Color Theory

- Chapter 3b

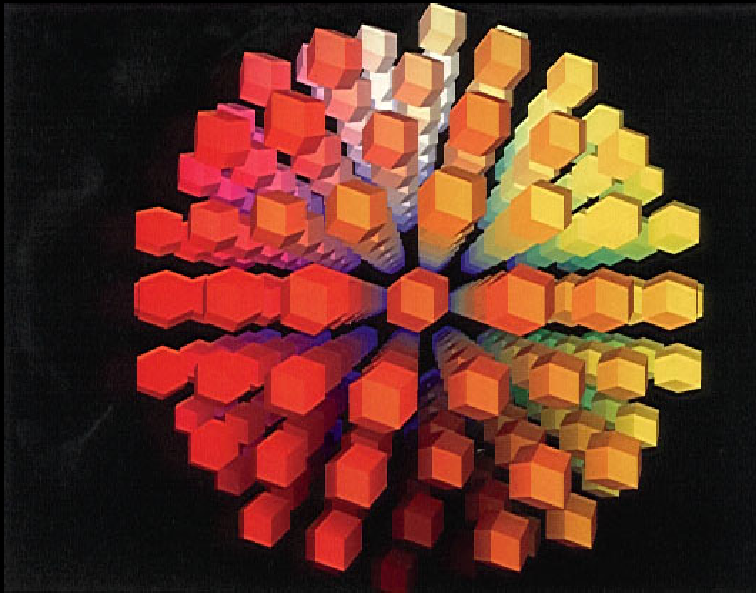
  Perceiving Color

- Color Constancy

Color Theory

- Chapter 3 **Perceiving Color** *(so far)*

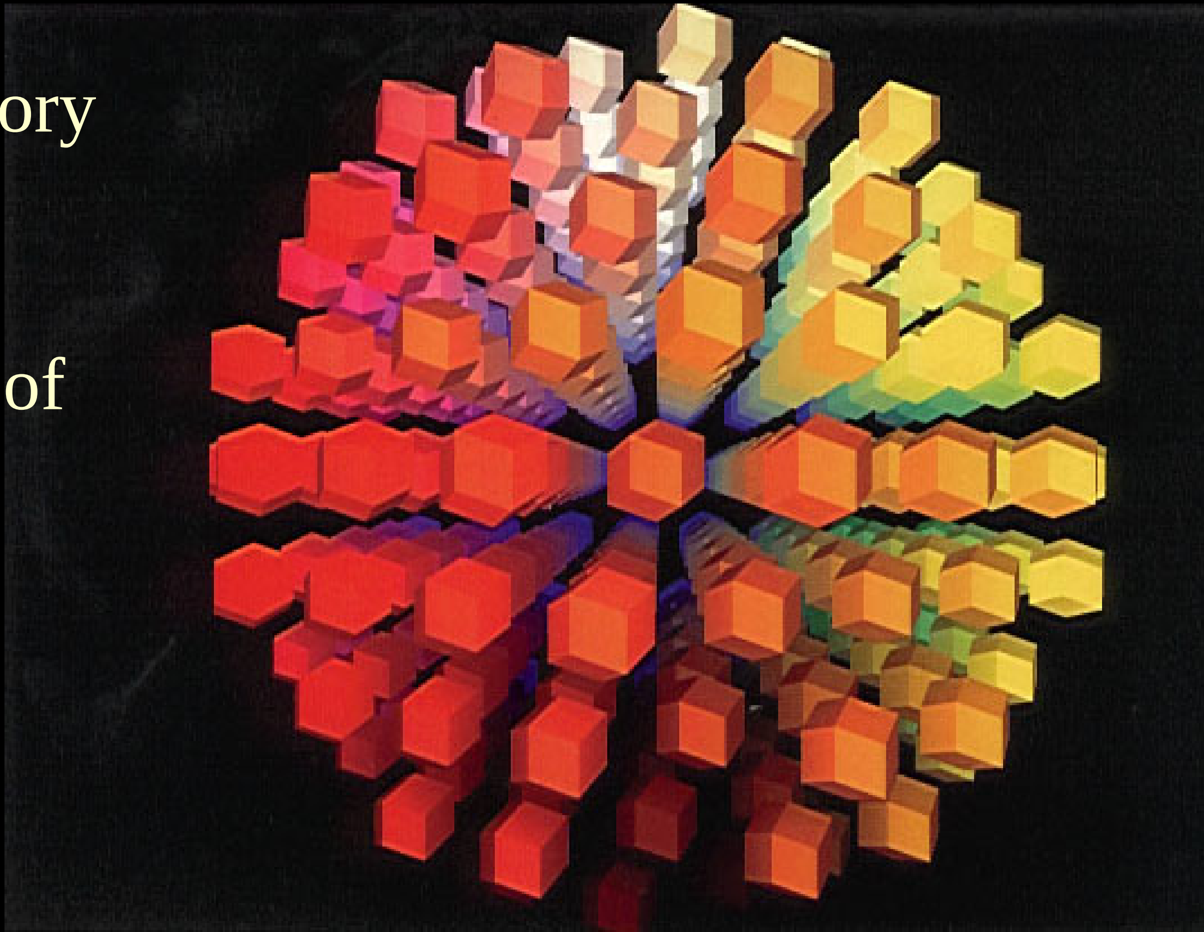
- Lens
- Iris
- Rods
- Cones x3
- Fovea
- Optic Nerve
- Iodopsin & Rhodopsin



Color Theory

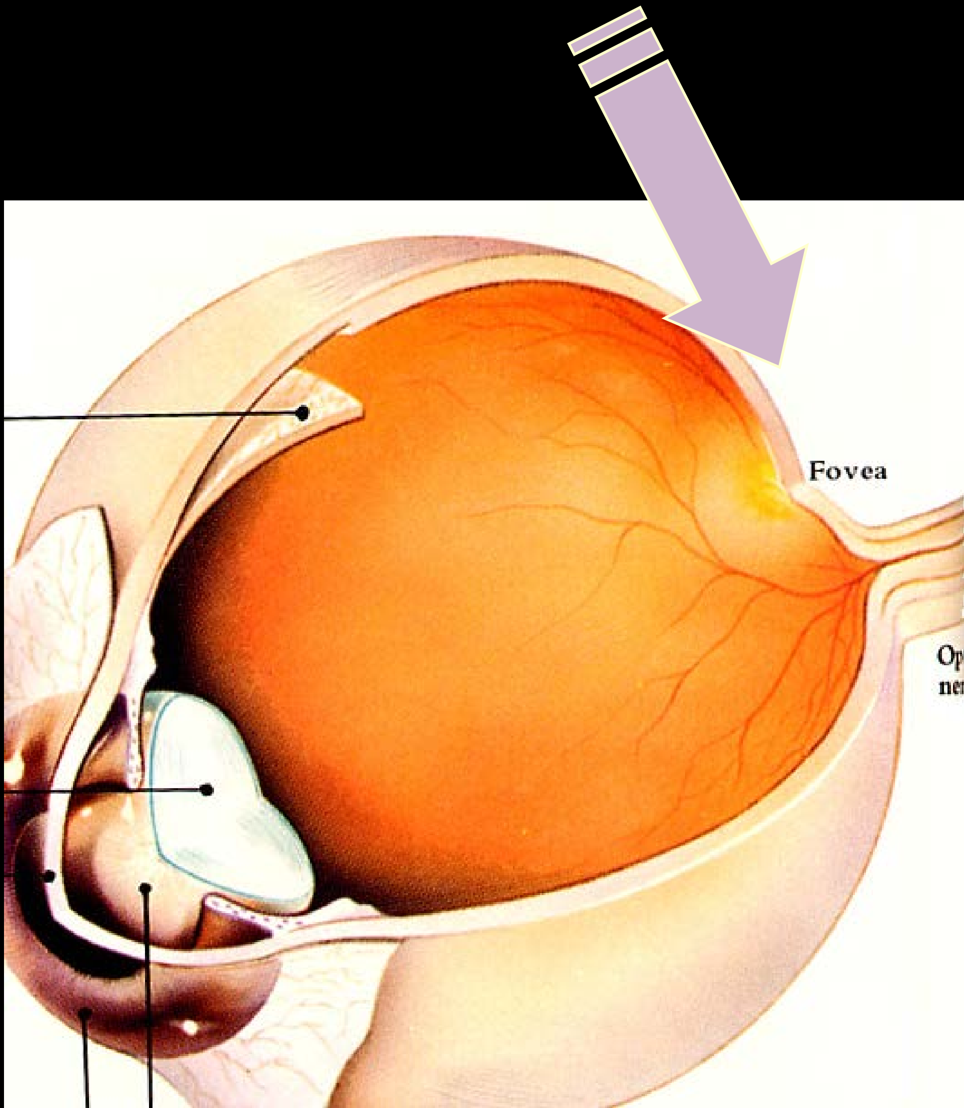
- Chapter 3
  Perceiving Color (today)

- Tri-Chromatic theory of color vision
- Color Afterimage
- Opponent Theory of color vision
- Color Constancy
- Monet's series
- Color Blindness



Fovea

- A tiny (1mm) area on the retina is covered with a dense collection of cones.
- This region is where we **see color distinctions best**.



Seeing Color

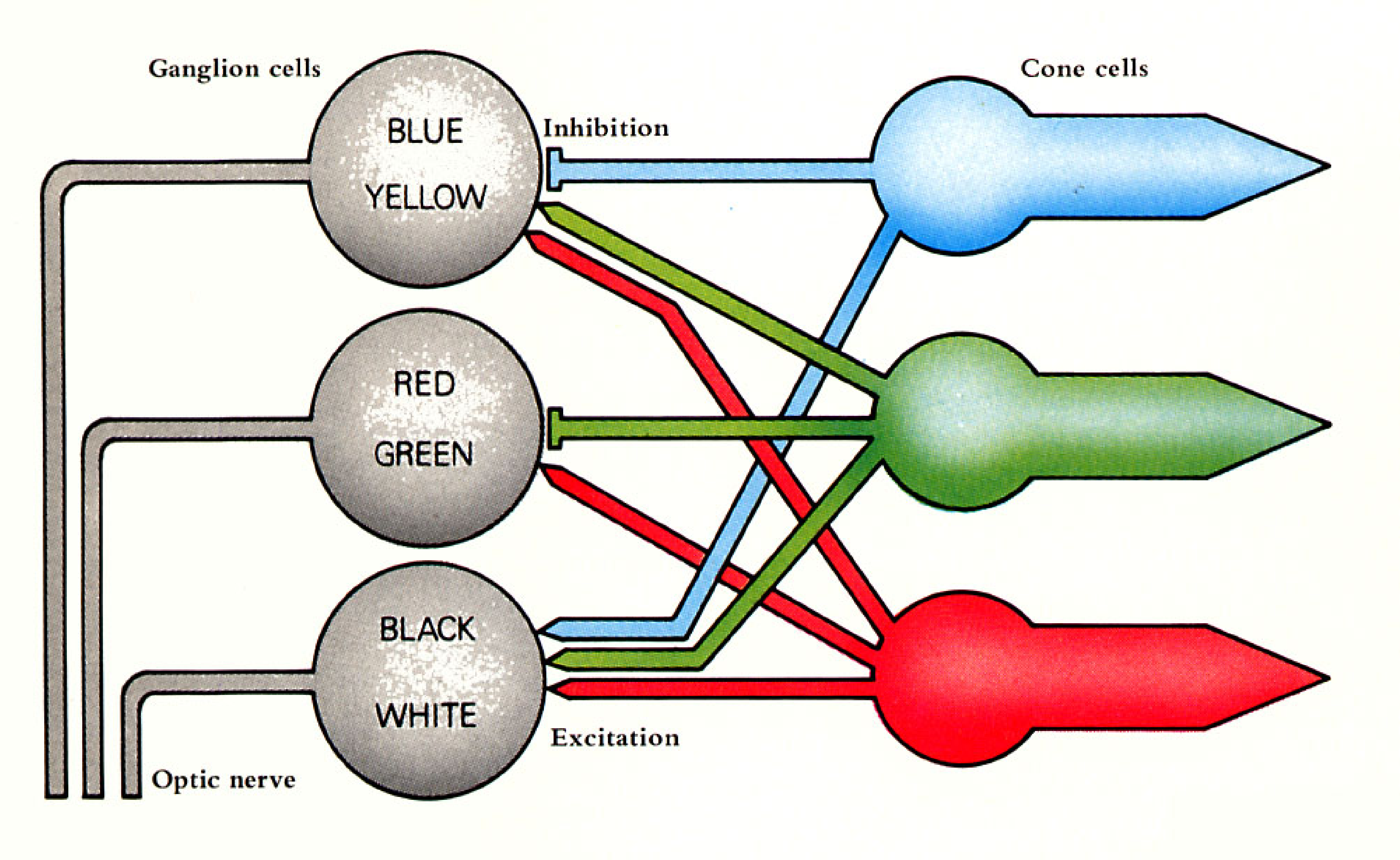
- Still **no proven model** of how color perception works.
- **Cones** contain light-sensitive pigments called Iodopsin.
- Iodopsin changes when light hits it -- it is photo-sensitive. Light is effectively converted/translated into a nerve impulse…a signal to the brain.

Trichromatic Theory & Opponent Theory

- 19th c. Trichromatic Theory first proposed the idea of *three types of cones*.
- Current theory -- *Opponent Theory* -- is that there are three types of iodopsin -- one that senses (or "sees") red light, one that sees green, and one blue-violet. Each is "blind" to its complement.
- We then combine the information from all three to perceive color.
- *We have mostly red- and green- sensitive cones – few blue-sensitive ones.*

Cones to Color

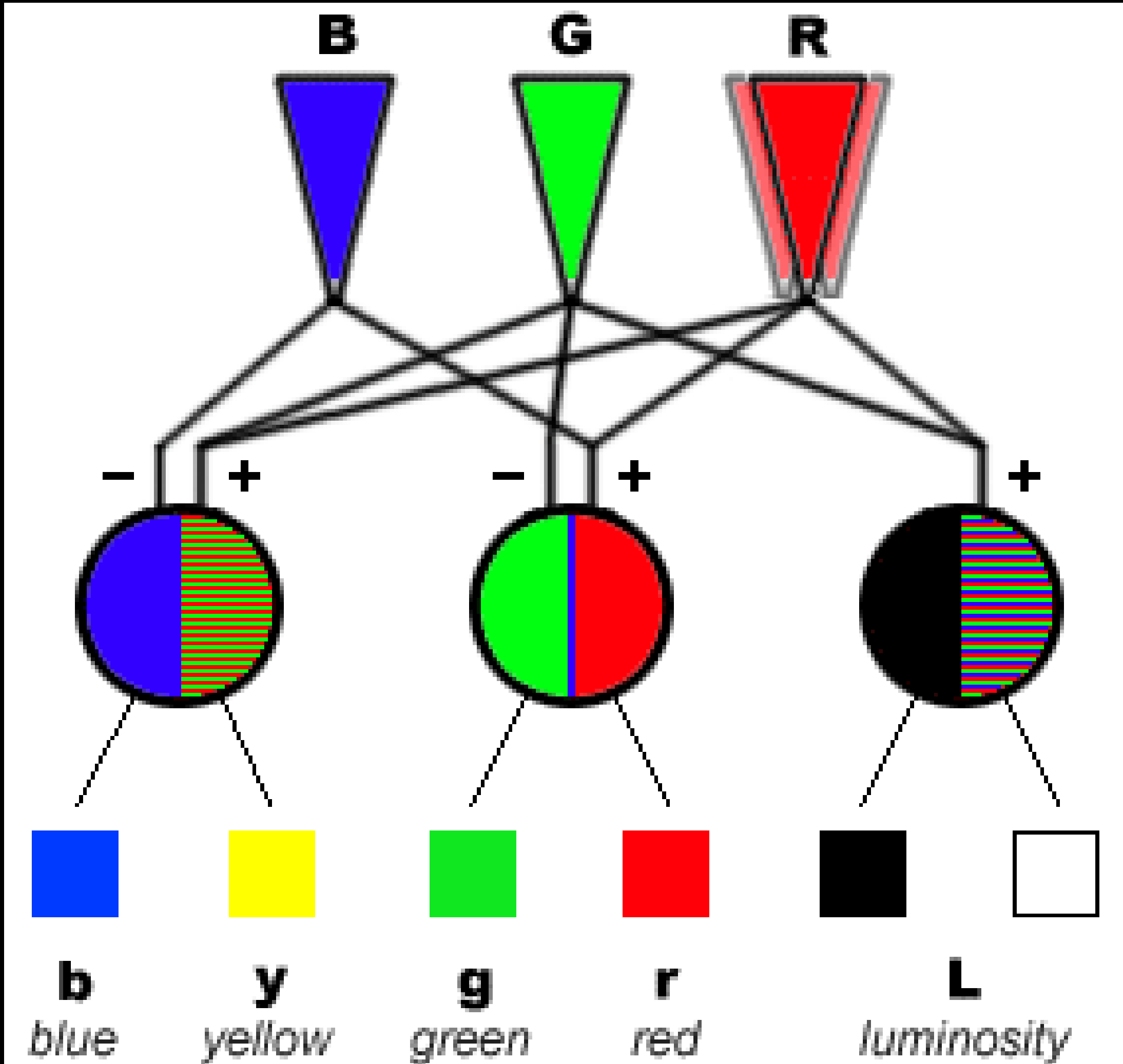
- Diagram of suspected "wiring" of cones to ganglion (nerve) cells.
- Light primaries are "read" individually, then results are combined.

