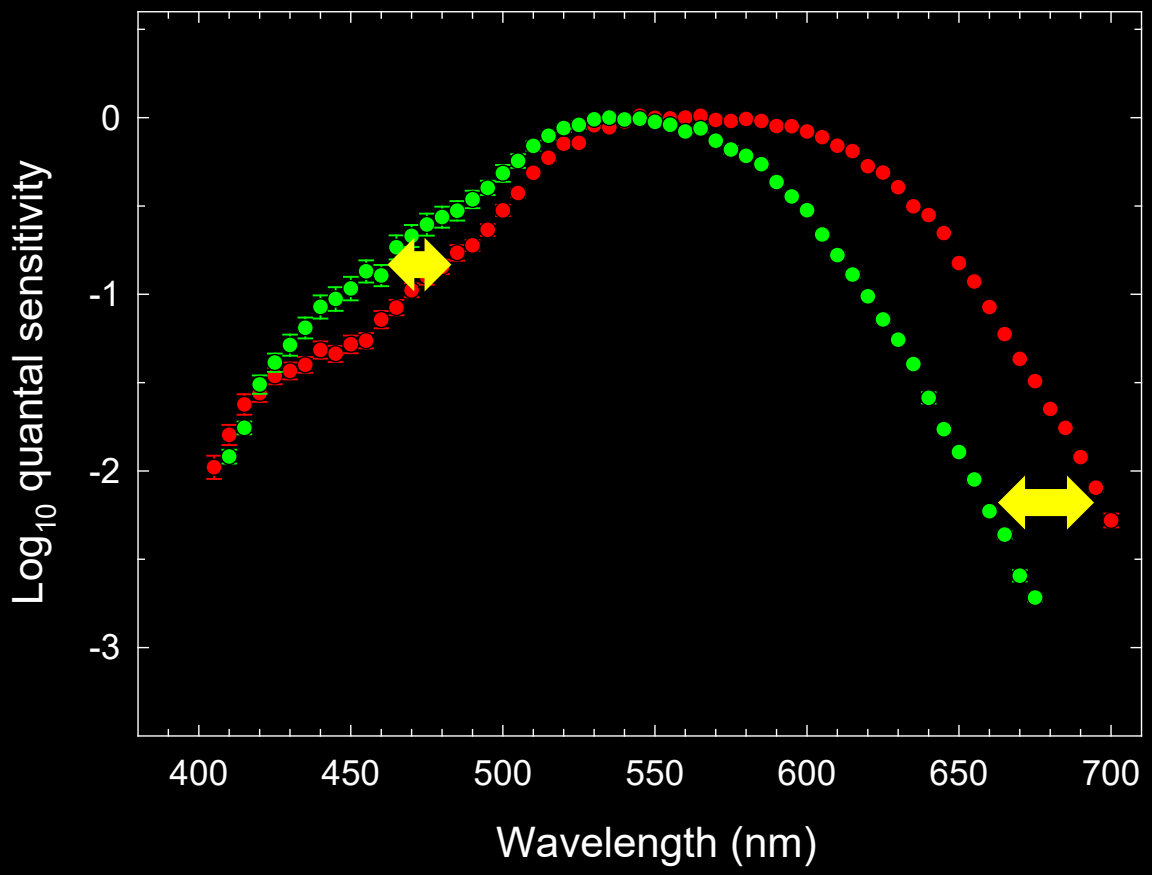
From Sharpe, Stockman, Jägle & Nathans, 1999

Intragenic crossovers produce hybrid or mixed L and M-cone genes



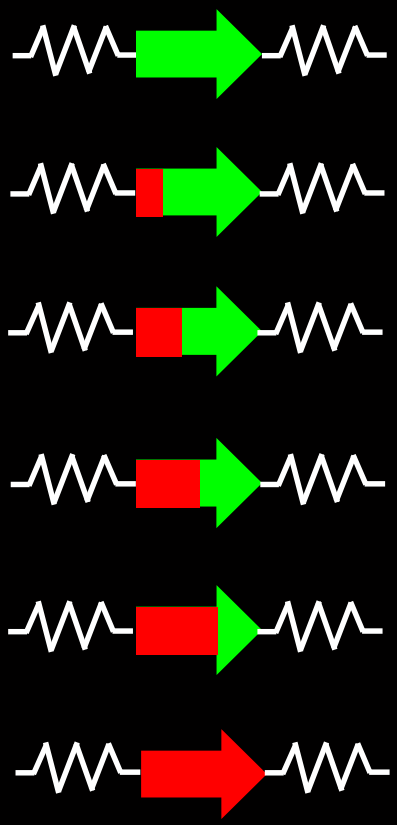
From Sharpe, Stockman, Jägle & Nathans, 1999





The spectral sensitivities of the hybrid photo-pigments vary between those of the M- and L-cones depending on where the crossover occurs.

Single-gene dichromats

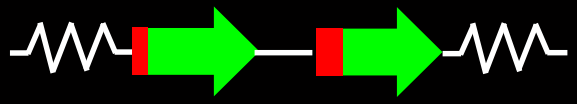


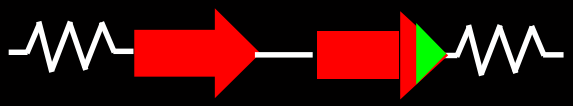
Protanope

Deuteranope

With a single gene male observers must be dichromats

Multiple-gene dichromats

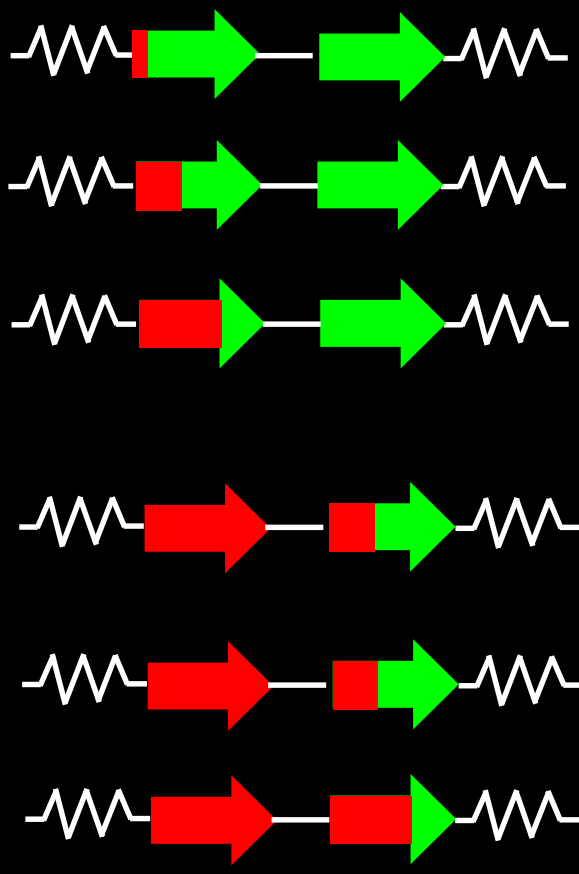




Male observers with two similar genes may also be effectively dichromats if the two genes produce similar photopigments.

Anomalous trichromats

Male observers with two different genes are "anomalous" trichromats



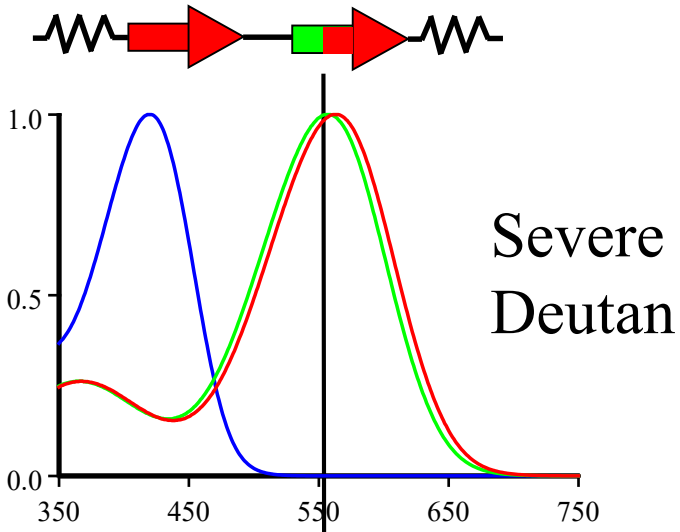
Severe

Protanomalous

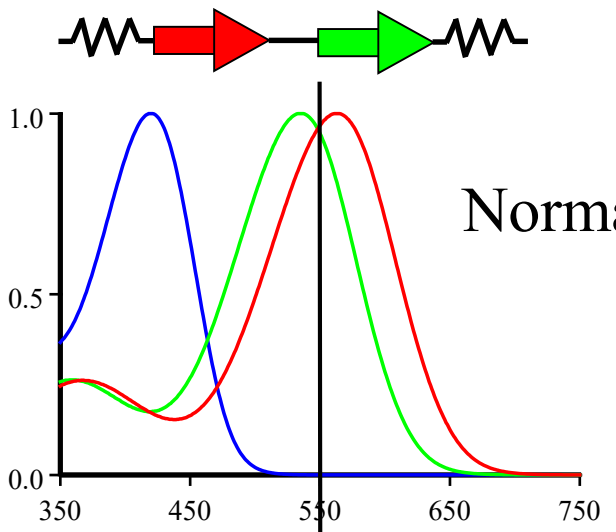
Mild

Deuteranomalous

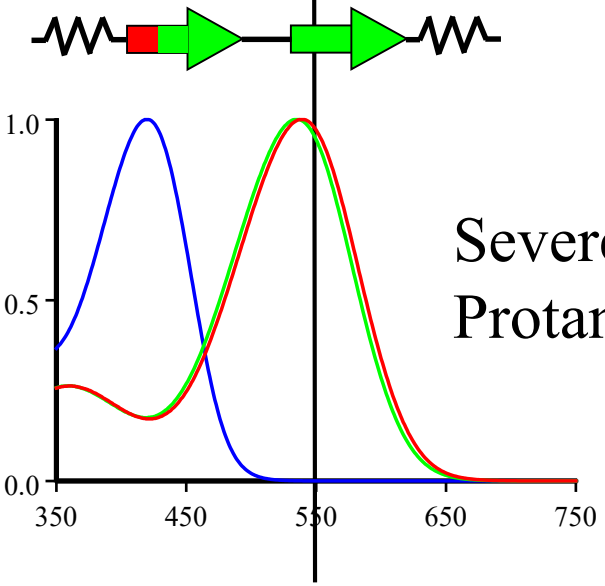
Severe



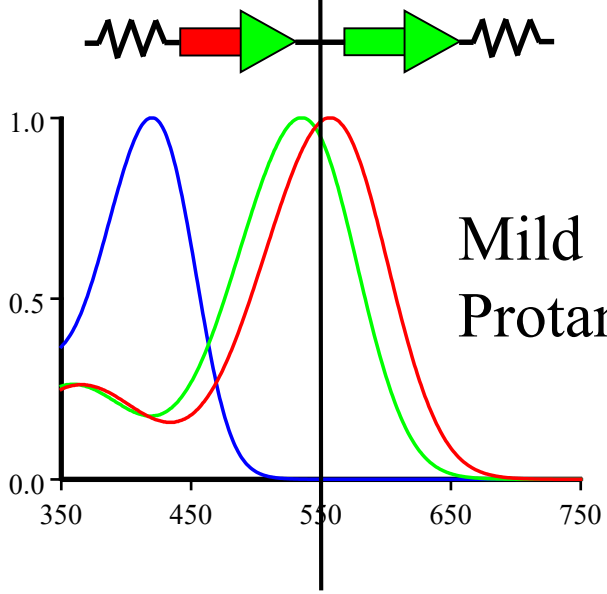
Severe
Deutan



Normal



Severe
Protan



Mild
Protan

Main types of colour vision defects with approximate proportions of occurrence in the population.