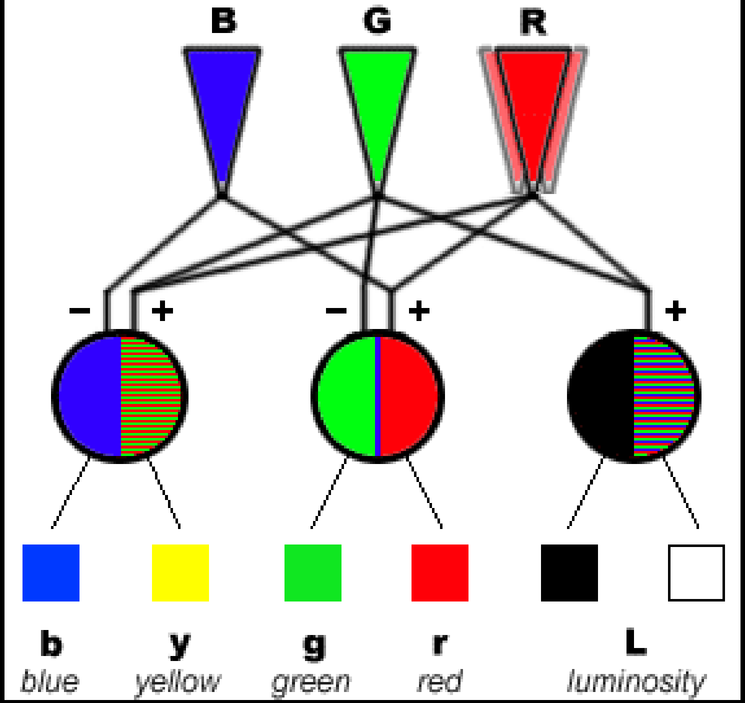


Cones to Color

- Diagram of suspected trichromatic “wiring” of cones to ganglion (nerve) cells.
- Light primaries are “read” individually, then results are combined.

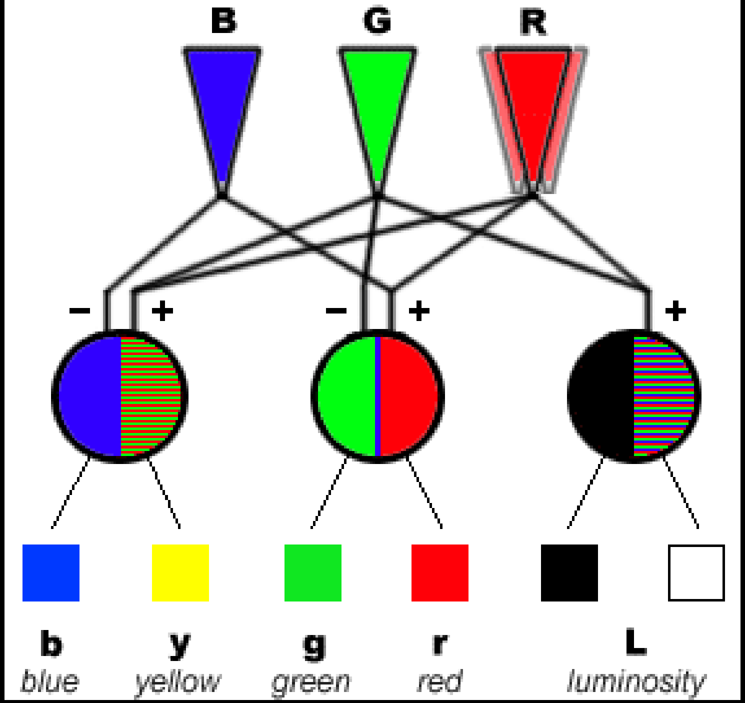
http://www.handprint.com/HP/WCL/color1.html





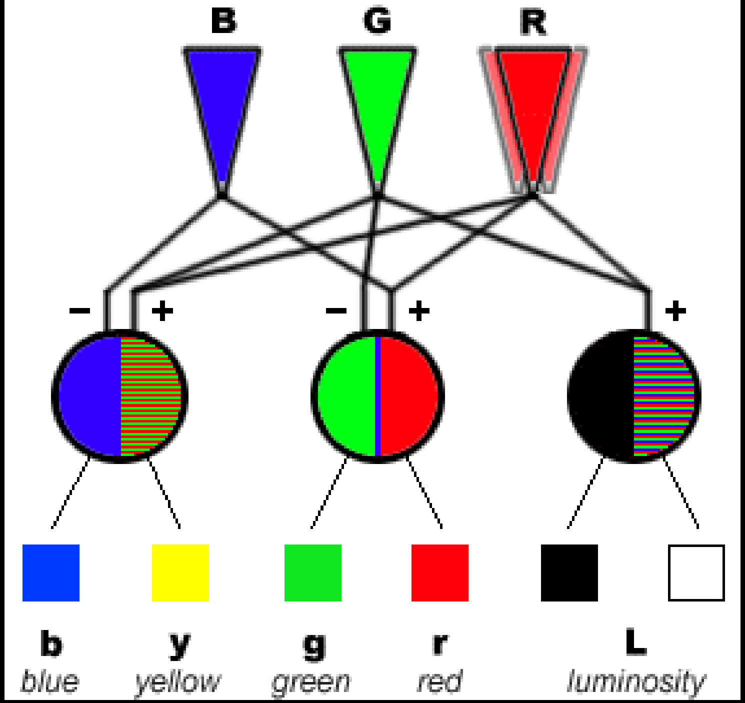
Opponent Processing

- "As the diagram shows, the opponent processing pits the responses from one type of cone against the others.
- "This transforms the raw R, G and B cone responses into **six separate channels** of visual information: four chromatic or color channels (shown as colored squares), and two achromatic (colorless) **luminosity** channels (shown as white and black squares)."
- http://www.handprint.com/HP/WCL/color1.html



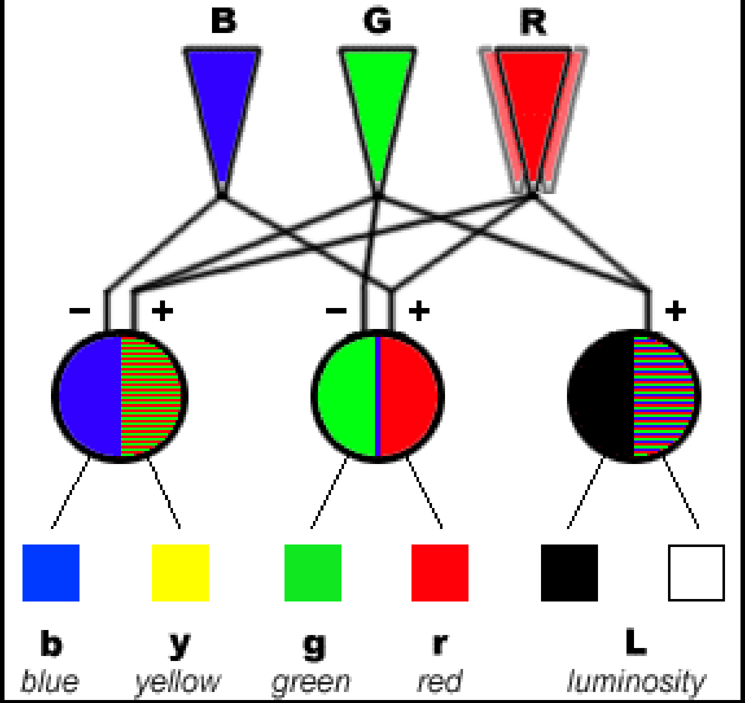
Opponent Processing

- "This retinal color circuitry can be summarized as a few **basic rules of color vision**:
- * The combined stimulation to the R and G cones (right circle) is interpreted as the **brightness** of lights or the **lightness** of a surface color. Luminosity is the **dominant visual information** recorded by the eye. (In scotopic or dark adapted vision similar brightness information is provided by the more numerous **rods**.)"
- http://www.handprint.com/HP/WCL/color1.html



Opponent Processing

- "The relative proportion of stimulation received by the R cones in contrast to the G cones (center circle) creates the perception of **red** or **green**. (The B cones contribute to the perception of **crimson and magenta** hues.)
- If the R and G cones are stimulated approximately equally (and much more than the B cones), we see the color **yellow**."
- http://www.handprint.com/HP/WCL/color1.html



Opponent Processing

- "The relative proportion of stimulation received by the B cones, in contrast to the R and G cones combined (left circle), creates the perception of **blue**.
- If all three types of cones are stimulated approximately equally, we see no specific hue — that is, we see **white, gray or black**, depending on the level of reflected light from a surface. (We never see direct light as gray, but as a **bright or dim light**.) "
- http://www.handprint.com/HP/WCL/color1.html

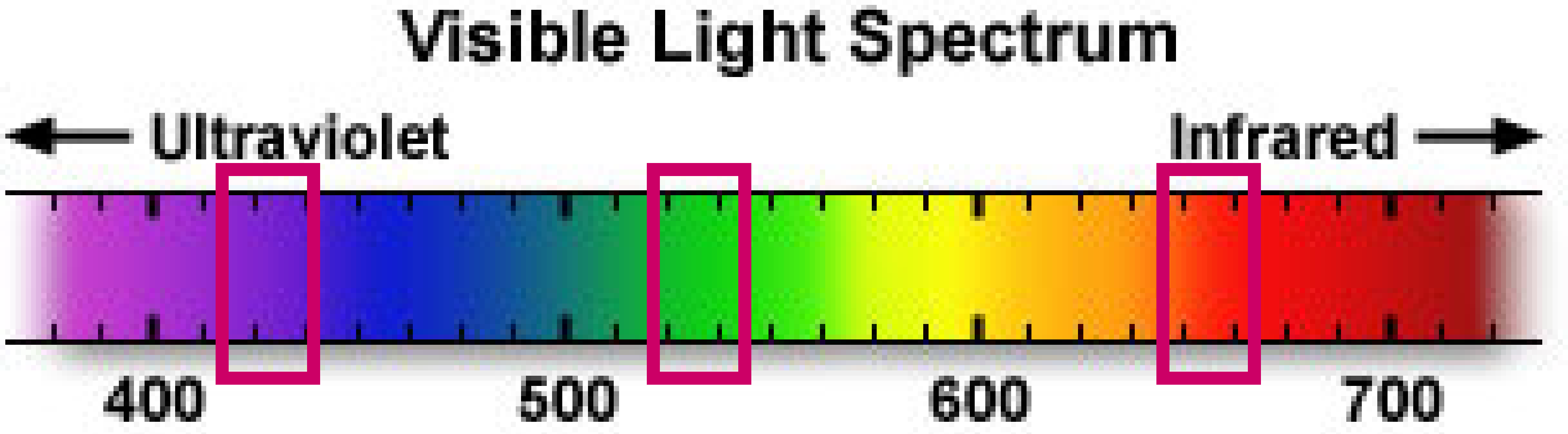
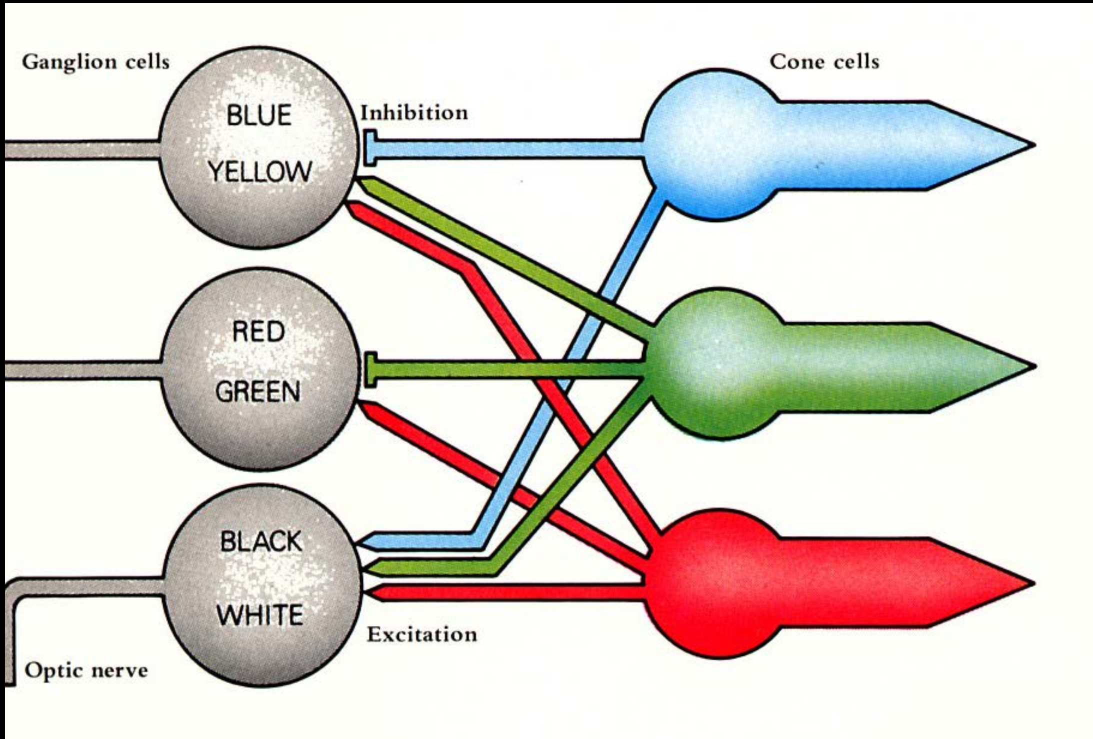
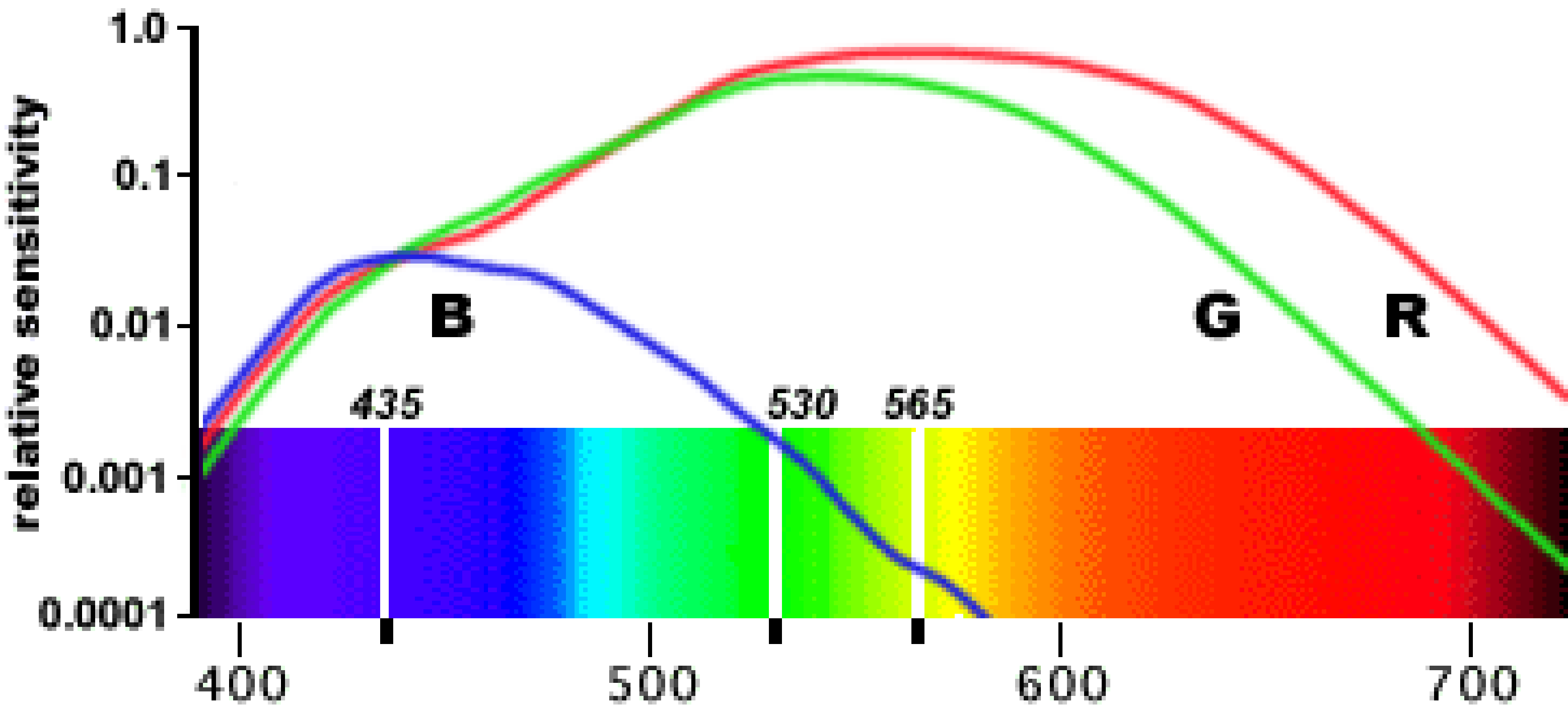