Condition		percent in UK Male	Female
Protanopia	no L cone	1.0	0.02
Protanomaly	milder form	1.0	0.03
Deuteranopia	no M cone	1.5	0.01
Deuteranomaly	milder form	5.0	0.4
Tritanopia	no SWS cone	0.008	0.008

XY inheritance

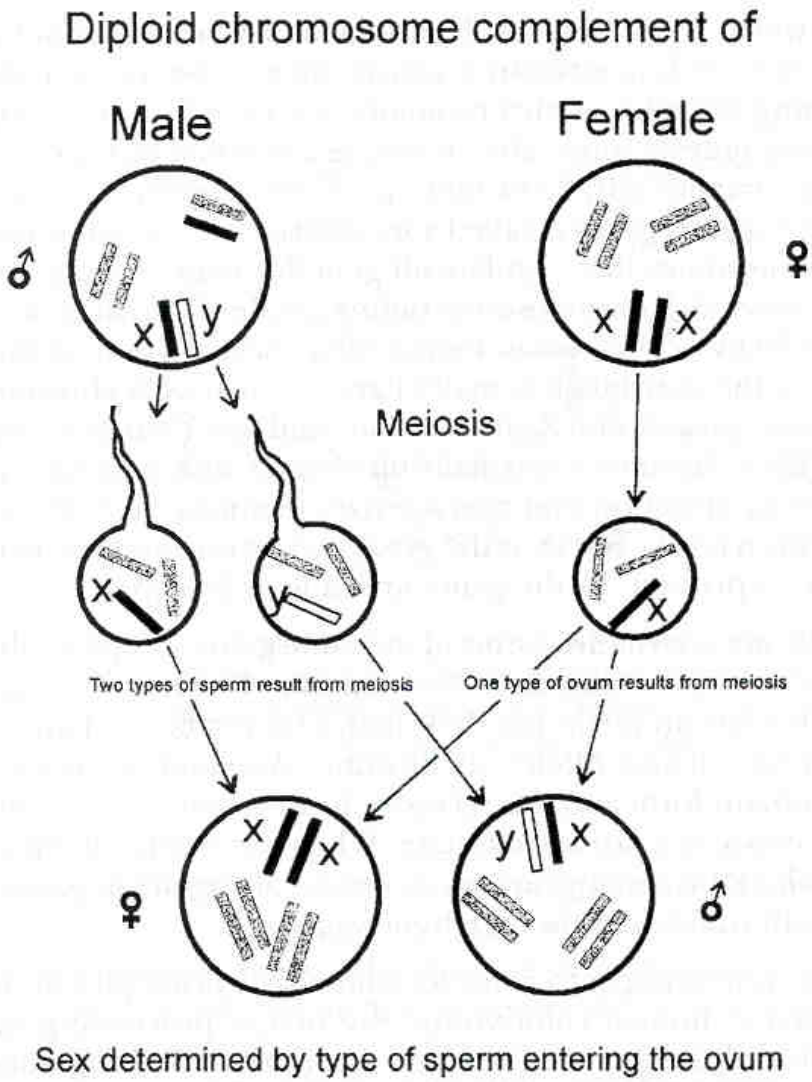


Figure 10.17 Prior to fertilization, meiotic division of germ cells results in two types of sperm, but only one type of ovum. Depending on which sperm is effective, the fertilized ovum will have two X cells and be female, or one X and one Y cell and be male. This diagram show why the X cell of the male offspring can come only from the mother. (From Watson, 1976, p. 14.)

The emergence of two longer wavelength (M- and L-cones) is thought to have occurred relatively recently in primate evolution.

Why is it important?

No red-green discrimination

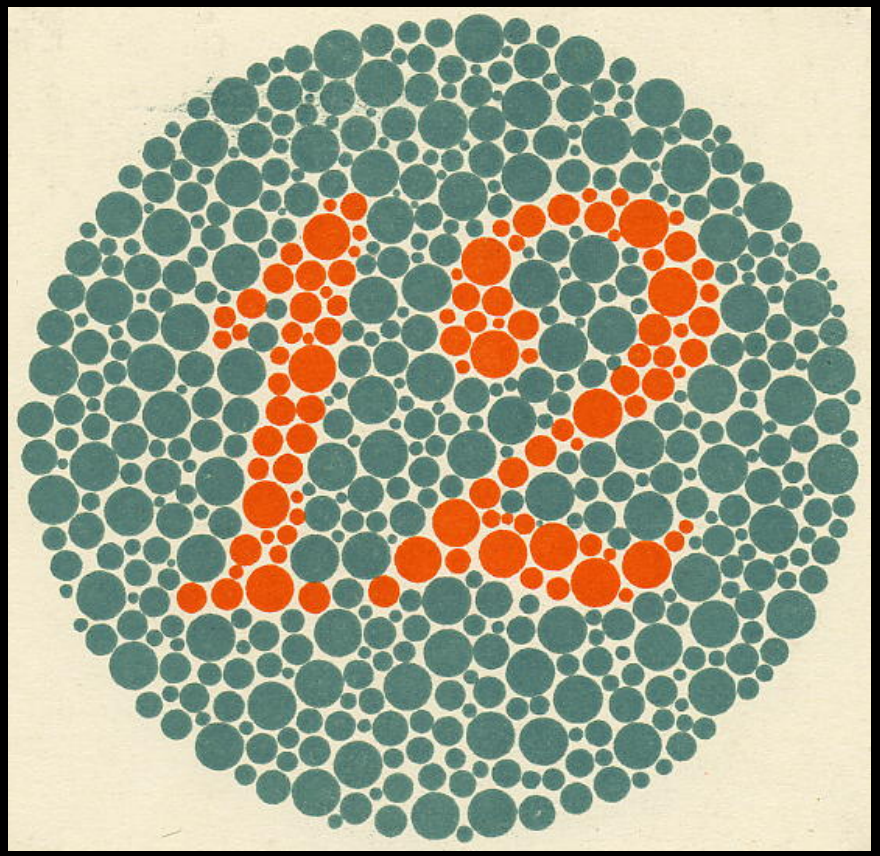
Source: Hans Irtel

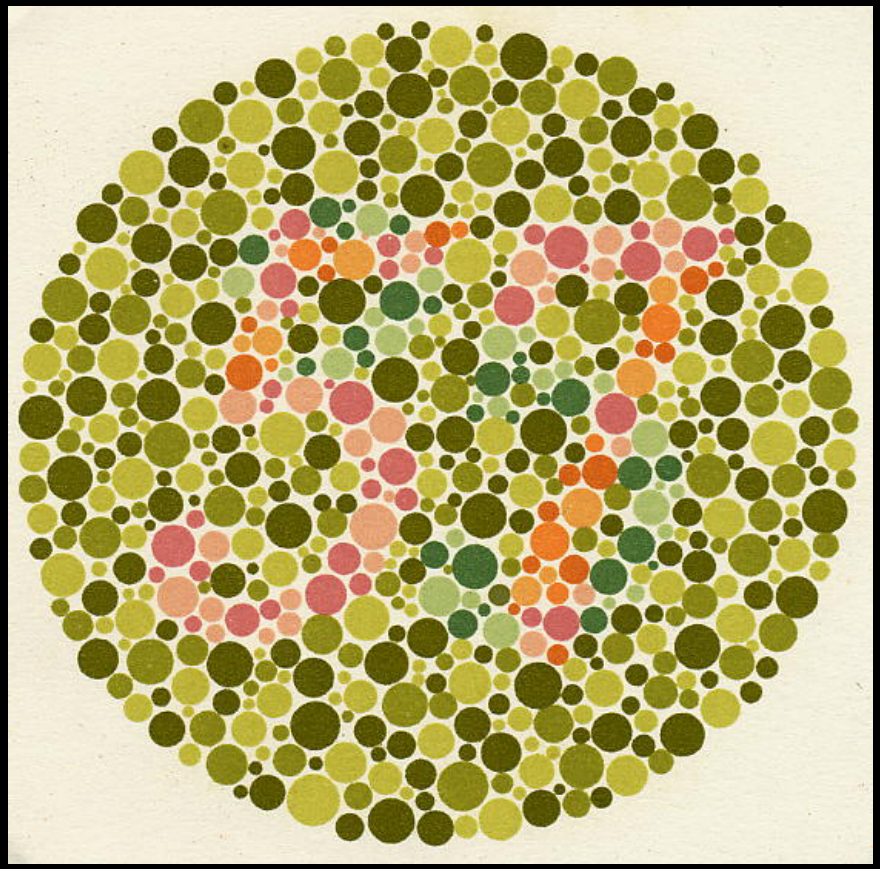
Red-green discrimination

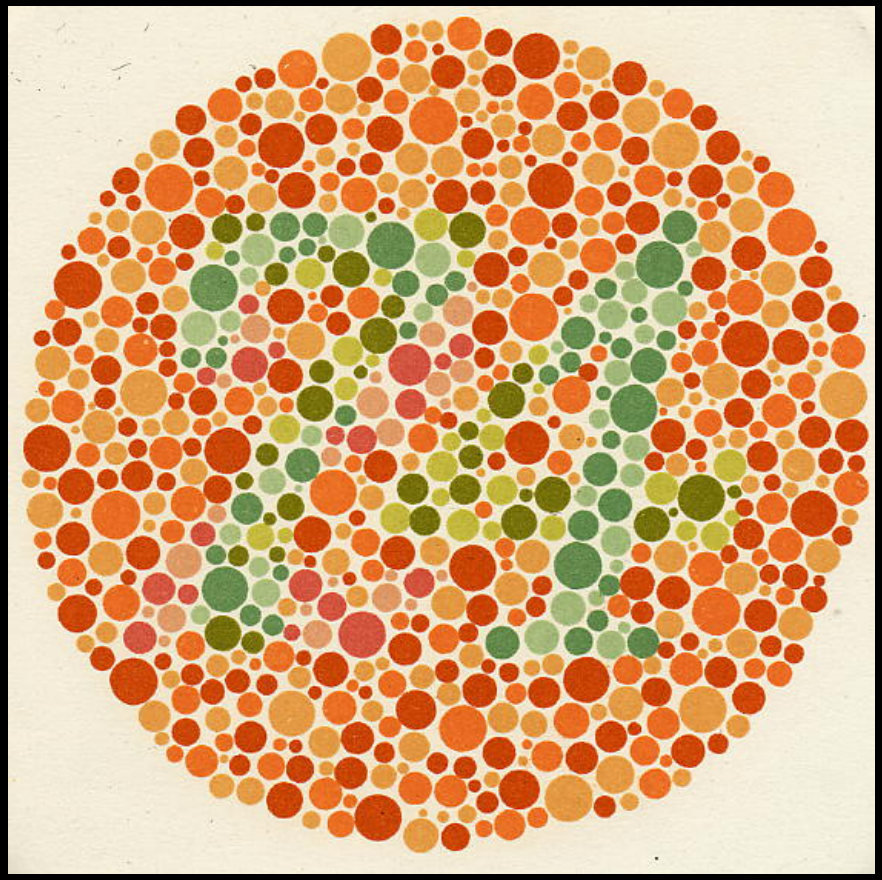
Source: Hans Irtel

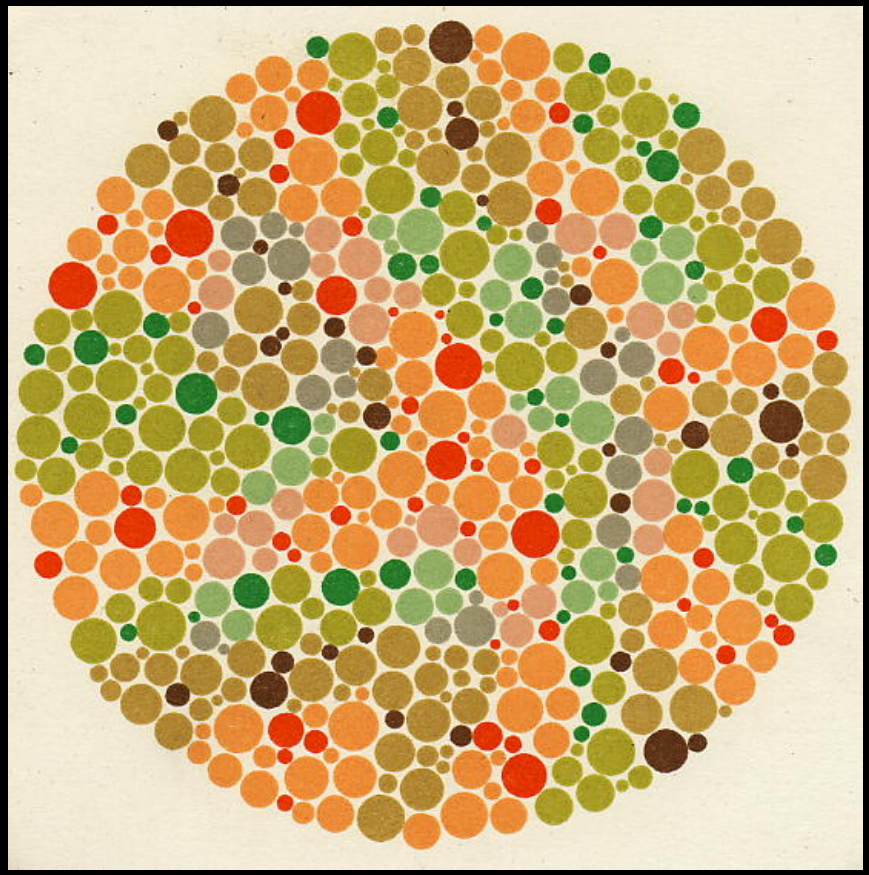
DIAGNOSING COLOUR VISION DEFICIENCIES

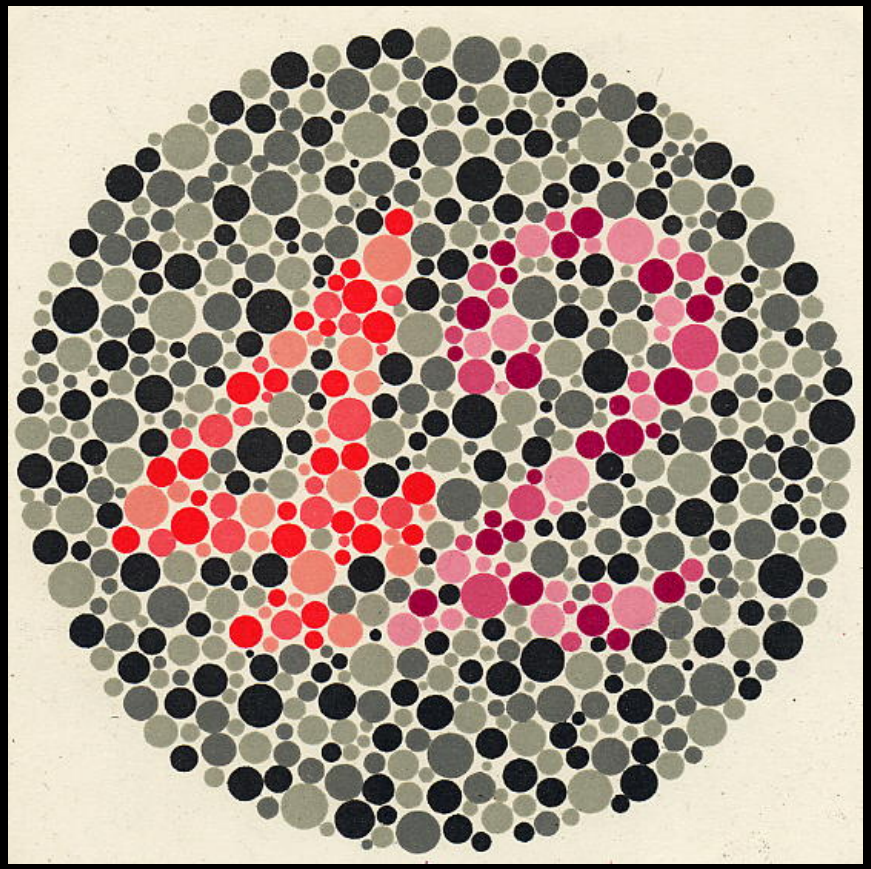
Ishihara plates







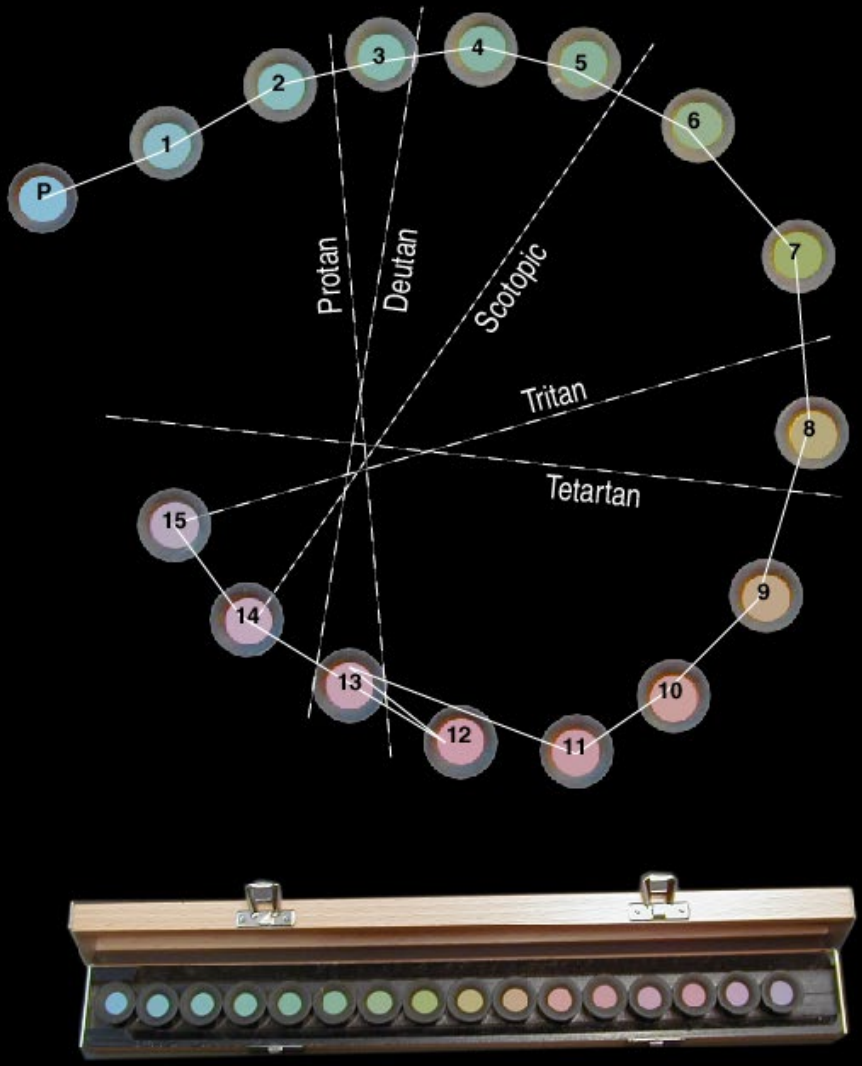




Tests measuring colour discrimination

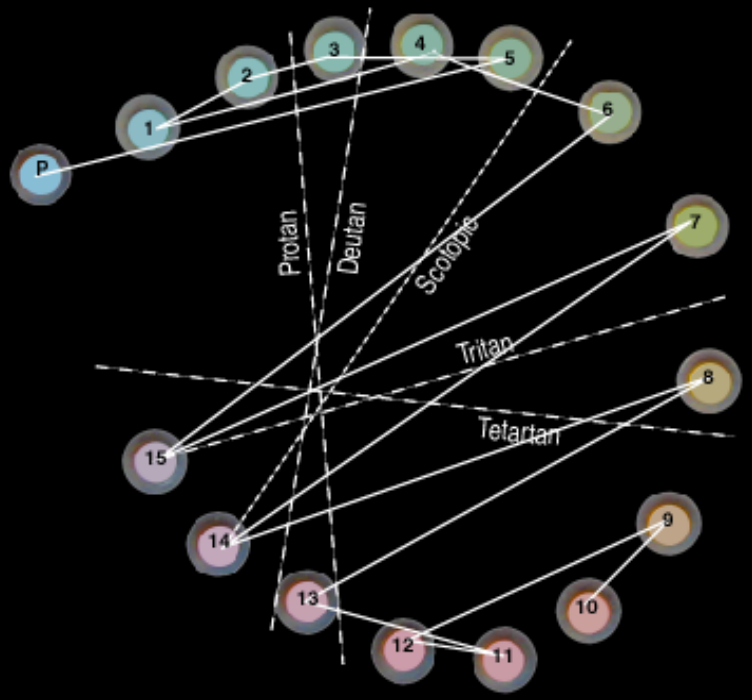
- Farnsworth-Munsell D-15 test

Farnsworth-Munsell D-15



From: Ted Sharpe

Farnsworth-Munsell D-15



From: Ted Sharpe

D15 results

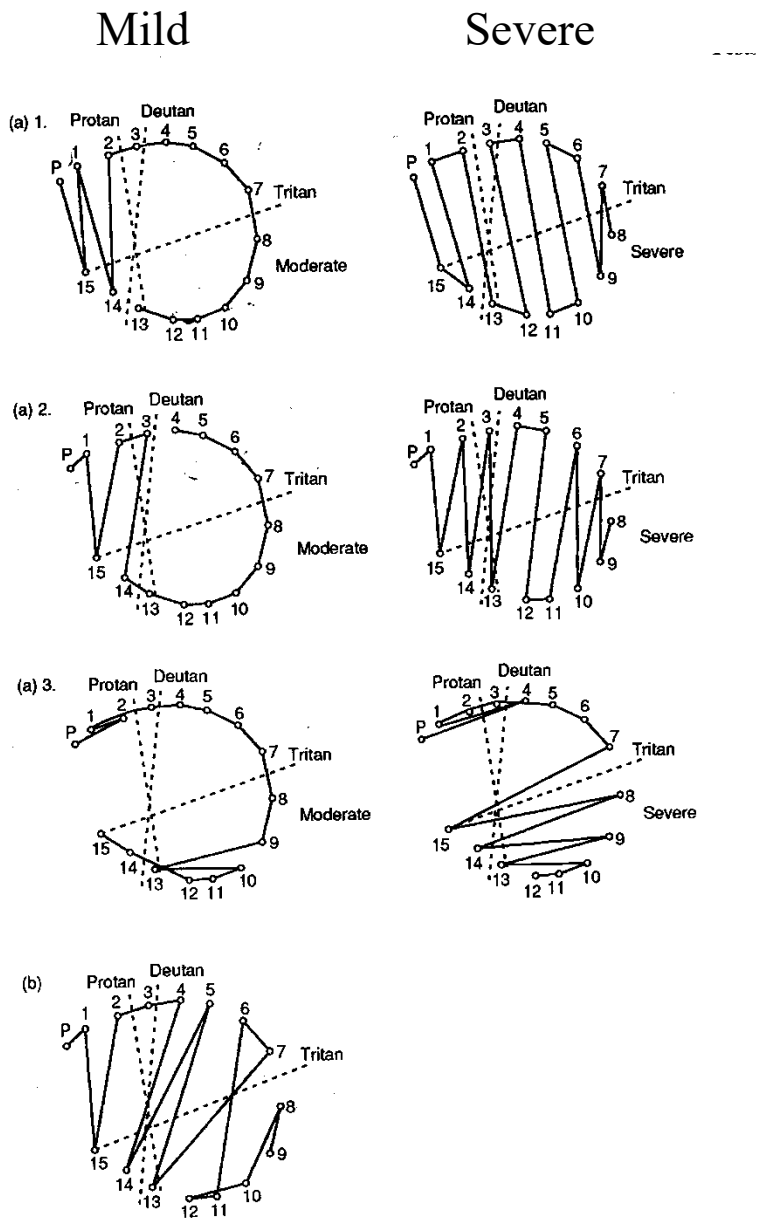