Figure 1

The pigments in the human eye/cones have peak sensitivities at about:
650 nm (red),
530 nm (green), and
425 nm (blue).

(light/additive primaries)



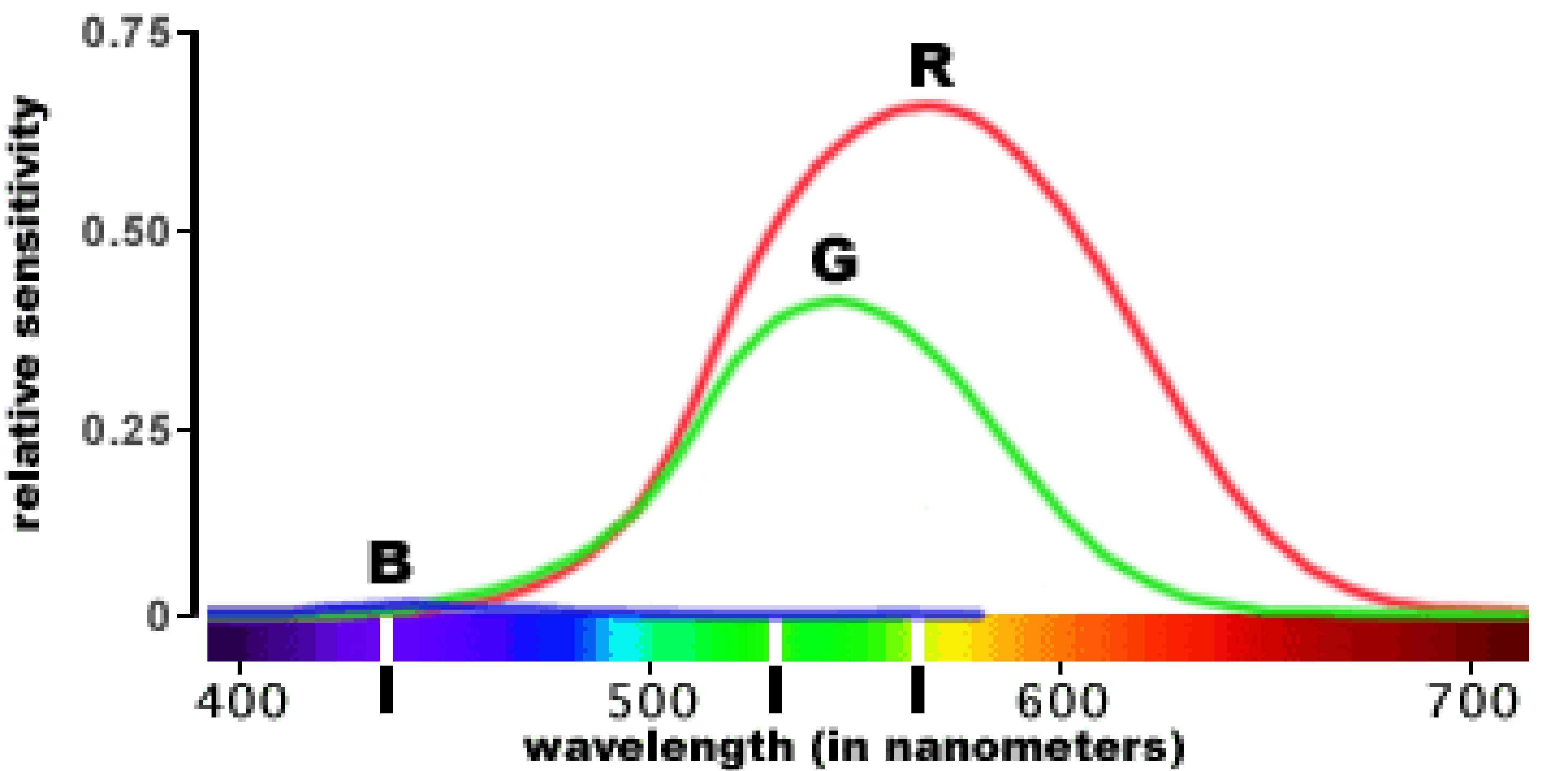


Wavelength Sensitivity of Cones in Human Eye

The curves show the cone responses for the three types of cones in the human eye: B, G and R.
Relative sensitivity curves for the three types of cones log vertical scale, cone spectral curves from "On the derivation of the foveal receptor primaries" by J.J. Vos and P.L. Walraven (1971) Vision Research 11, 799-818.

Note that the response curves largely overlap one another - in particular the R and G curves - which is the fundamental reason why there can be different choices when selecting and defining "primary" colors.

[NOTE **vertical logarithmic scale** -- amplifies the relatively insensitive B cone.]



relative sensitivity curves for the three types of cones
the Vos & Walraven curves on a ***normal*** **vertical scale.**

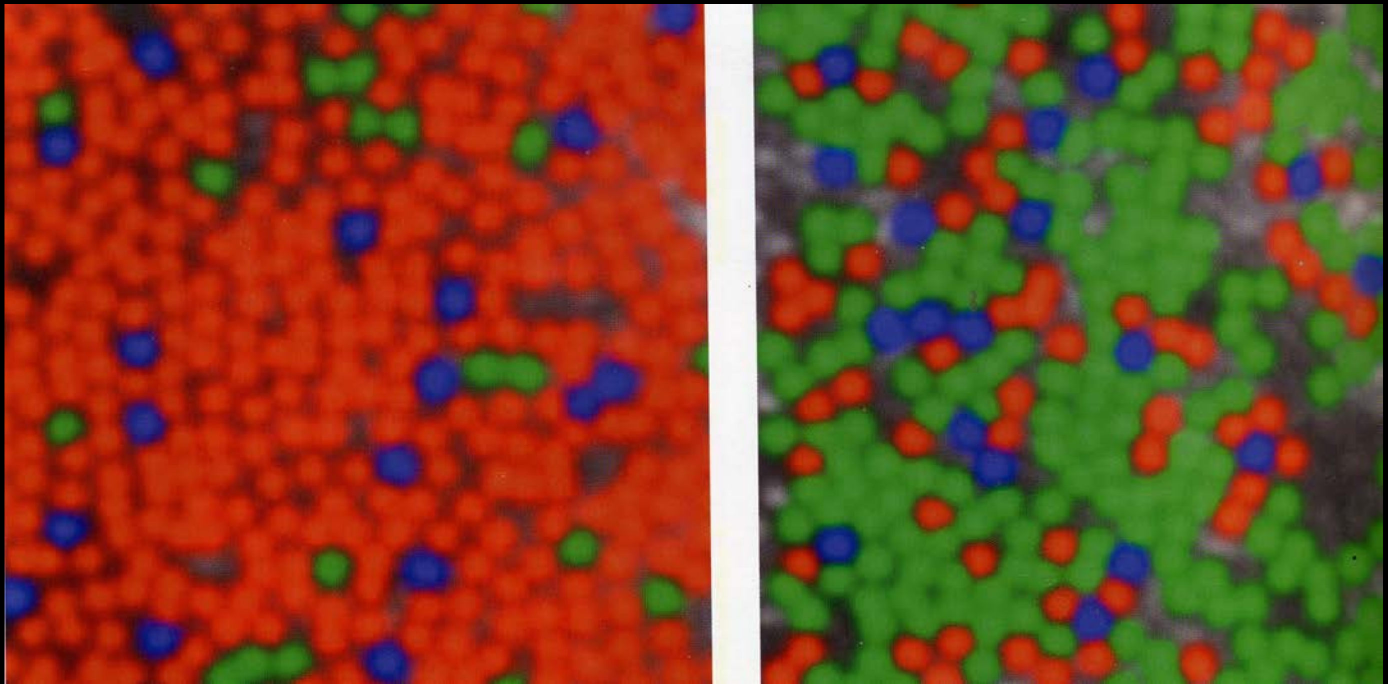
(compare to prior logarithmic scale)

http://www.handprint.com/HP/WCL/color1.html

Variations in Vision between People

- Researchers are able to shine light on living retinas to see where specific colors are absorbed, and where particular colors are reflected.

- Surprisingly, our eyes vary a lot — some of us have many red-sensing cones and few blue or green cones (left). Others have predominantly green-sensing cones.

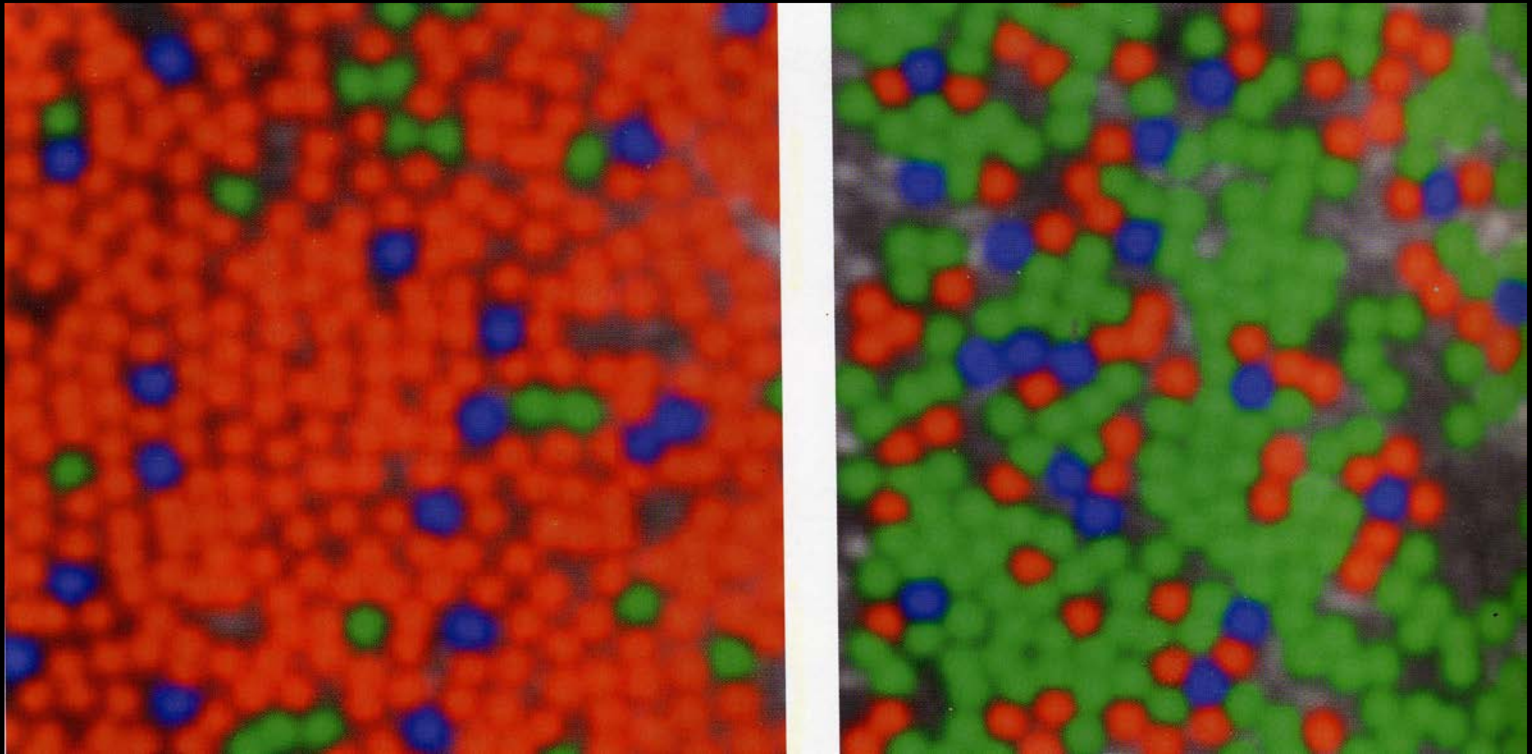


Color/6th ed.
P. 30

Variations in Vision between People

Still more surprising, we still have roughly the same color vision.

Varying sensitivity to hues, hue nuance and color blindness do occur. However, the dramatic differences in the quantity of cones are generally compensated for by the mind, enabling most of us to have similar vision.



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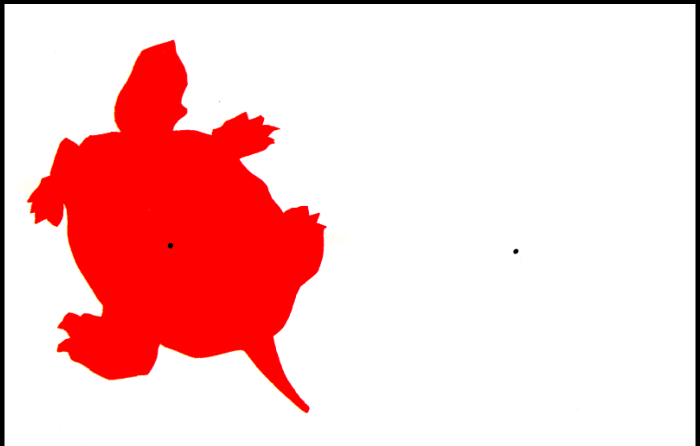
P. 30

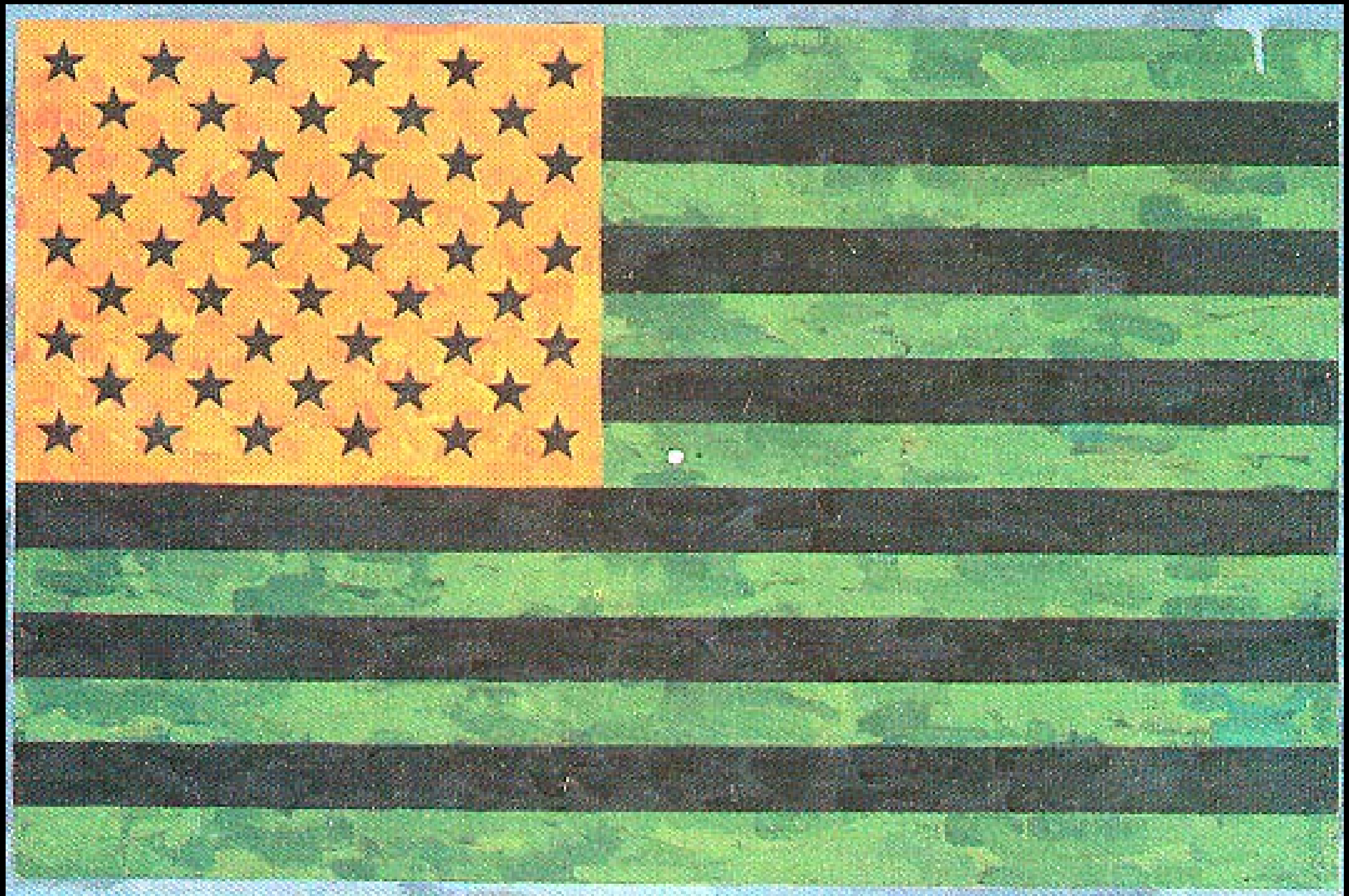
Exhausted cones and color After-Images.

- **Color after-images** involve seeing color that is not there…sort of.
- If you stare at one color for 15-30 seconds and then look at a white surface, you will see a color (hue, esp.) that is opposite the color you were looking at – that is, you will see the complement.



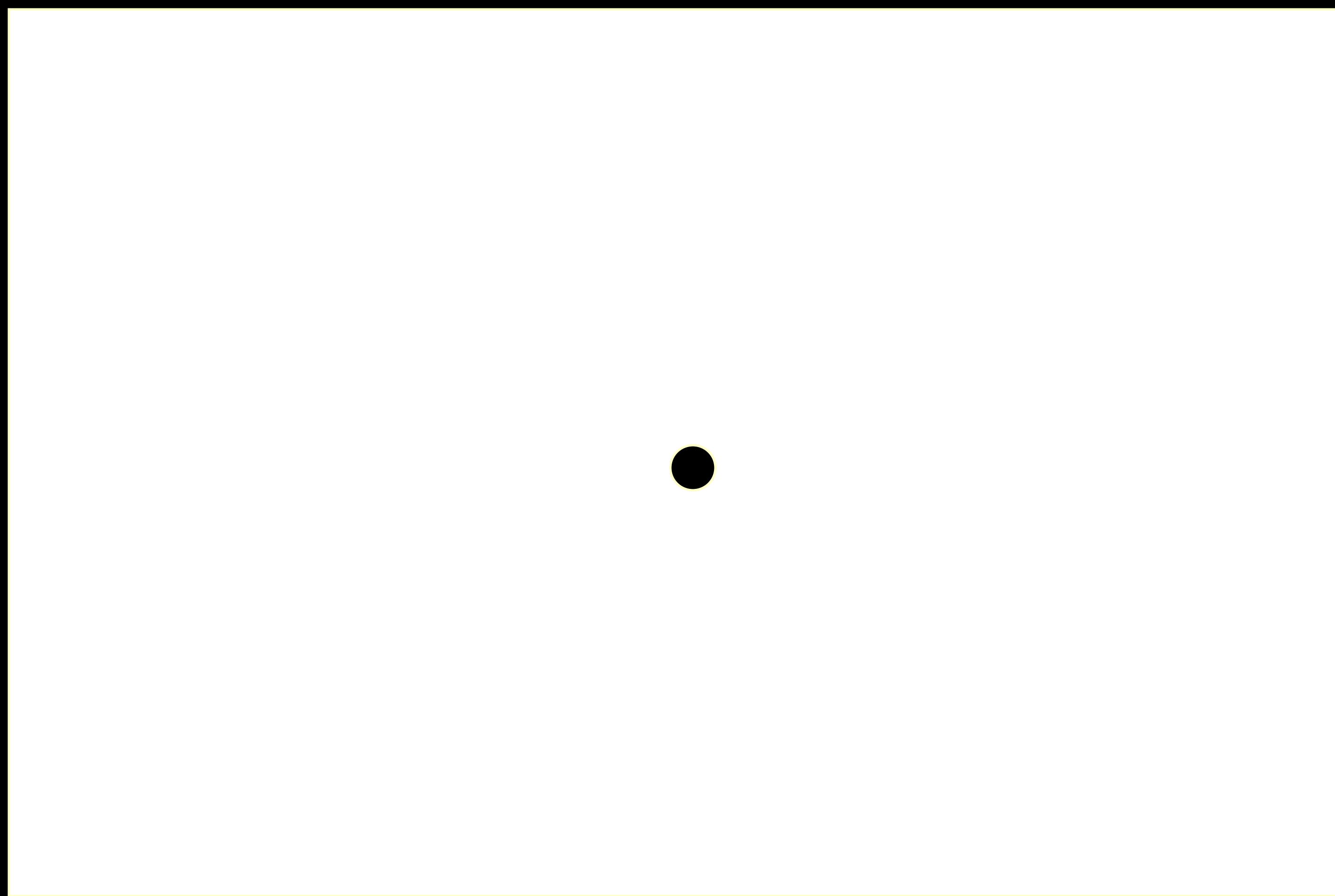
Exhausted cones and color After-Images.

- Stare steadily at dot for 30 seconds, then ....



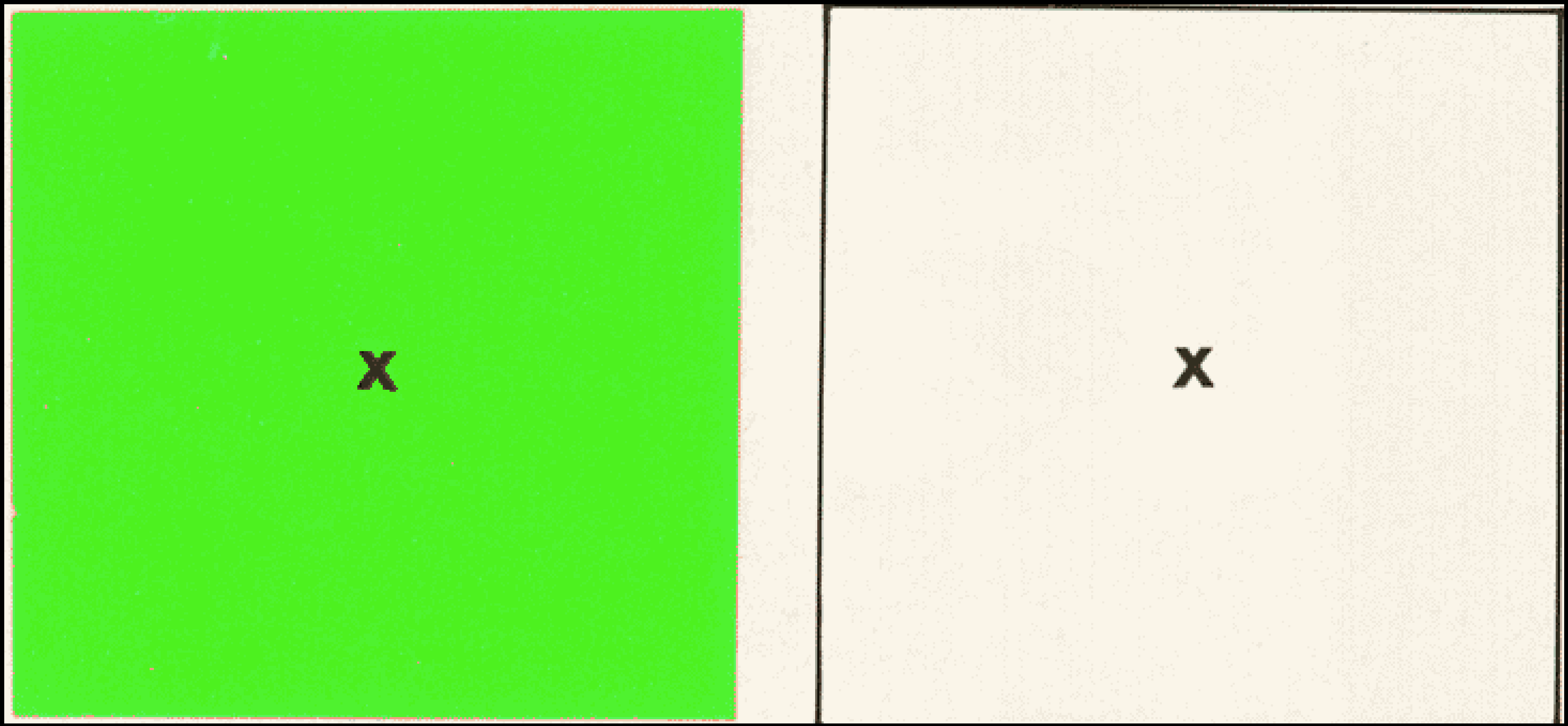
Exhausted cones and color After-Images.

- ….stare at dot.



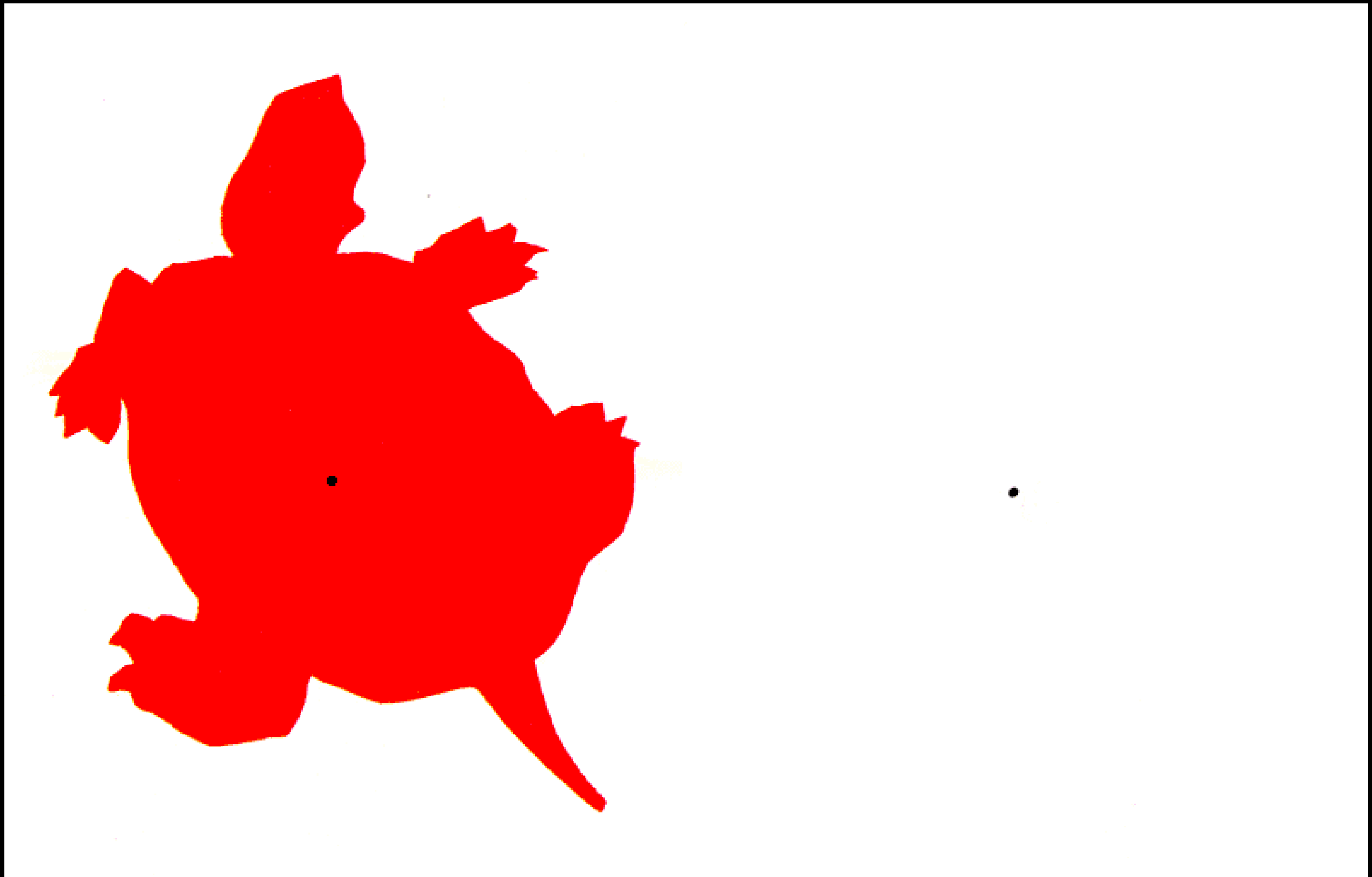
Exhausted cones and color After-Images.

- Stare steadily at green X for 30 seconds, then stare at white X.



Exhausted cones and color After-Images.

- Stare steadily at dot in red for 30 seconds, then stare at red dot in white.