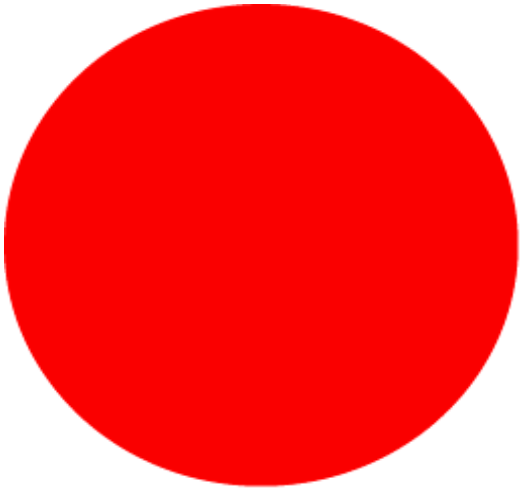
Fig. 7.1 Classification of the type of colour deficiency with the Farnsworth D15 test. (a) Protan, deutan, and tritan defects. 1. Moderate and severe protan defects. 2. Moderate and severe deutan defects. 3. Moderate and severe tritan defects. (b) Typical 'rod' monochromatism. The arrangement represents a lightness scale not isochromatic colour confusions.

Credit: Jenny Birch

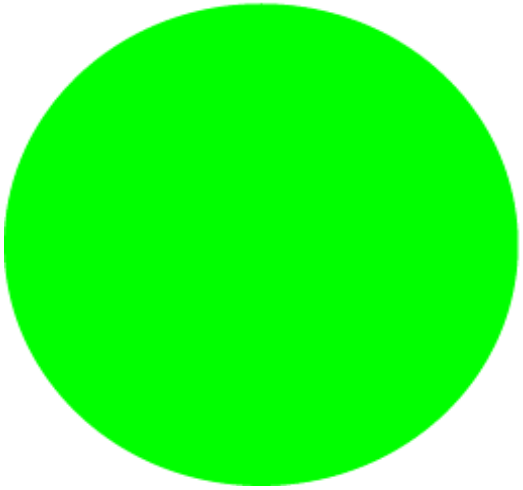
COLOUR AFTER-EFFECTS

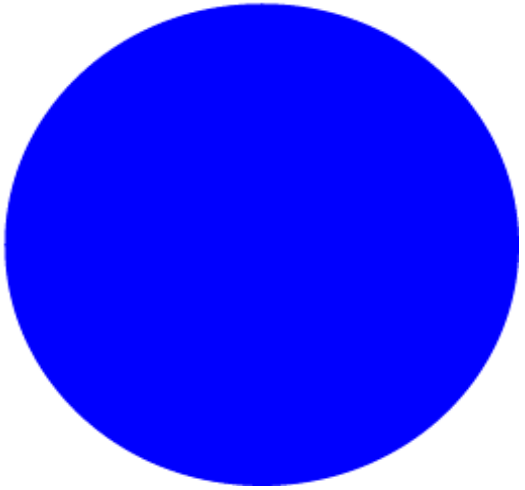
(what precedes the patch)

Colour
after-effects



+





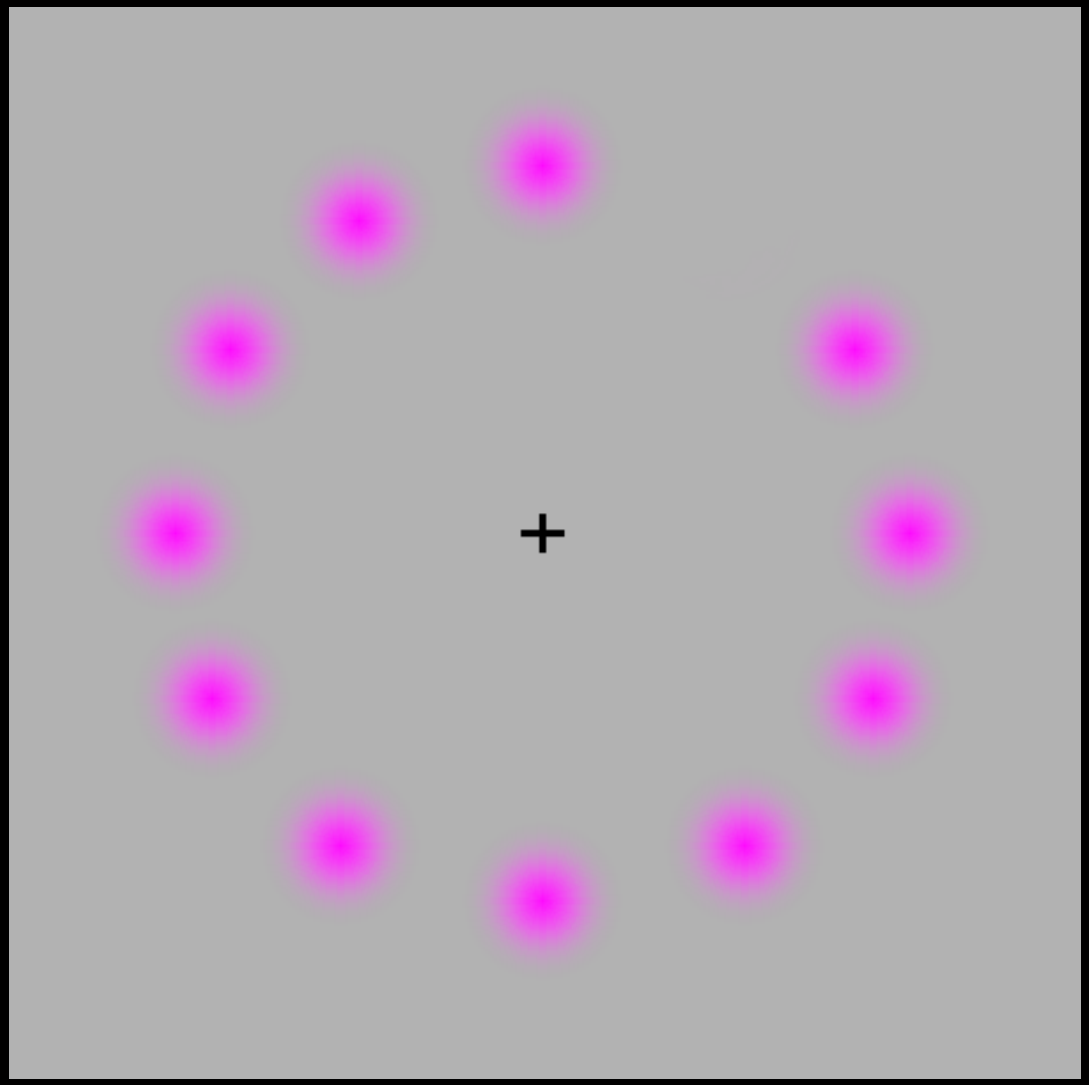
You don’t have to see things for them
to produce an after-effect...

Beer & MacLeod

Beer & MacLeod

Mediafire

Lilac chaser or Pac-Man illusion



Jeremy Hinton

Lilac chaser or Pac-Man illusion

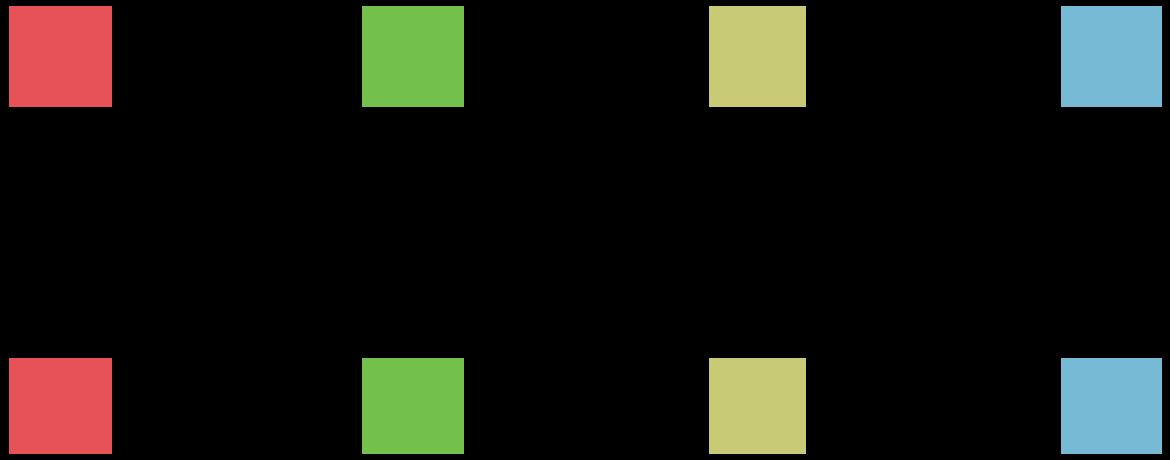
http://michaelbach.de/ot/index.html

Michael Bach and Jeremy Hinton

COLOUR CONTRAST

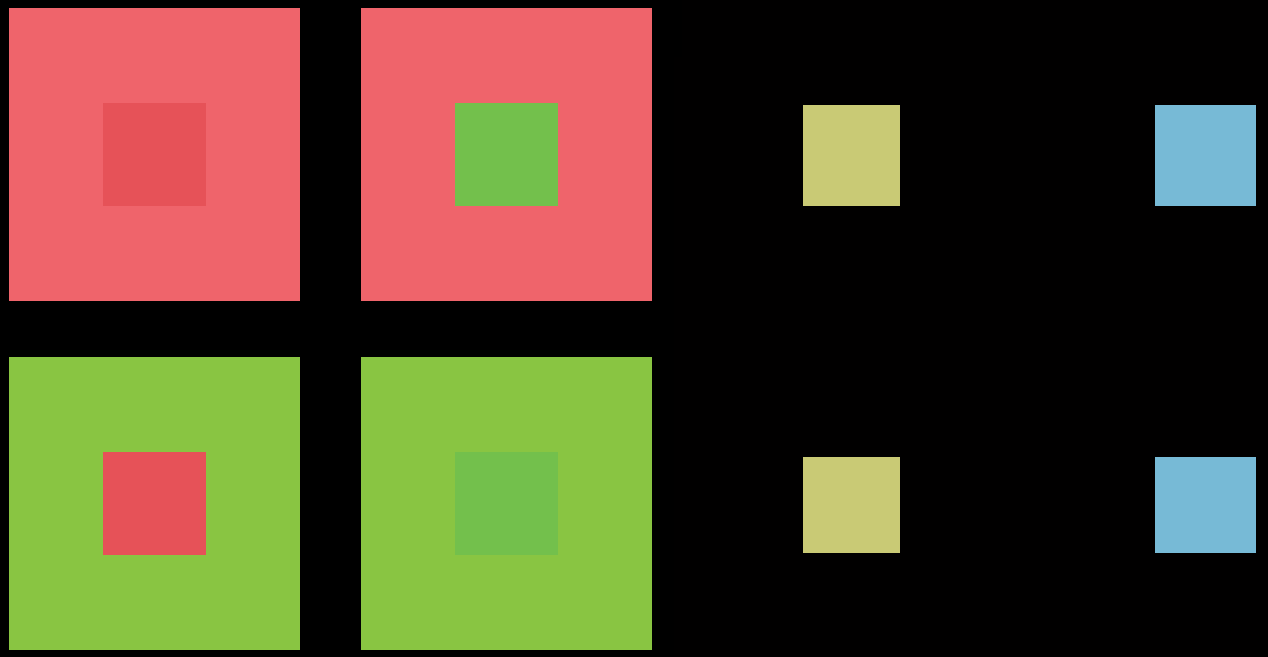
(what surrounds the patch)