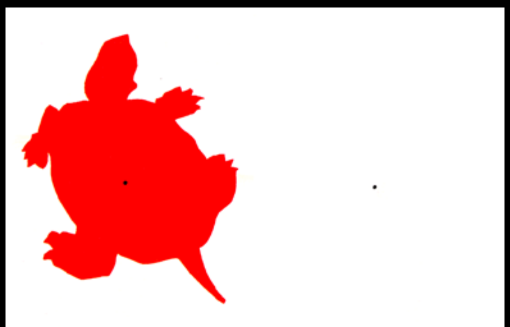


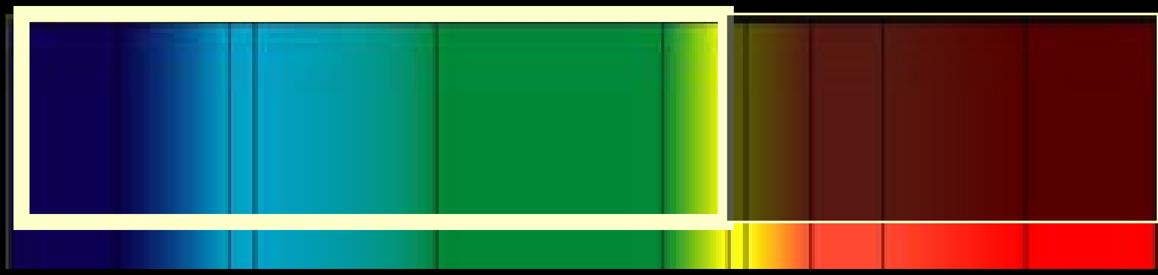
Exhausted cones and color After-Images.

- We speculate that the ability to see, for instance, a bright red color diminishes after staring at that bright red color.
- Our red-sensing cones get temporarily *exhausted* and can no longer see or sense red, but the blue-green that is also present in white light is still "read" by the eye.
  Thus blue-green —on a white surface —is the after-image.

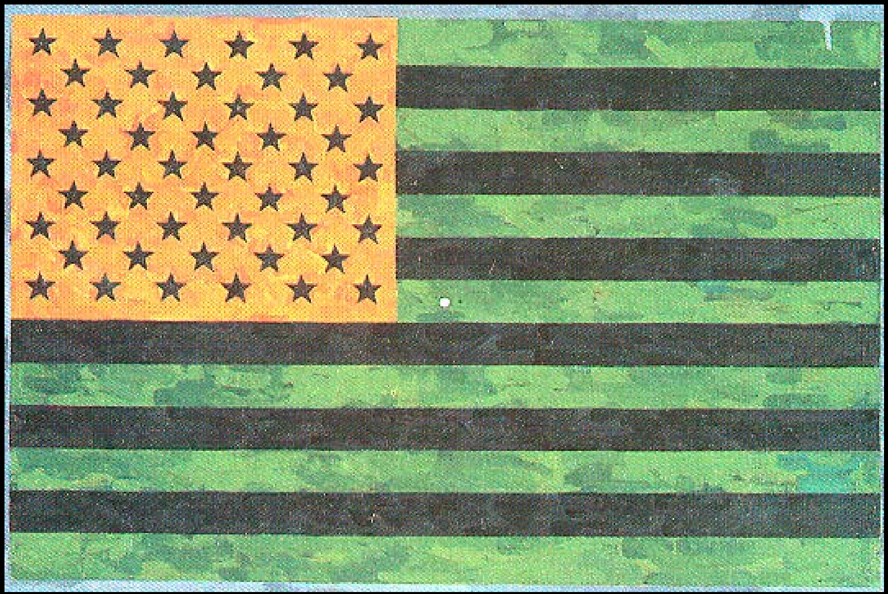
...Exhausted cones and color After-Image.

- When we then look at a white surface we are *receiving all* of the colors of light, but our eye can no longer *sense* the red, …
- ... *so* the *other* colors within the white light are seen ***MINUS*** the red. Thus we perceive the complement of red—a blue-green.





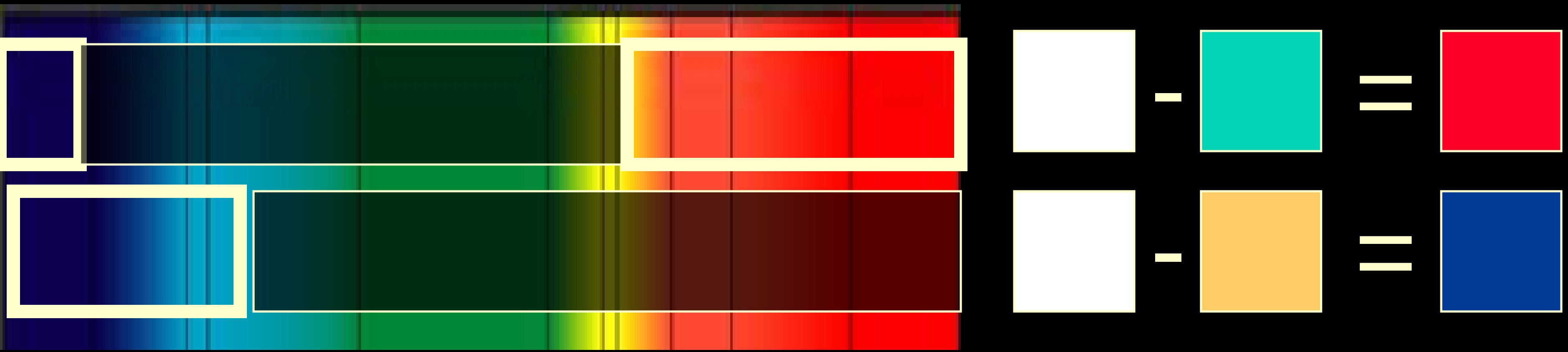
…Exhausted cones and color After-Image. (color arithmetic)



- When your eye is exhausted by staring at green, your cones can no longer “report” green…

  …but white light is coming at you…

- Your cones “announce” the unexhausted Red *in* the white. So you “see” the red, but *not* the “unreported” green.



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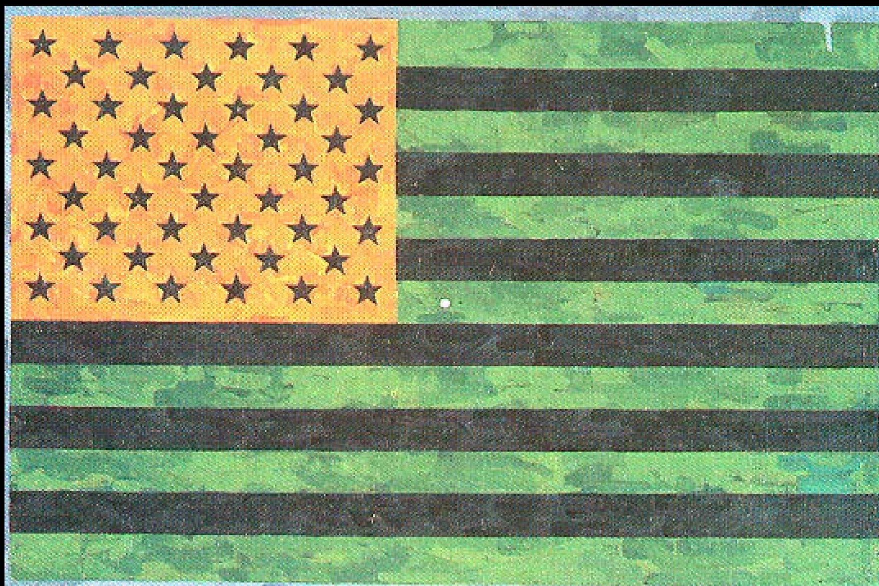
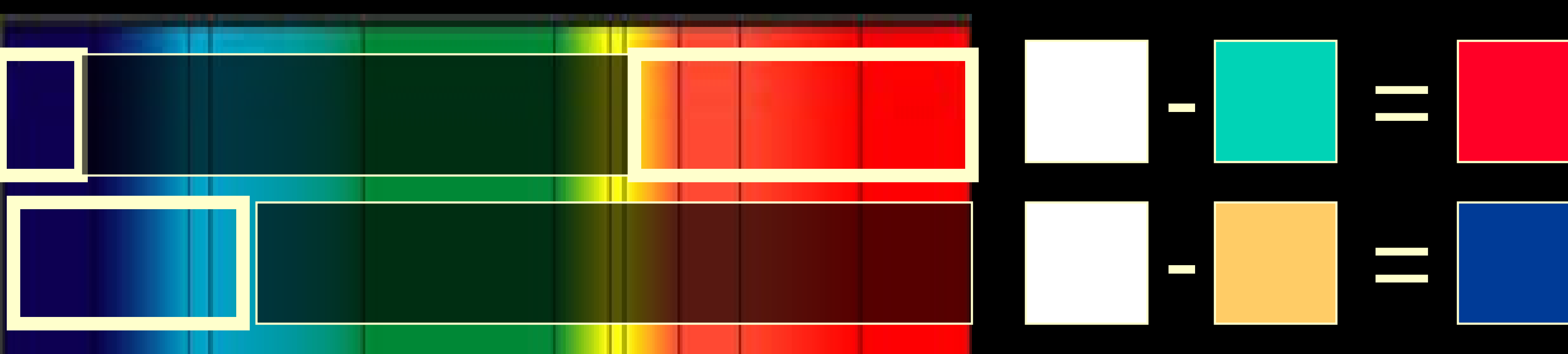


- When your eye is exhausted by staring at YO, your cones can no longer “report” YO…

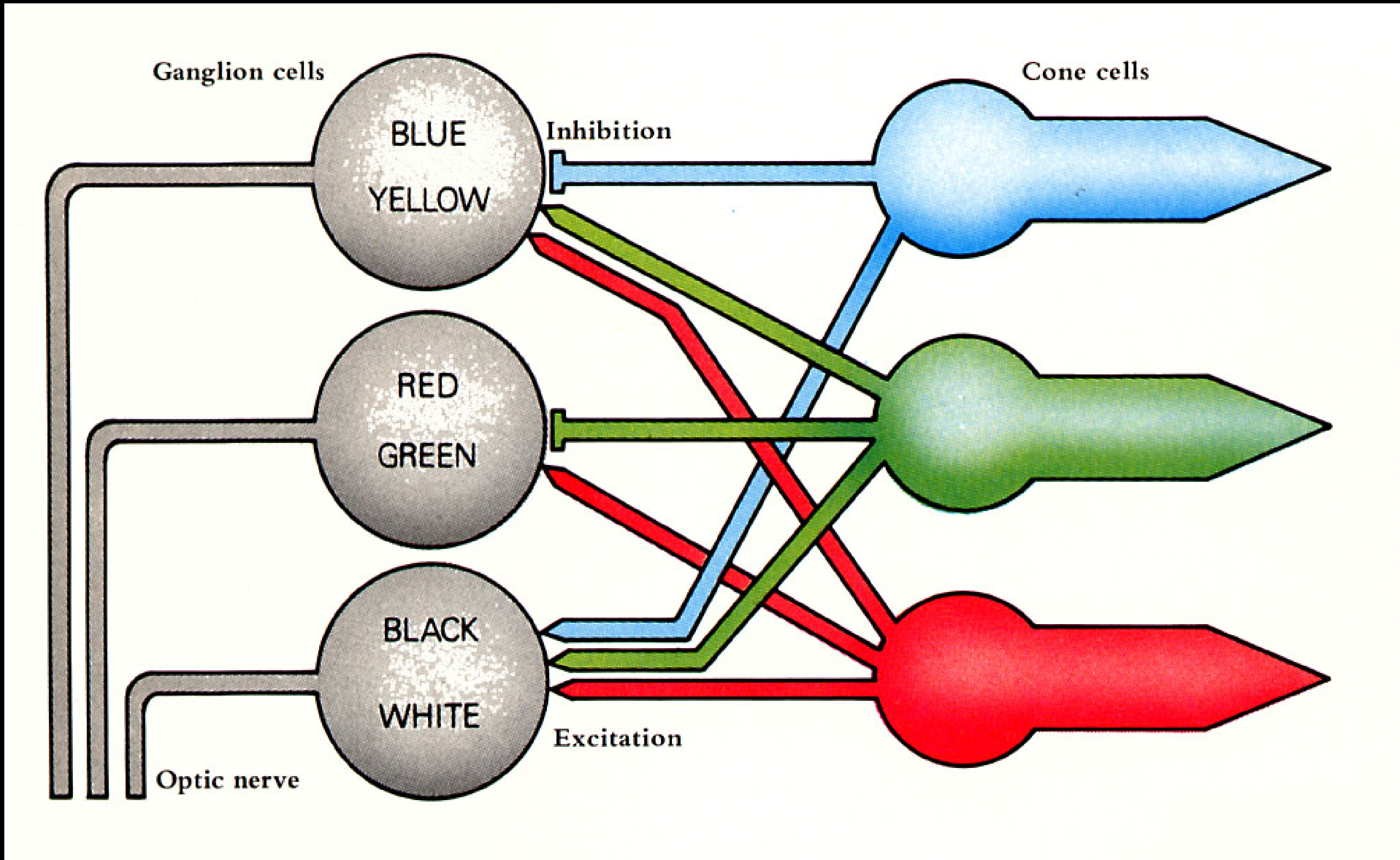
  …but white light is coming at you…

- Your cones “announce” the unexhausted Blue *in* the white. So you “see” the Blue, but *not* the “unreported” YO.



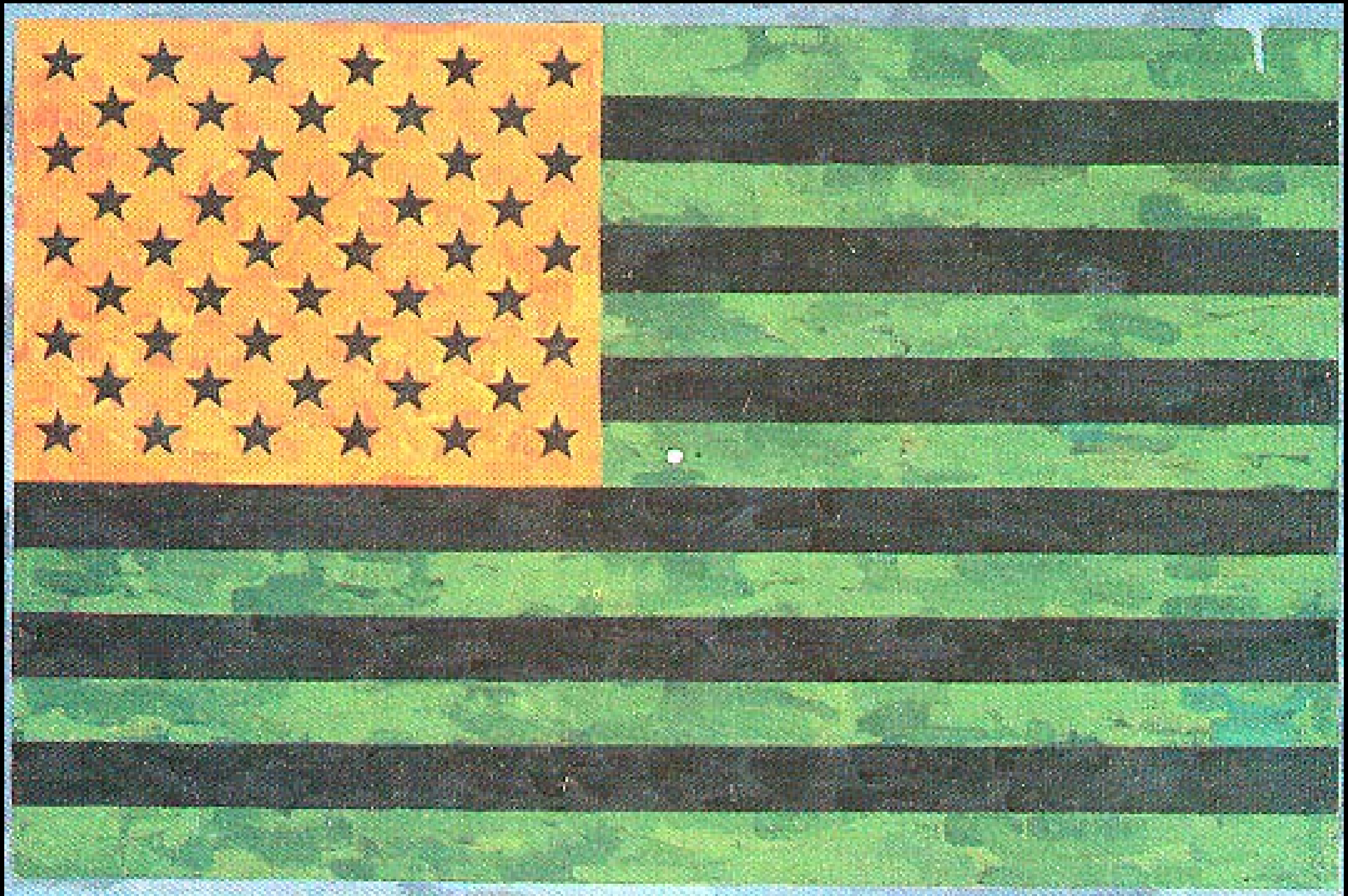
Cones to Color

- 3 Light primaries are “read” individually (Trichromatic vision/Theory),
- …then results are combined by the Ganglion cells (Opponent vision/theory)