Color contrast

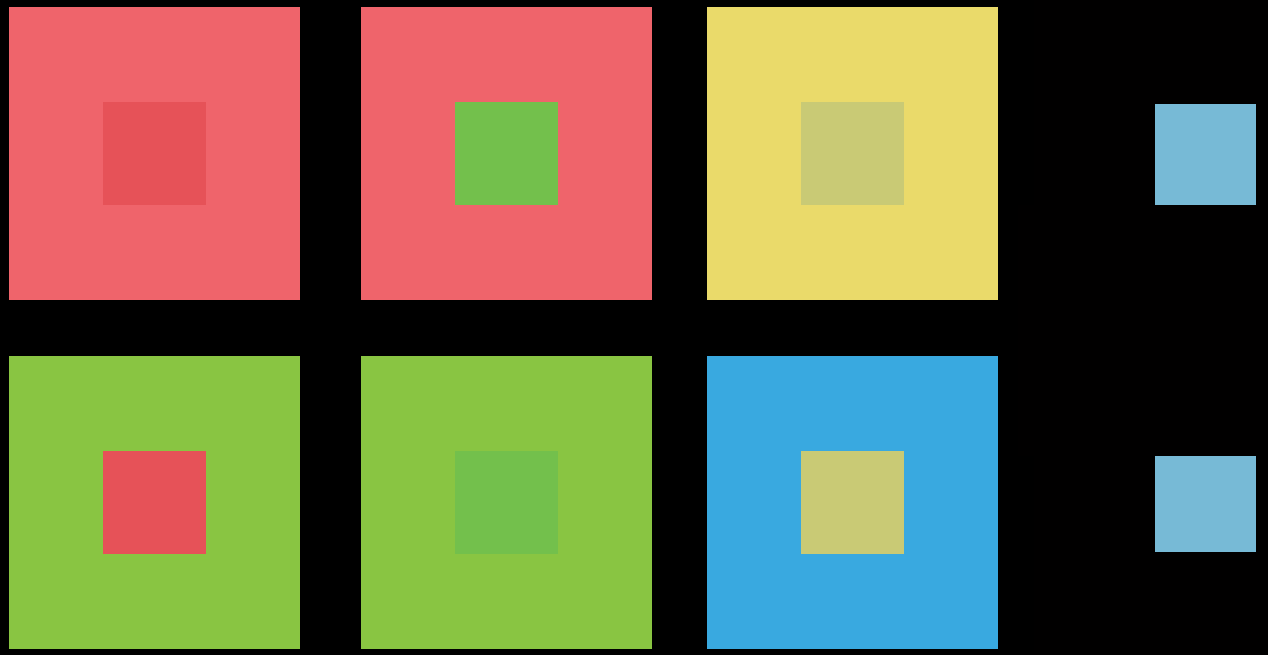


Color contrast

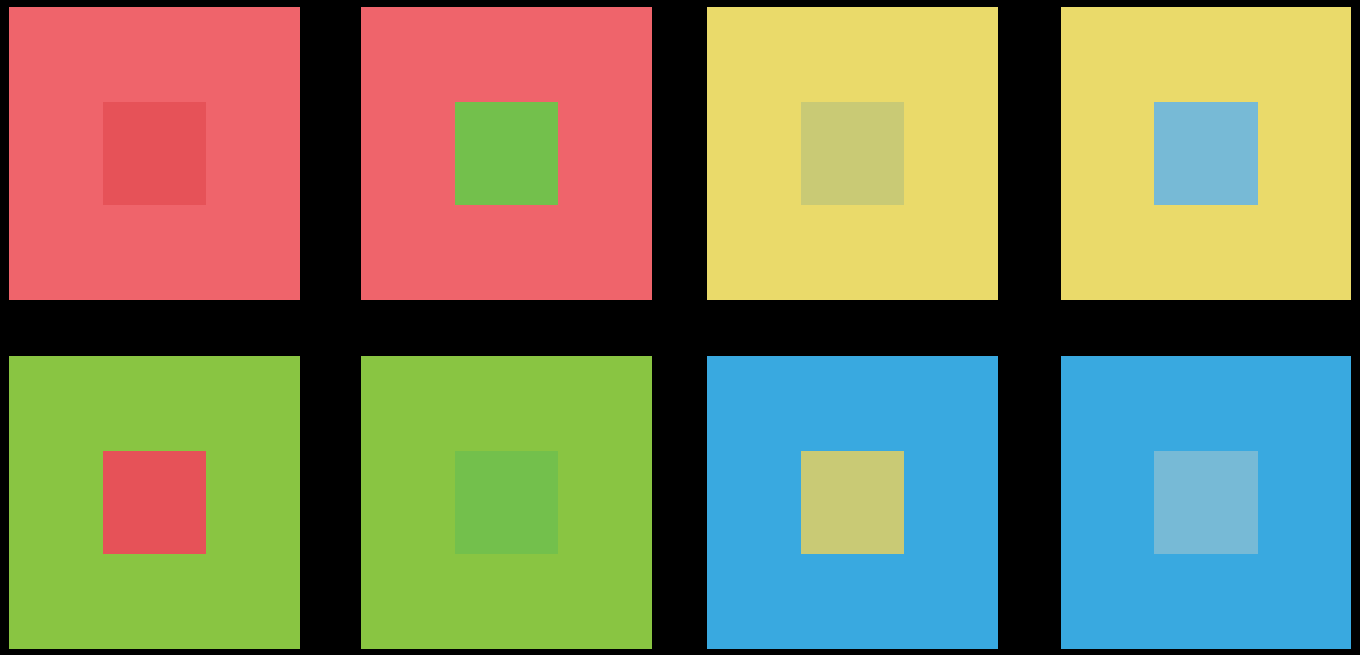
Color contrast

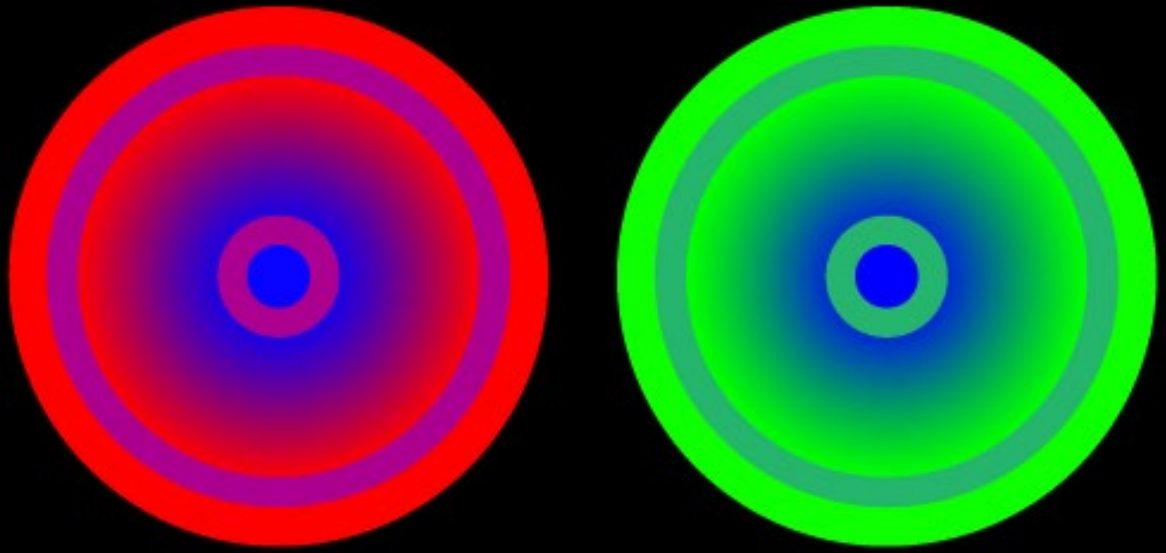


Color contrast

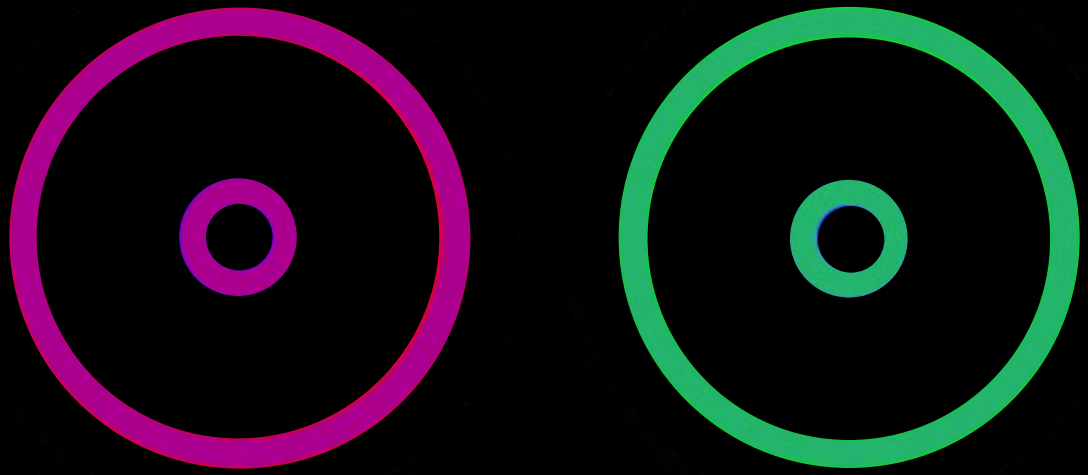


Color contrast





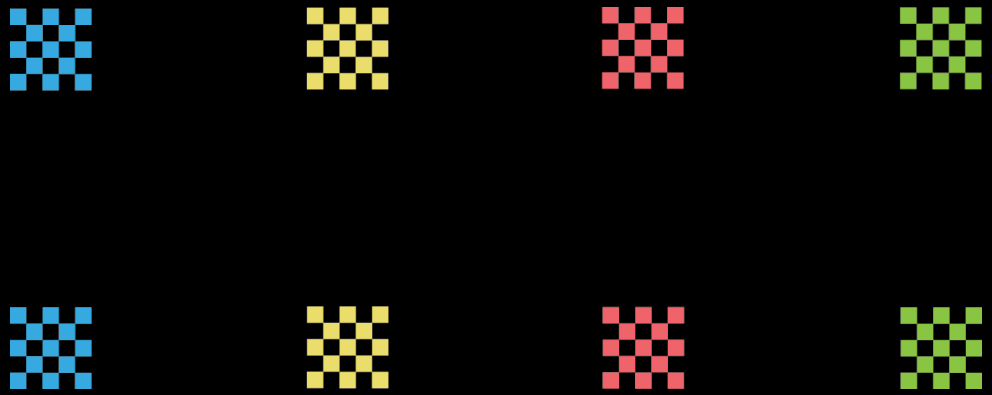
MacLeod



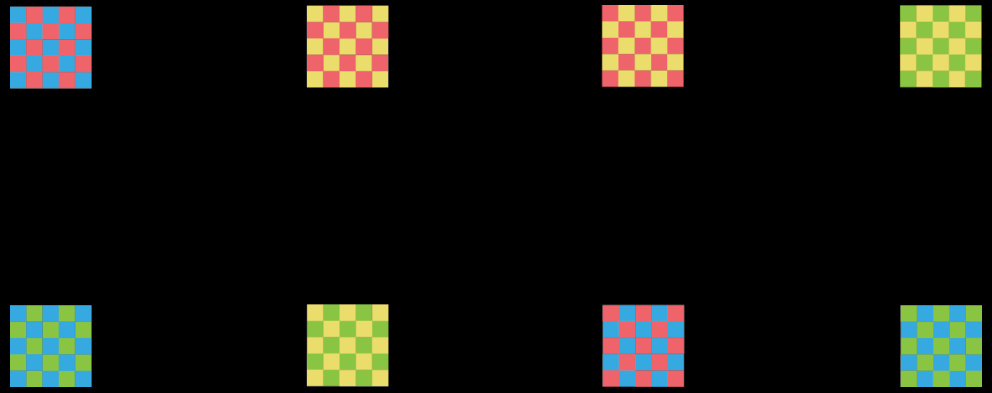
MacLeod

COLOUR ASSIMILATION

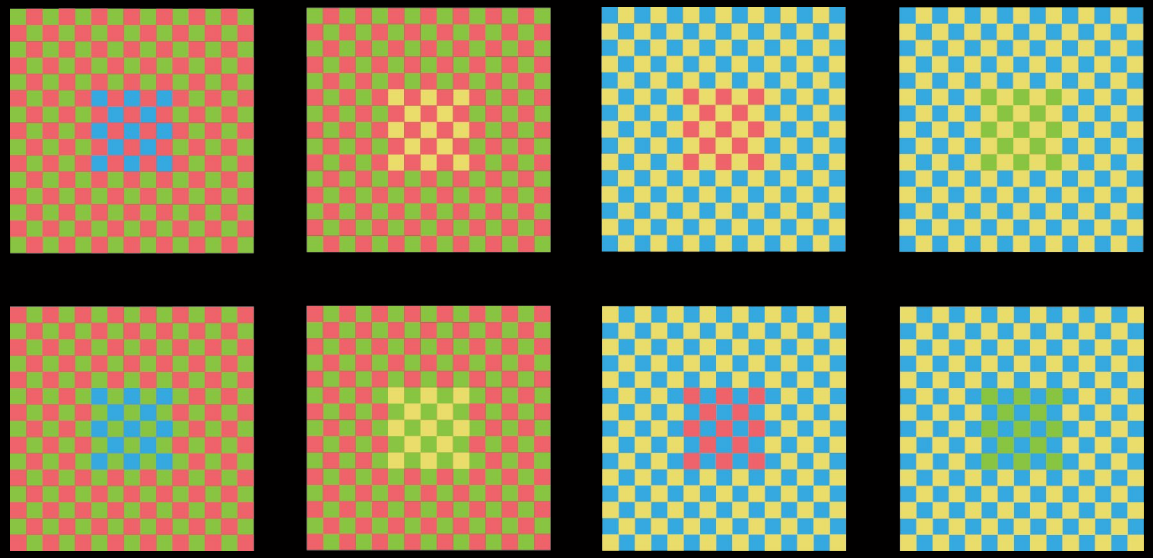
Colour assimilation



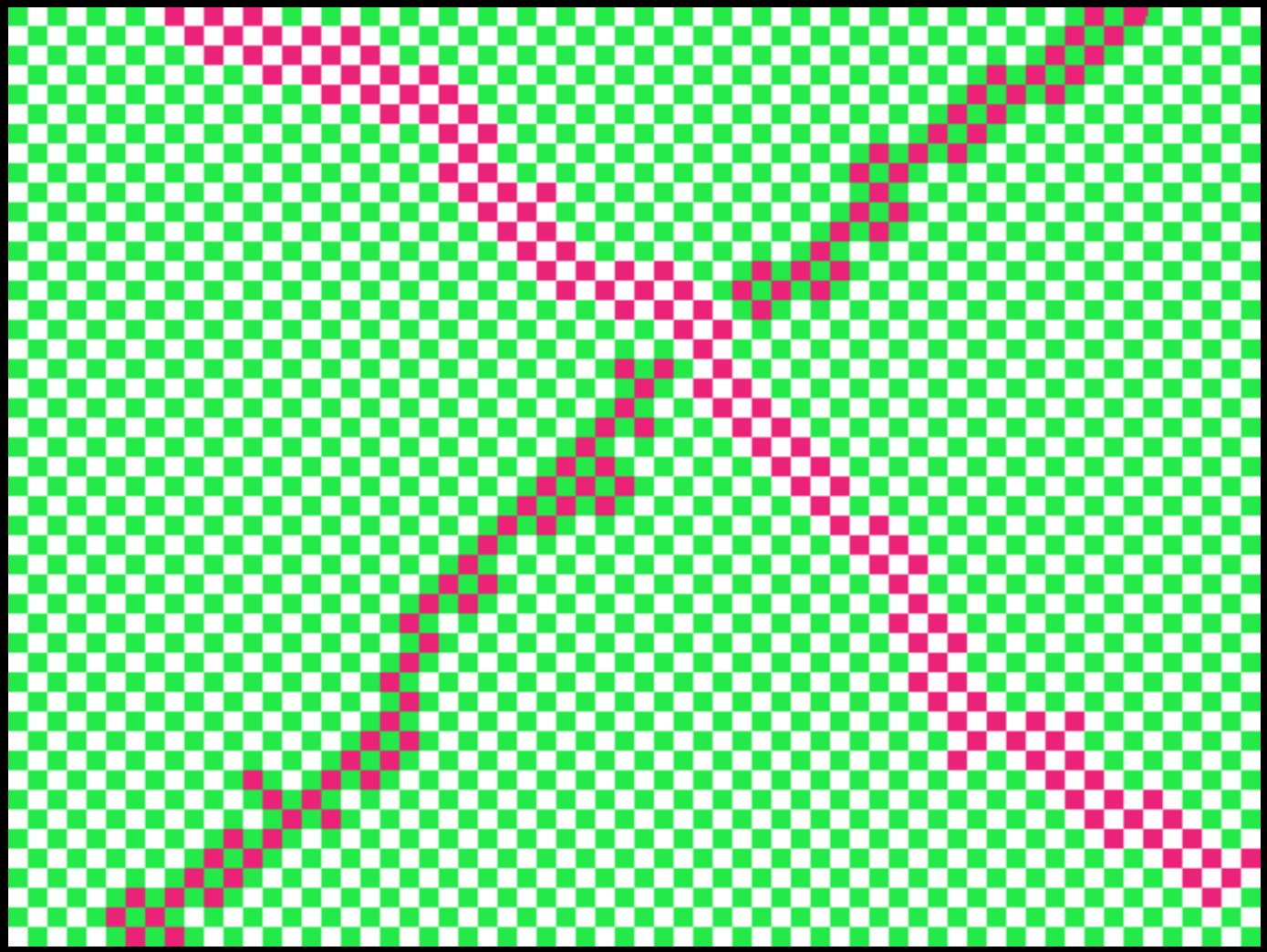
Colour assimilation