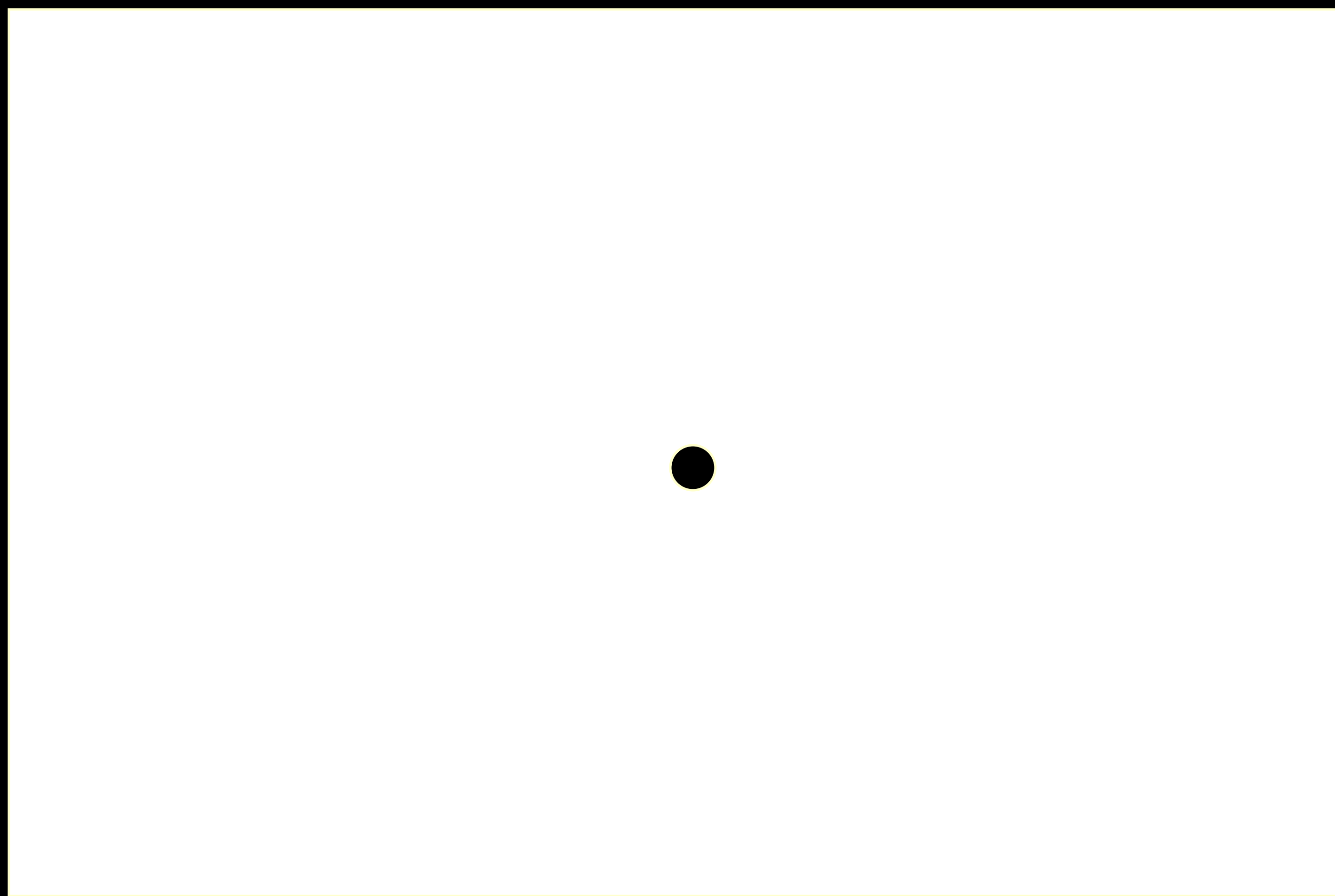
Jasper Johns flag

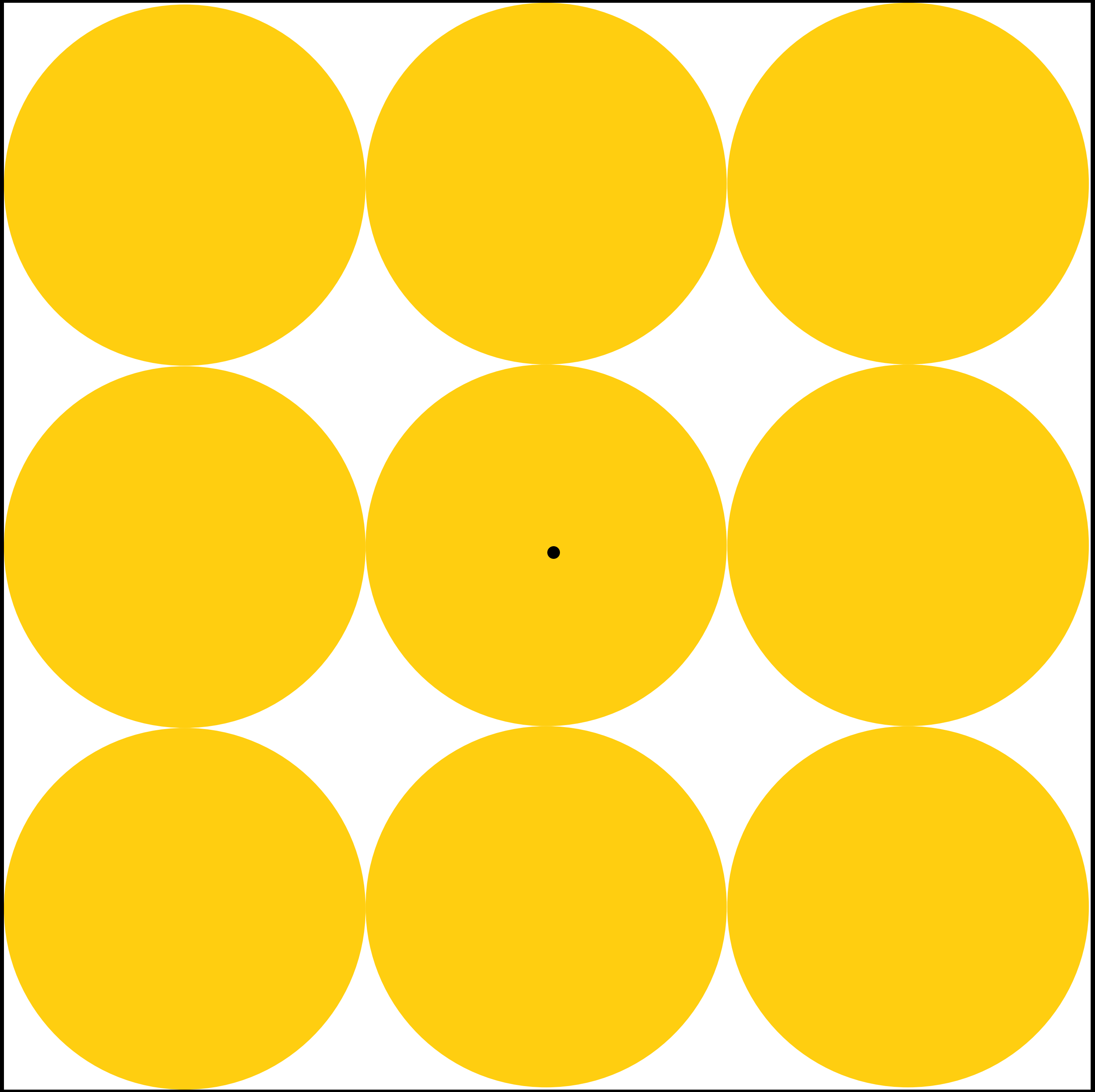
- Why does this work?
- Cones (iodopsin) gets exhausted.
- “exhausted” colors can no longer be seen in white light.
- Color afterimage (subsequent contrast)



Exhausted cones and color After-Images.

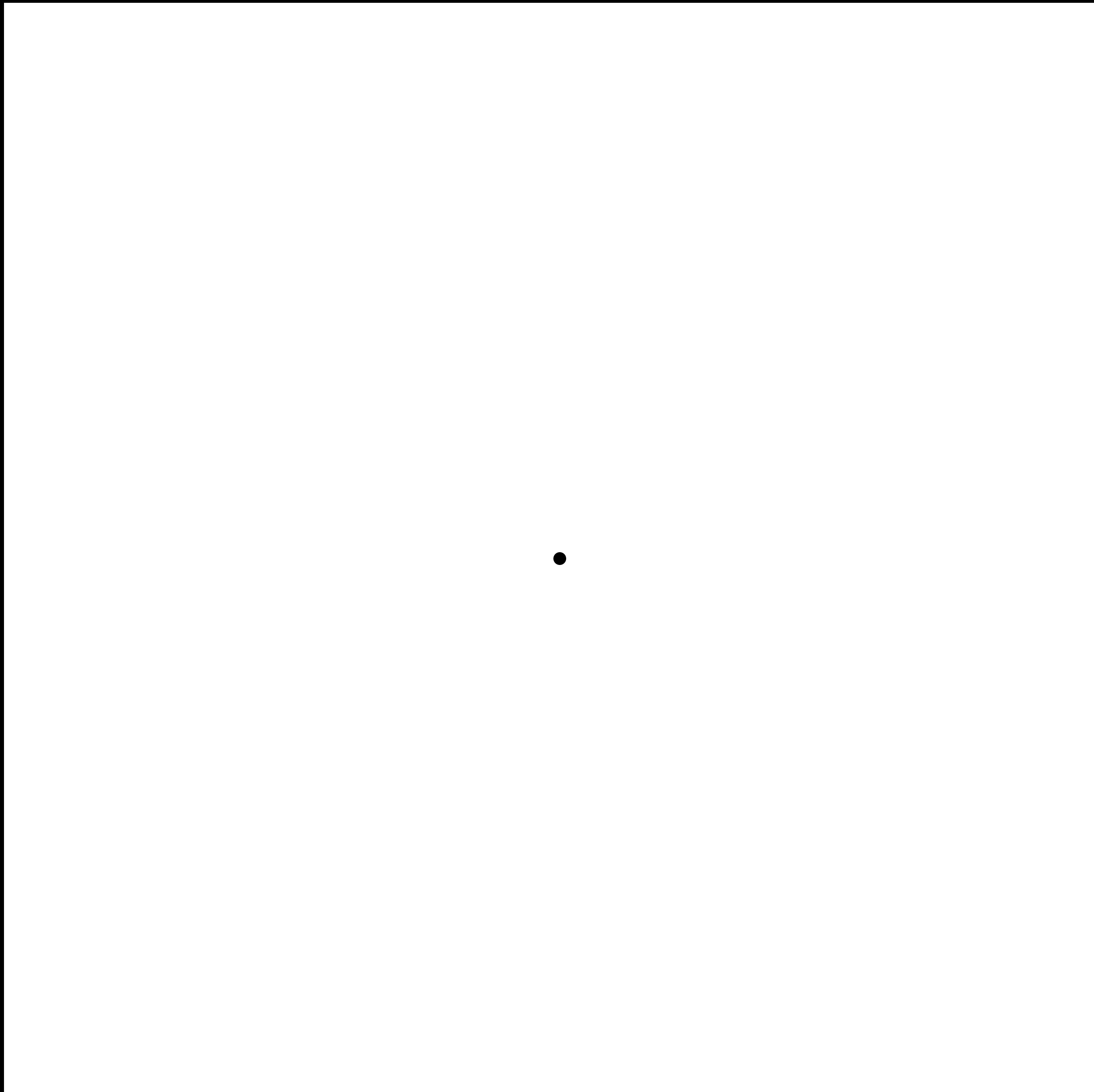
- ….stare at dot.





Joseph Albers explored, theorized and taught color at Germany’s pre-war Bauhaus, and then at Yale.

He used this diagram to explore still another odd effect related to color-afterimage.



What do you see?

You may expect to see circles opposite yellow — blue-violet circles.

But what is in between them?

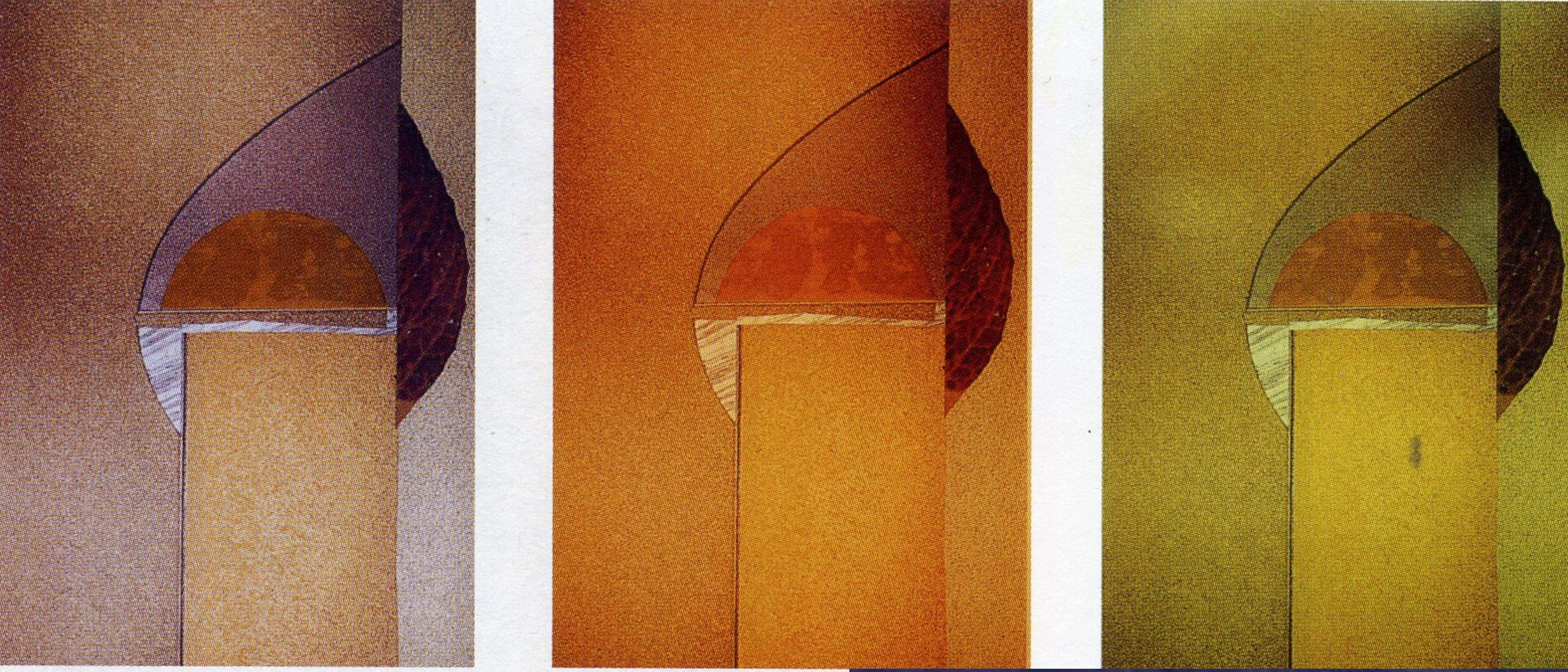
Color Constancy

- Another largely unexplained color-perception phenomena.
- When the color of general lighting changes gradually, we do not normally notice the shift in hue, but adjust to the colored illumination and continue to see natural or local colors as though normal white-balanced illumination were present.

Color Constancy

- Late-day photos and photos under mis-matched artificial lights record the distorted color that our minds compensate for.
- We have a sort of "auto-white-balance" — as do most digital cameras.

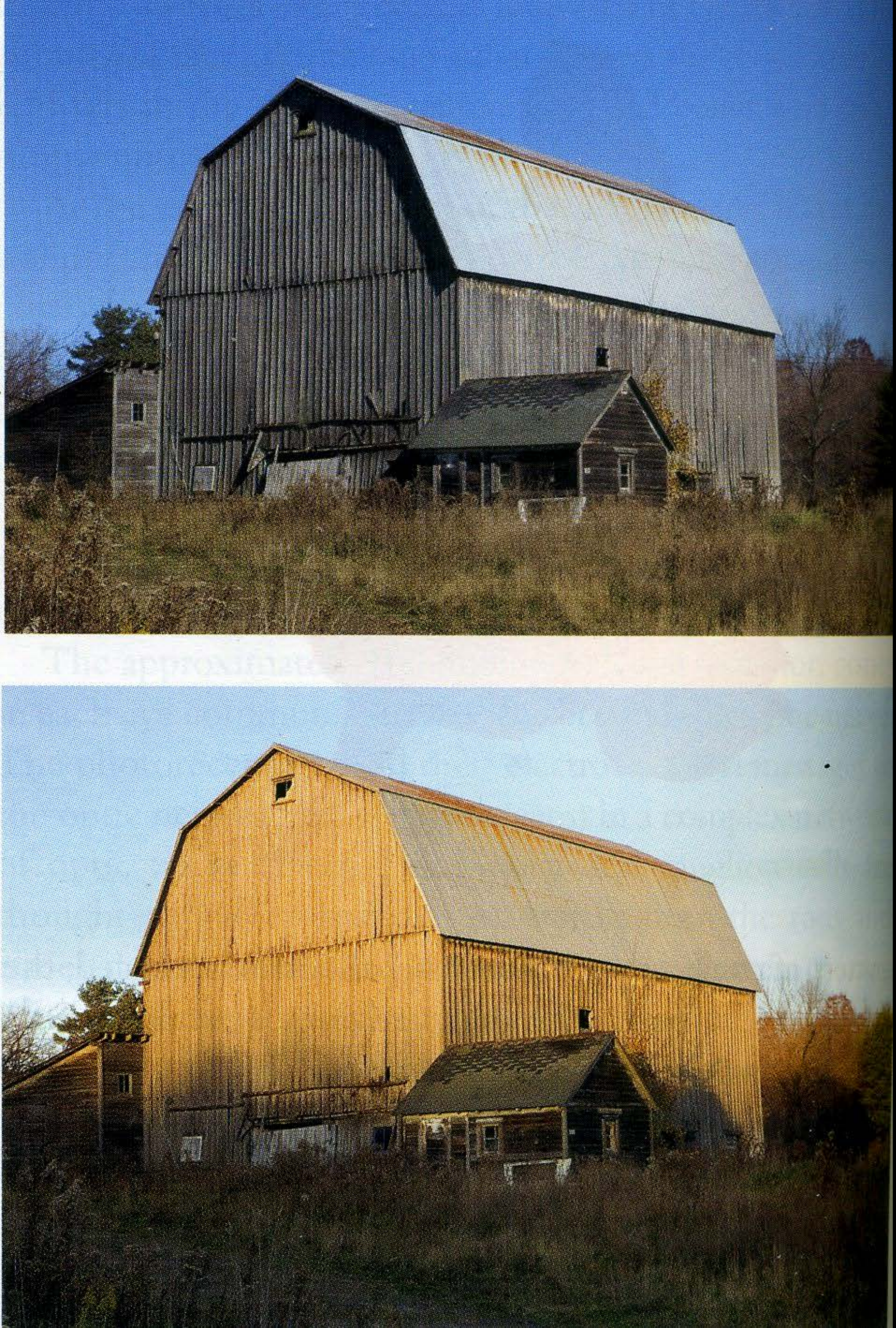
http://www.schorsch.com/kbase/glossary/adaptation.html



- Photos of the same object taken under:
- **Daylight**
- **Incandescent Tungsten light**
- **Fluorescent light**
- A film camera with daylight film was used.

Source	Color Temperature	
Computer Monitor	9300 K (adjustable)	Bluer
Average Daylight	6500 K	
Television Monitor	6500 K	
Cool White Fluorescent	4300 K	
Tungsten Lamp	2800 K	Yellower
Sunlight at Sunset	2000 K	

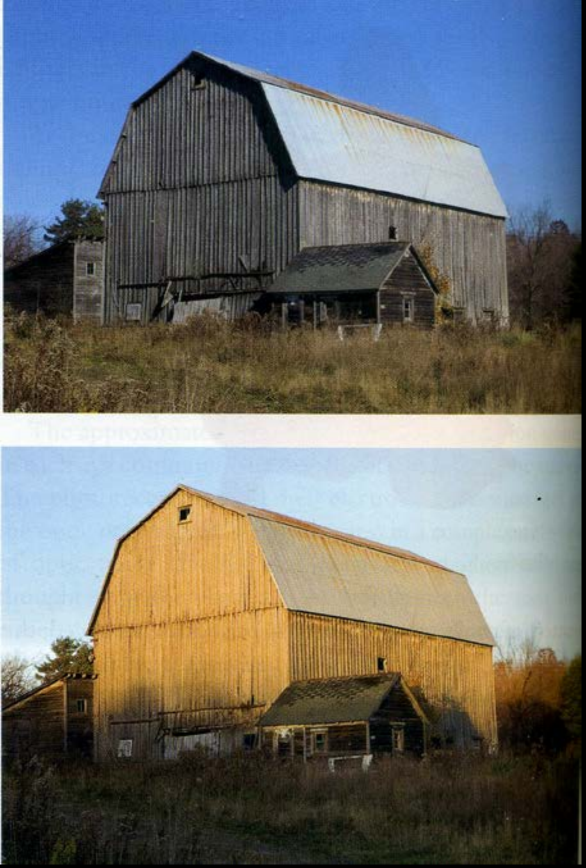
K = Kelvins



Color Constancy

- "A camera will reveal that a building looks bluish in the morning and reddish in later afternoon, because of different lighting effects. By contrast, ***humans tend to perceive the building as if its color were constantly that which is perceived in white midday sunlight.*** …observers' brains tell them that the building is actually grayed wooden siding as it appears in the white noon light.
  Color Constancy
- *Color*, 6th ed. P. 29

Why Color Constancy?



Why do humans need colour constancy?

Vision scientists generally assume that colour constancy is there ***to aid object recognition***.

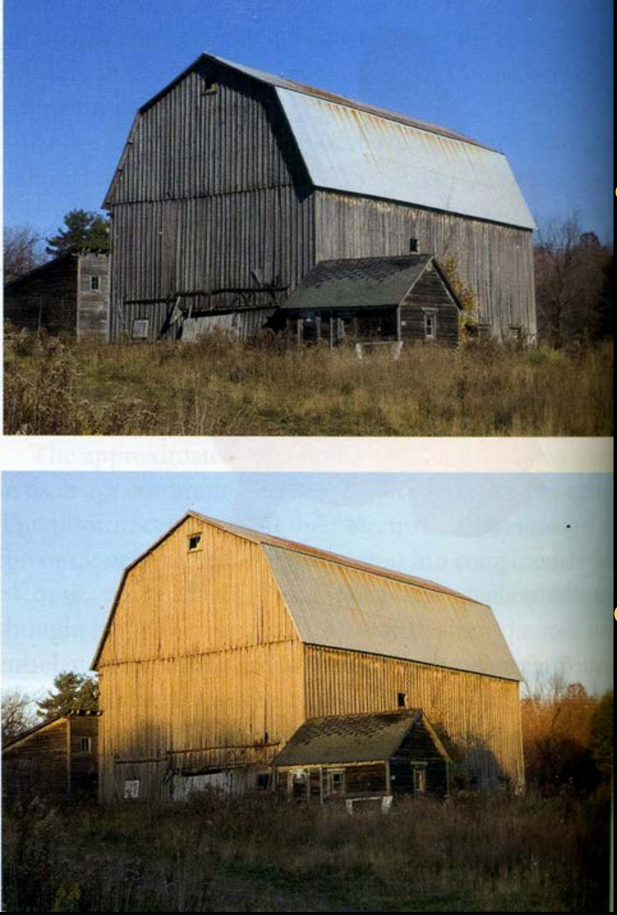
Without colour constancy, colour would be an unreliable cue to object identity: your favourite coffee mug would change from pale green to grey at the flick of a switch; your rental car would be unrecognisable in the evening glow.

But there is no proof that colour constancy is essential for object recognition; the role of colour itself, with or without constancy, is not fully understood.

Some studies suggest that the super-fast initial stages of object recognition bypass colour completely, relying on shape only.

Current Biology
Volume 17, Issue 21, 6 November 2007, Pages R906–R907

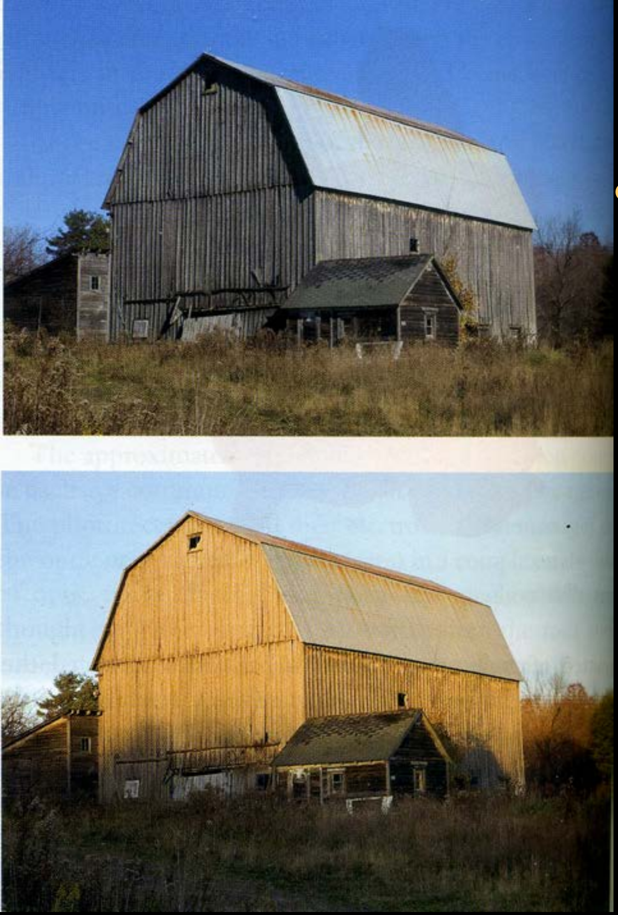
Color Constancy



- "Color constancy is the most important property of the color system," declares neurobiologist Semir Zeki of University College, London.

- "Color would be a poor way of labeling objects if the perceived colors kept shifting under different conditions, he points out. But the eye is not a camera. Instead, the eye-brain pathway constitutes a kind of computer—vastly more complex and powerful than any that human engineers have built—designed to construct a stable visual representation of reality."

http://www.hhmi.org/senses/b140.html



Color Constancy

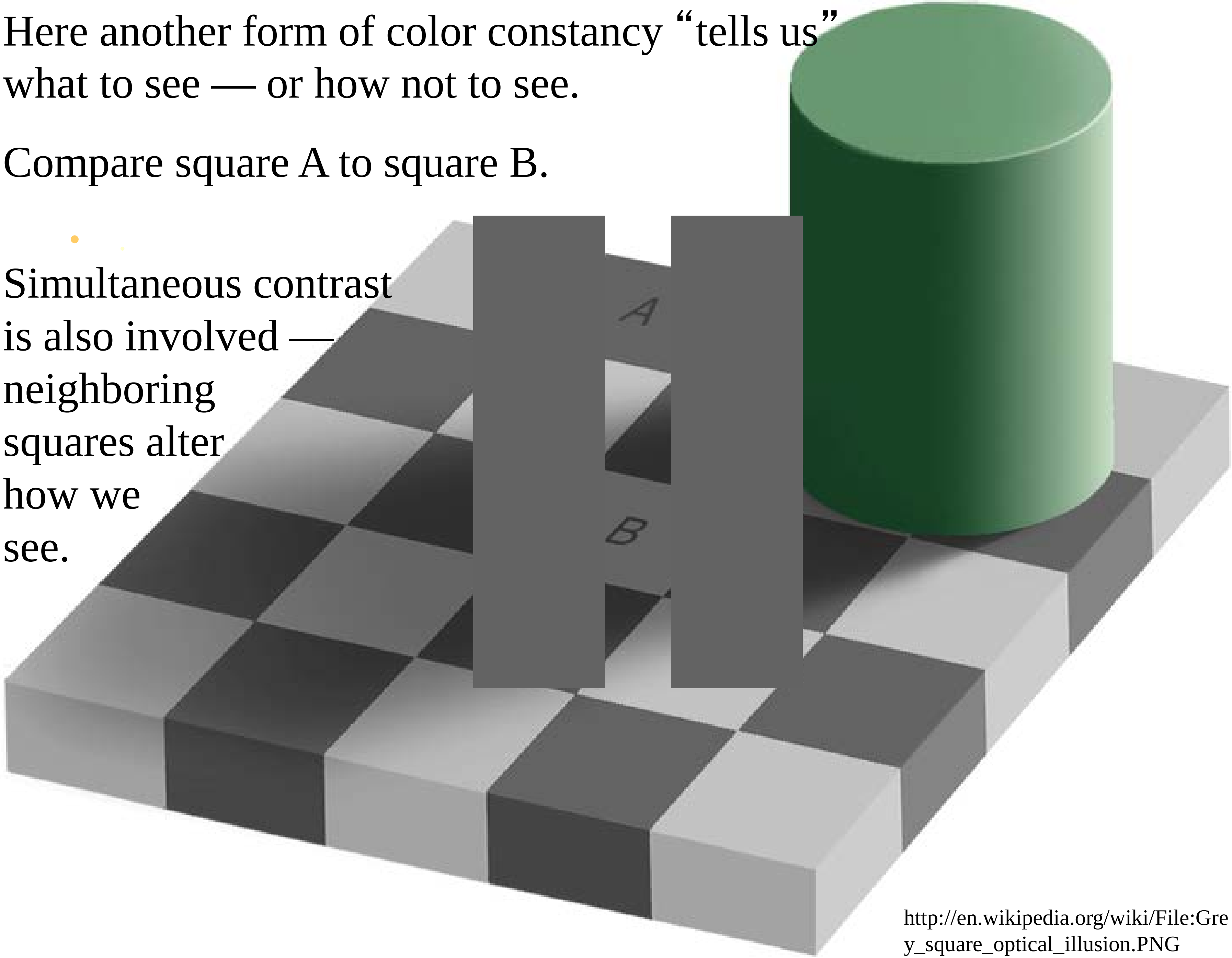
- "The key to color constancy is that we do not determine the color of an object in isolation; rather, the object's color derives from a comparison of the wavelengths reflected from the object and its surround.
  “In the rosy light of dawn, for instance, a yellow lemon will reflect more long-wave light and therefore might appear orange; but its surrounding leaves also reflect more long-wave light. The brain compares the two and cancels out the increases.”

http://www.hhmi.org/senses/b140.html

Here another form of color constancy “tells us” what to see — or how not to see.