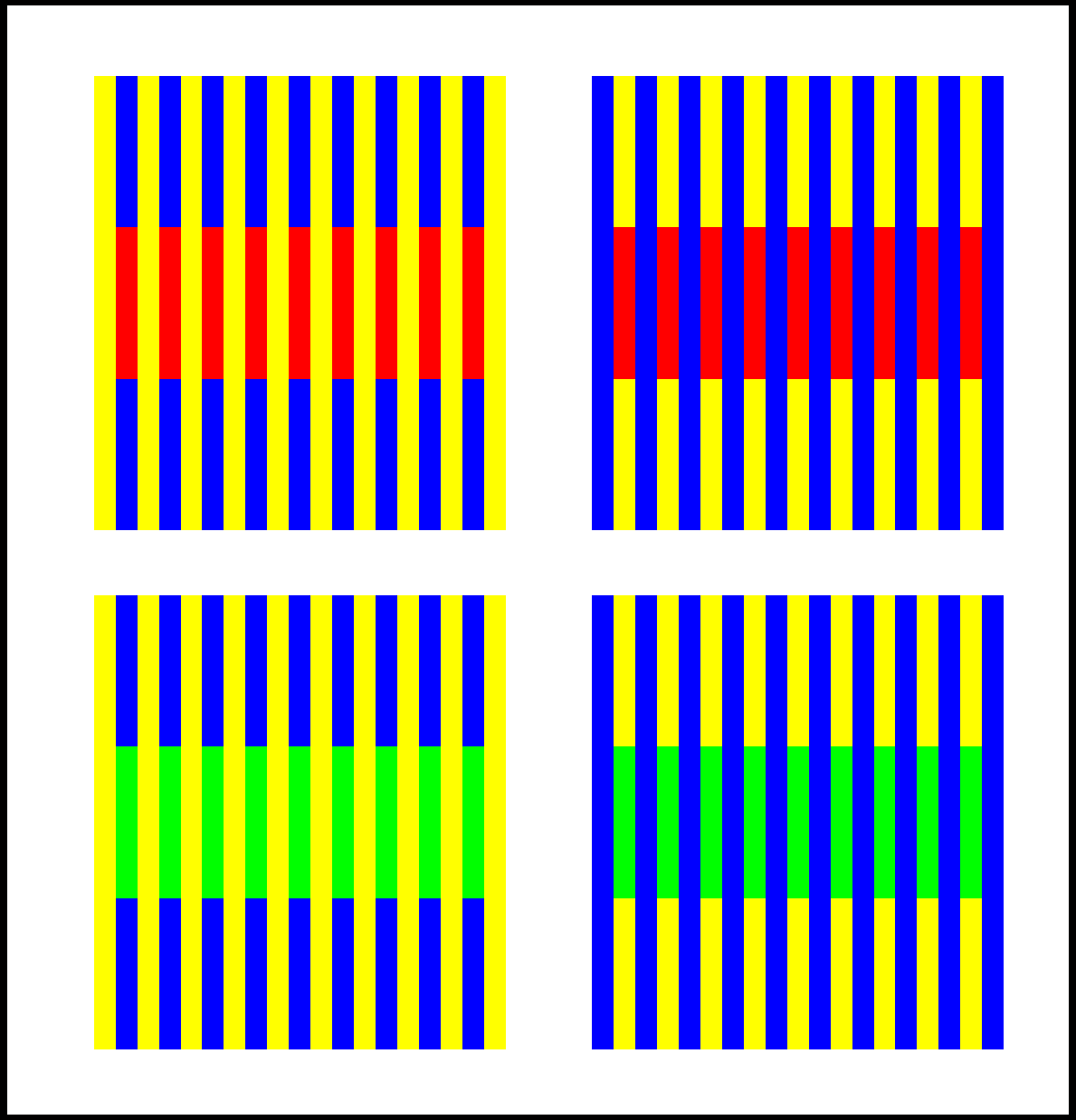
Colour assimilation



Colour assimilation



Munker illusion

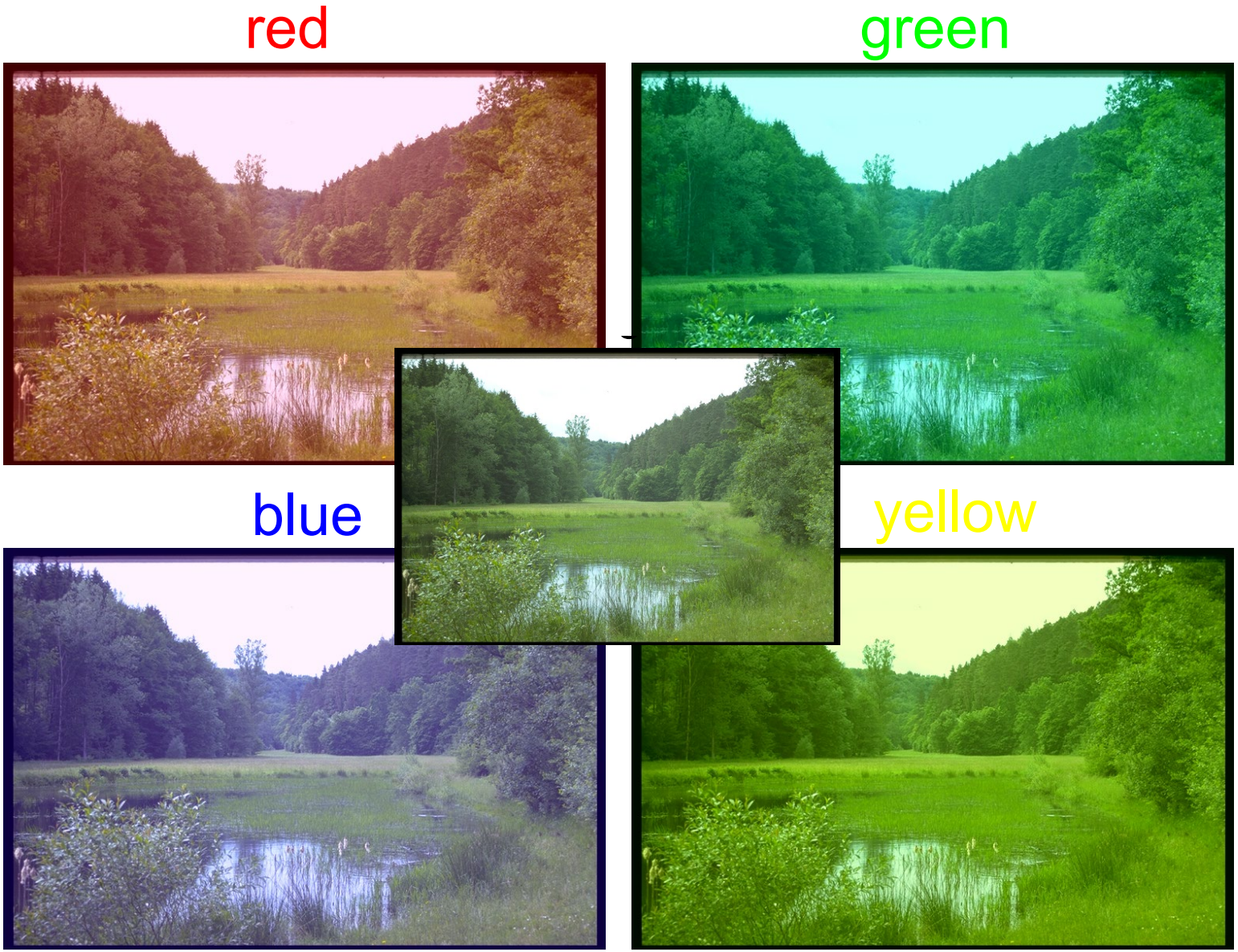


COLOUR CONSTANCY

Colour constancy

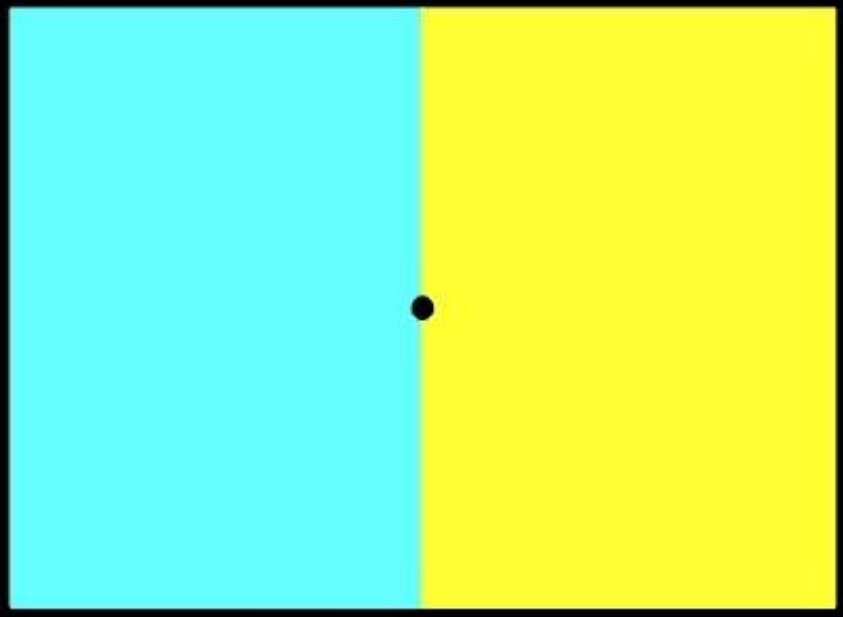
Credit: Gegenfurtner

Colour constancy



Chromatic adaptation and colour constancy

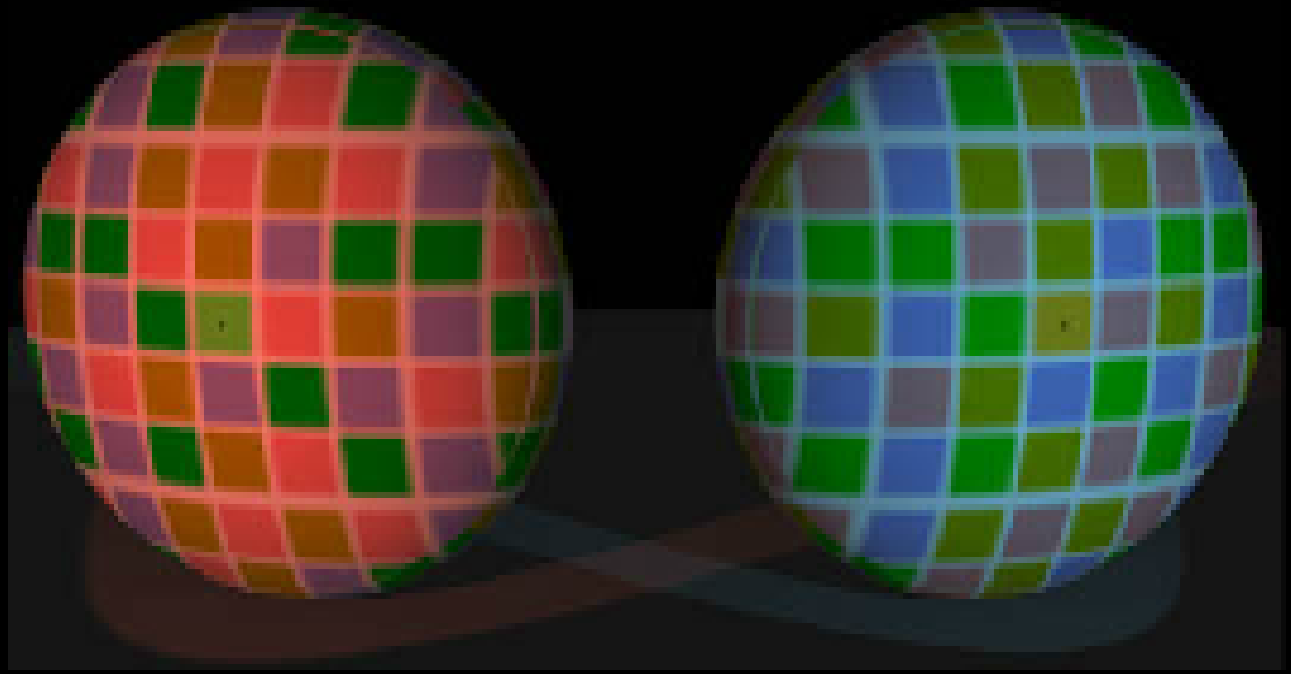
The change in colour appearance following adaptation is due to chromatic adaptation. Chromatic adaptation is adaptation to the colour is of the ambient illumination.



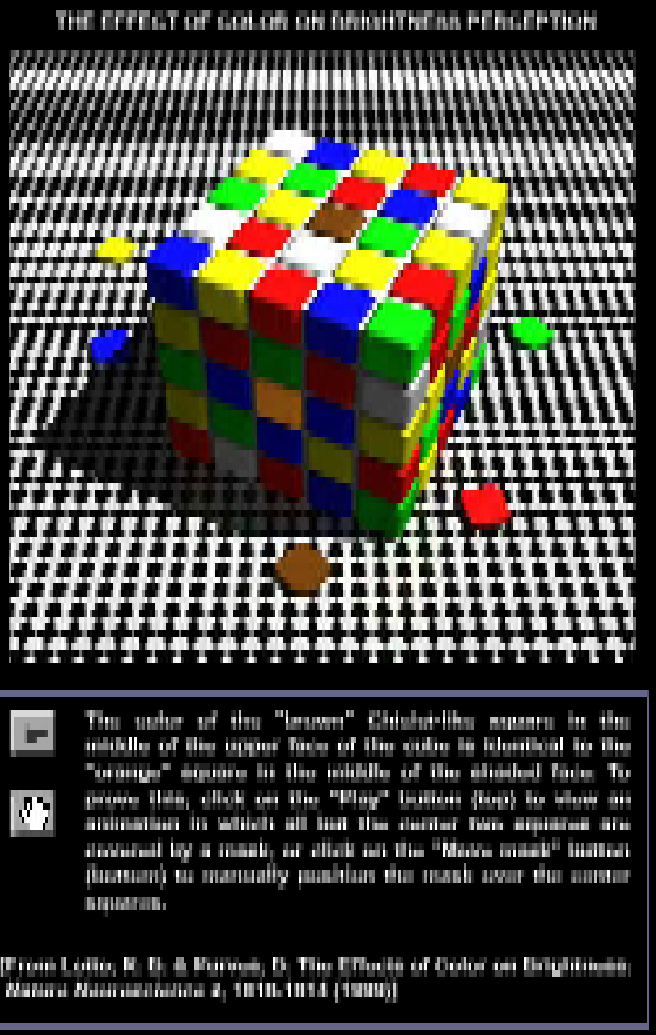
Amazing Art, Viperlib

Colour and the illuminant

Show mask

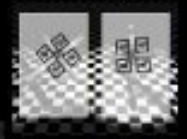


Colour and brightness



This image combines illusions of form and colour. The central element of the two 'X' objects appear very different in colour (dark blue on the left and light yellow on the right). What's more, the angles of each 'X' appear either smaller or larger than 90 degrees.

'MASK'



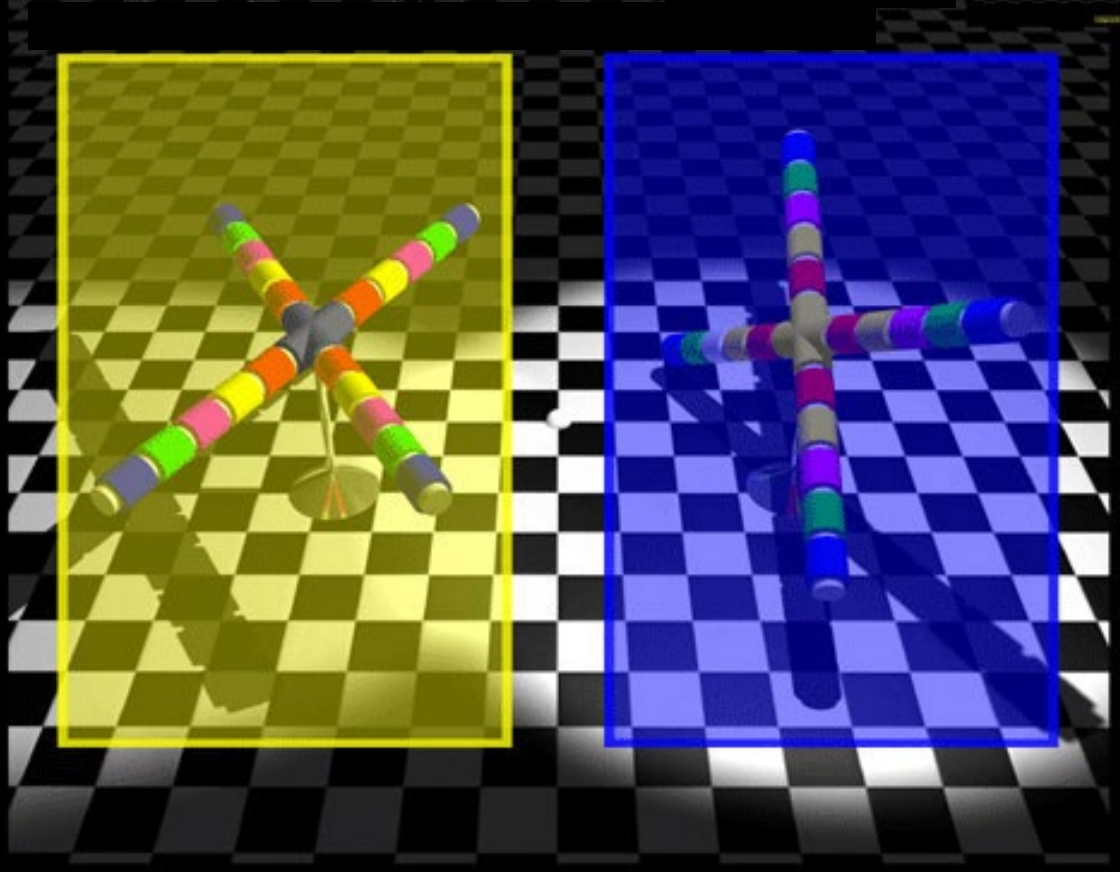
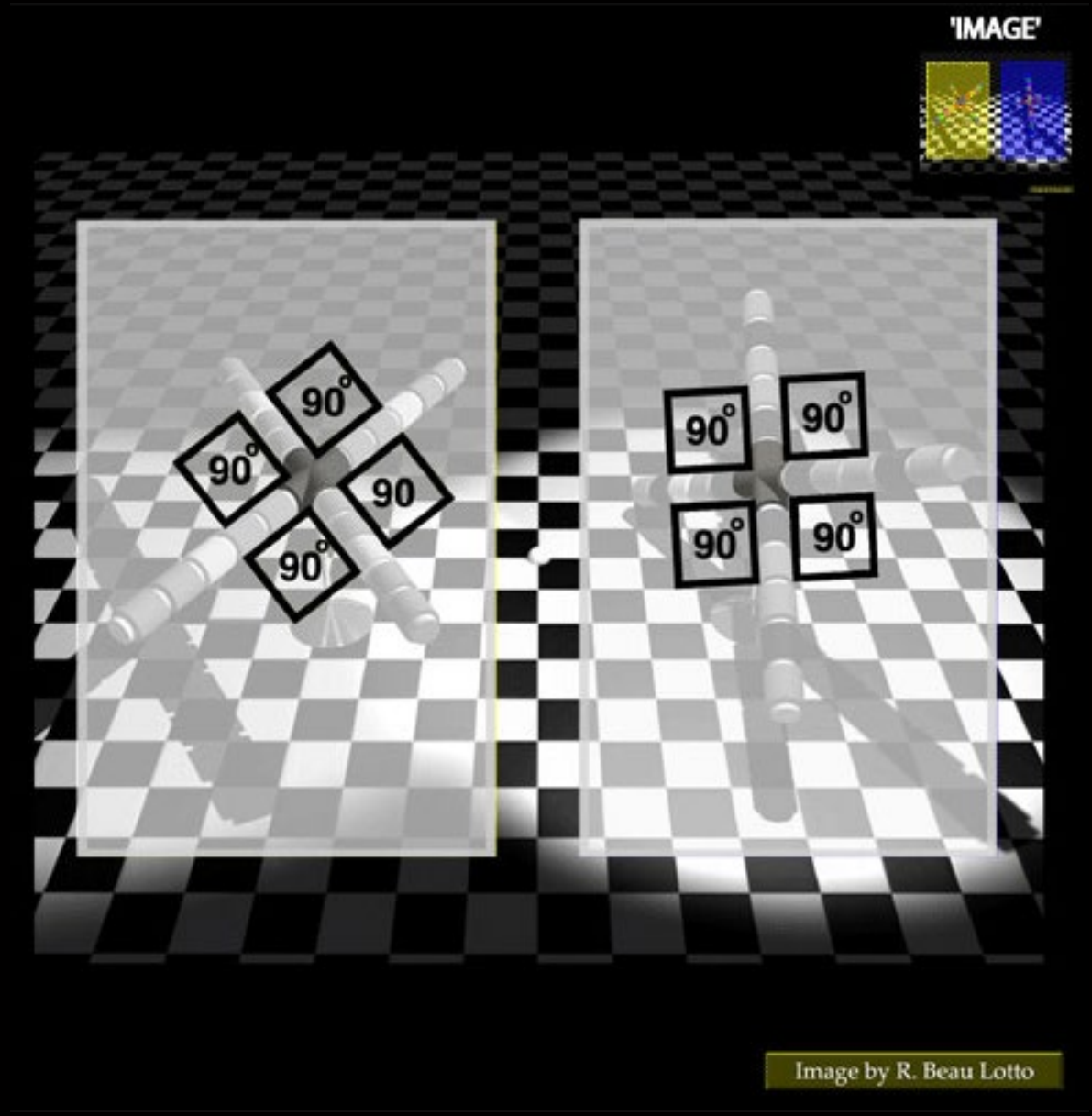


Image by R. Beau Lotto


'IMAGE'
90°
90°
90
90°
90°
90°
90°
90°
Image by R. Beau Lotto

Stroop effect

Say to yourself the colours of the **ink** in which the following words are written -- as fast as you can.

So, for **RED**, say “red”.

But for **RED**, say “green”

Ready, steady…

TEST 1

RED GREEN BLUE YELLOW PINK

ORANGE BLUE GREEN BROWN WHITE

GREEN YELLOW PINK RED ORANGE

BROWN RED WHITE BLUE YELLOW

WHITE ORANGE GREEN BROWN RED

How long?

TEST 2

BLUE	PINK	WHITE	RED	BROWN
BROWN	RED	BLUE	GREEN	ORANGE
YELLOW	BLUE	RED	ORANGE	WHITE
BROWN	RED	GREEN	WHITE	RED
RED	PINK	BLUE	GREEN	WHITE

How long?