Compare square A to square B.

Simultaneous contrast is also involved — neighboring squares alter how we see.



http://en.wikipedia.org/wiki/File:Grey_square_optical_illusion.PNG

Monet's Explorations of Illumination

- Monet consciously "overrode" his natural habit of color constancy to perceive the rich changes in color caused by the changing color of sunlight throughout the day and in varied weather. Many of his series of painted explored these variations.
- "This is what I was aiming at: first of all, I wanted to be true and accurate (to the)… air and light, which constantly change."

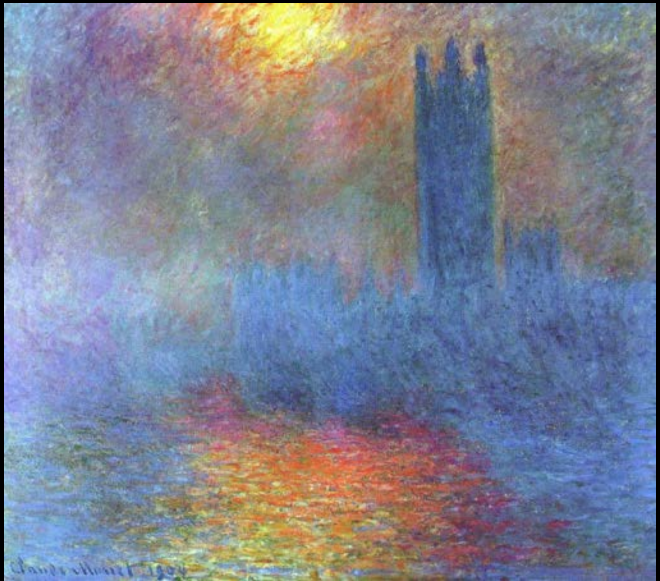
Monet: overriding color constancy

"In his serial paintings of Rouen Cathedral, Monet portrayed dramatic changes in the colour of its western facade as the day progressed, from the misty blue of early morning to the orange-gold of evening.
An ordinary observer would not perceive this shift to nearly the same extent, because of the phenomenon of colour constancy, a fundamental stabilising mechanism that compensates for changes in the colour of the light source in order to keep object colours constant.
Monet's skills were not just in putting paint on canvas, but also in knowing how to disable this hard-wired feature of the human visual system.

Current Biology
Volume 9, Issue 15, 12 August 1999,
Pages R558–R561

Monet's Explorations of Illumination

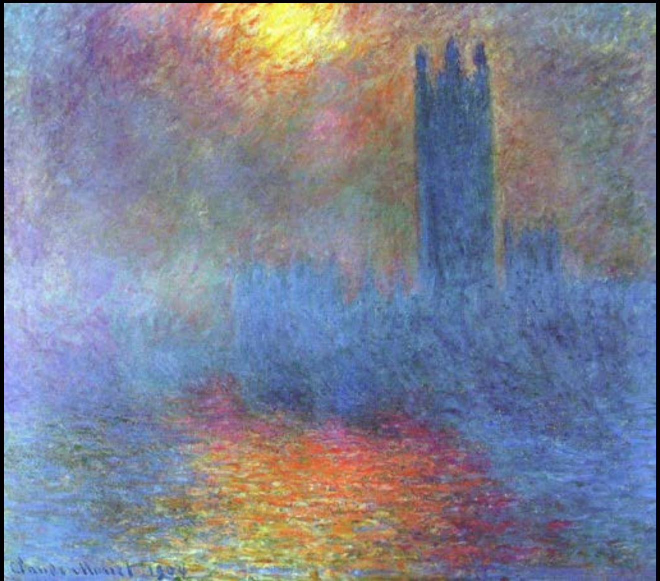
"I wanted to *be true and accurate*. For me, a landscape does not exist as a landscape, since its appearance changes at every moment, but *it lives according to its surroundings, by the air and light, which constantly change*." Claude Monet



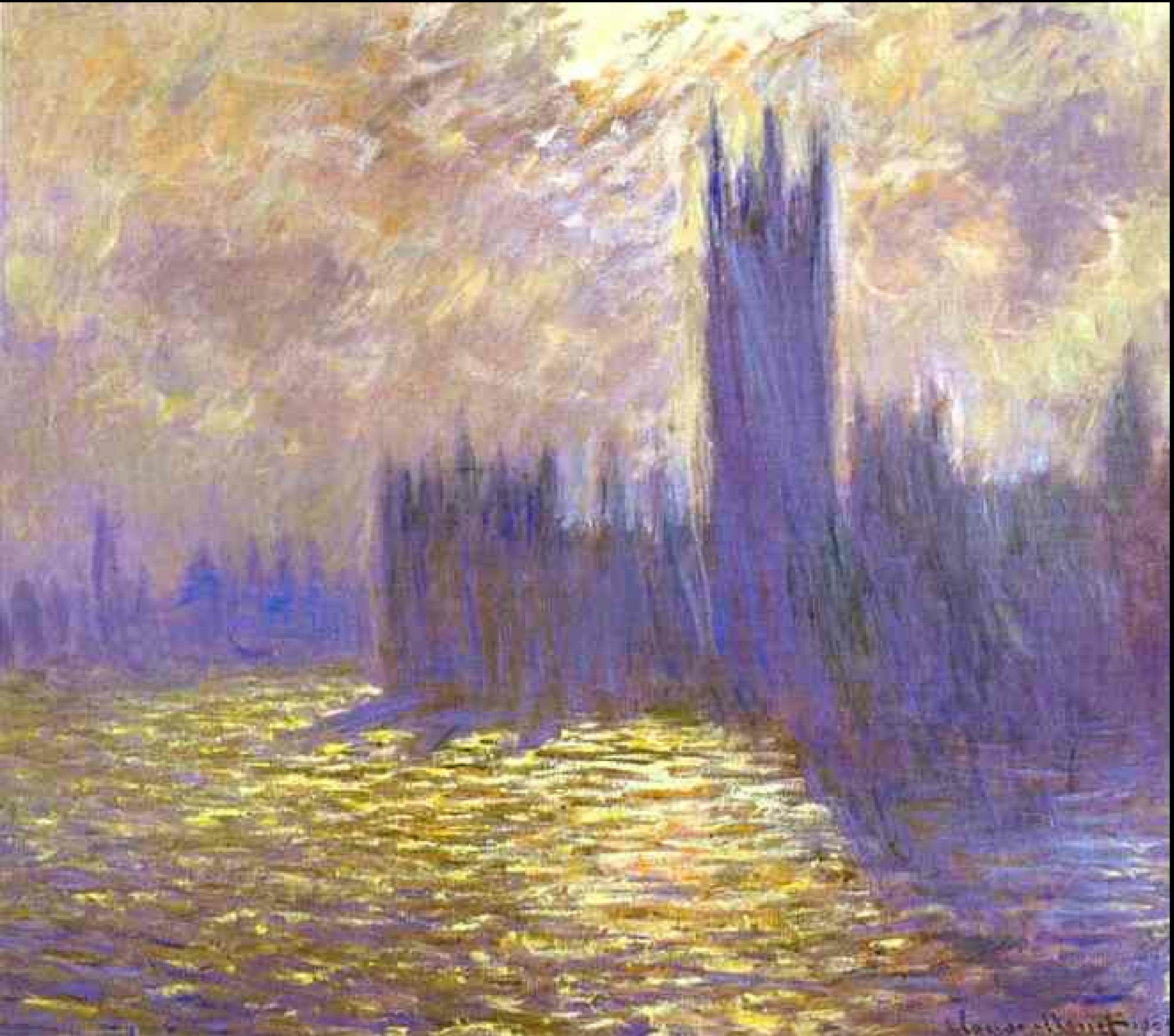
Monet's Explorations of Illumination

He repeatedly painted the same scene, switching canvases every hour or so, as the daylight changed.

Over a period of months, he would complete many images different only in their color scheme – due to different illumination.



Monet: Houses of Parliament (across the Thames, London)



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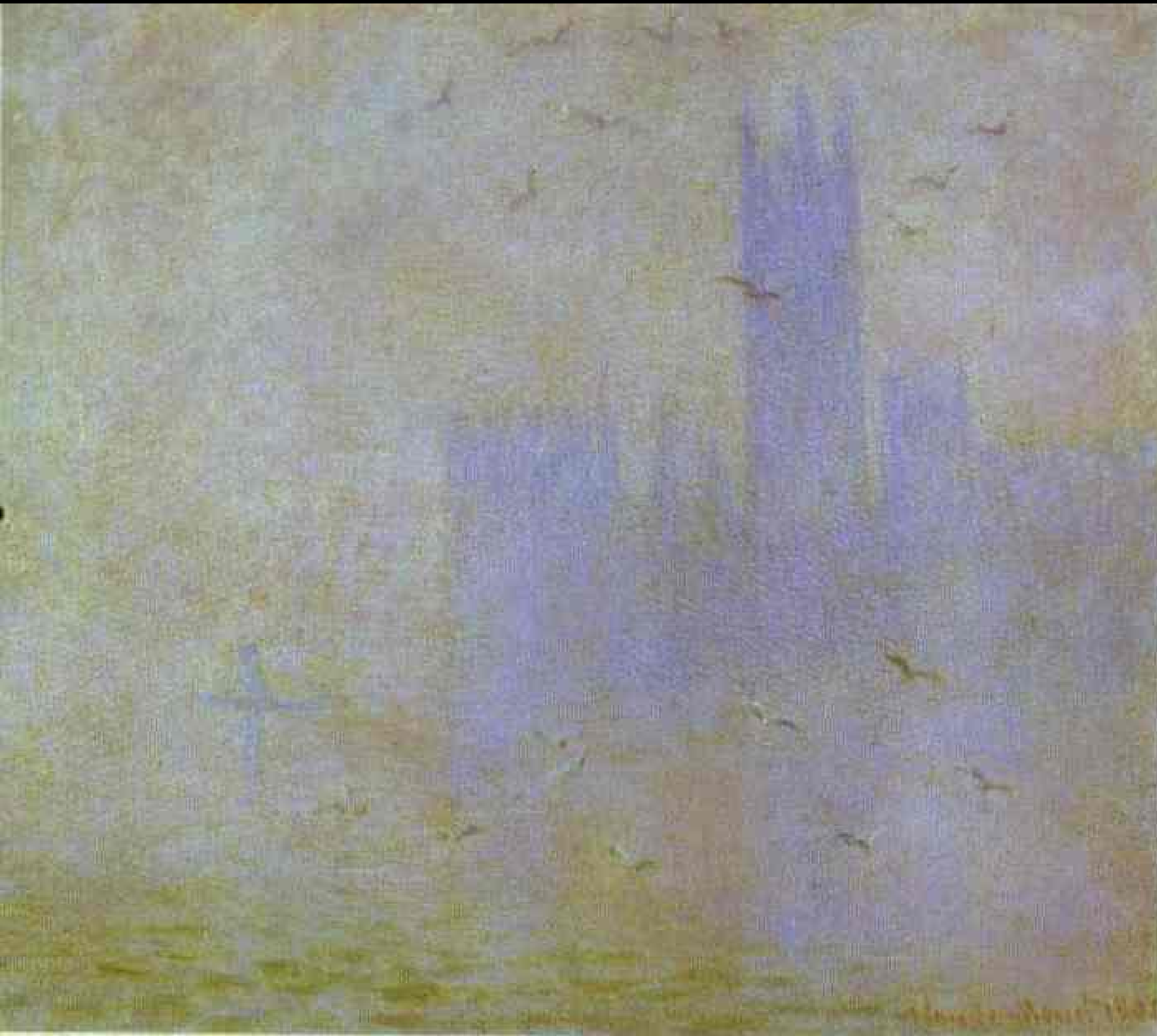

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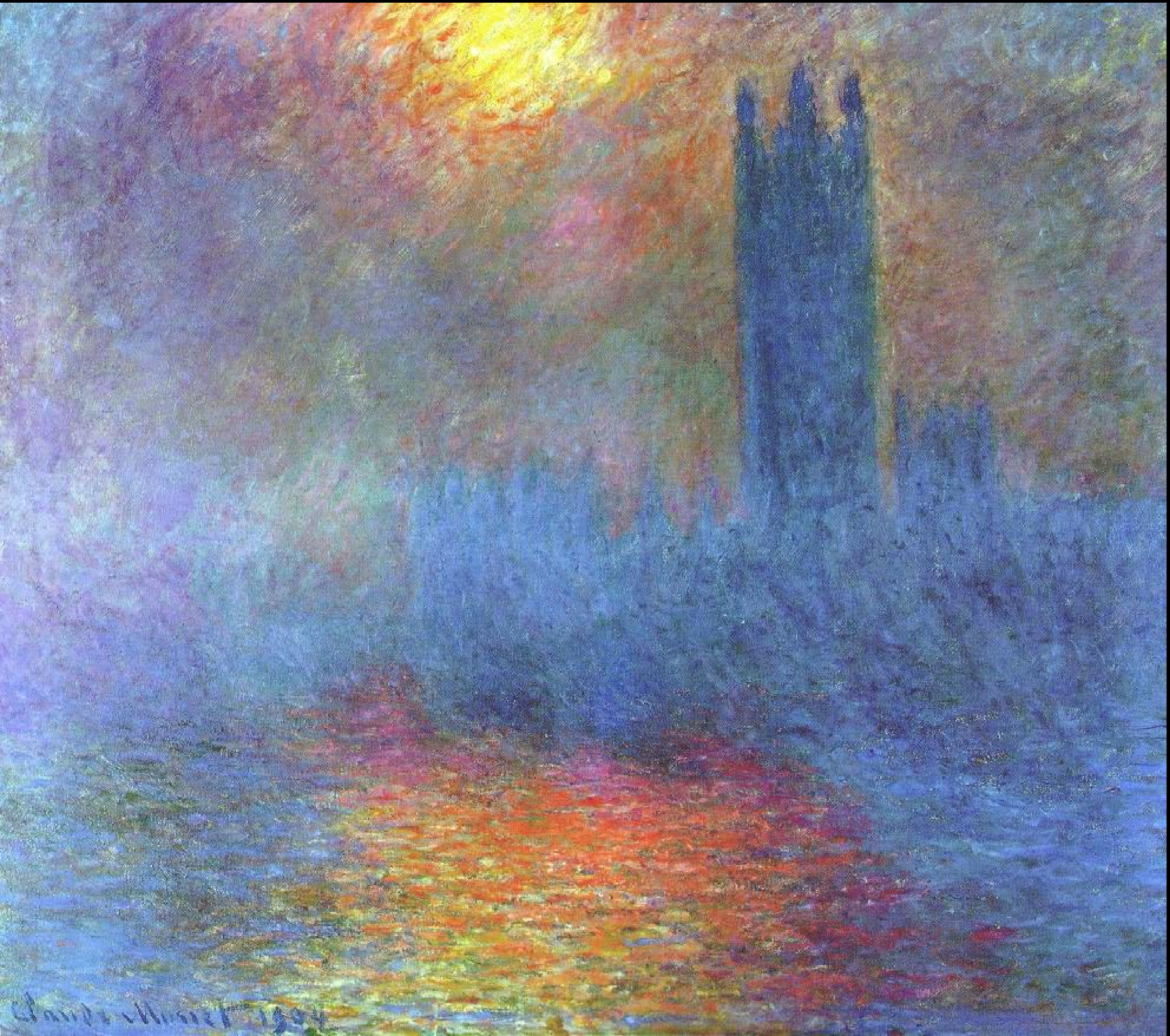

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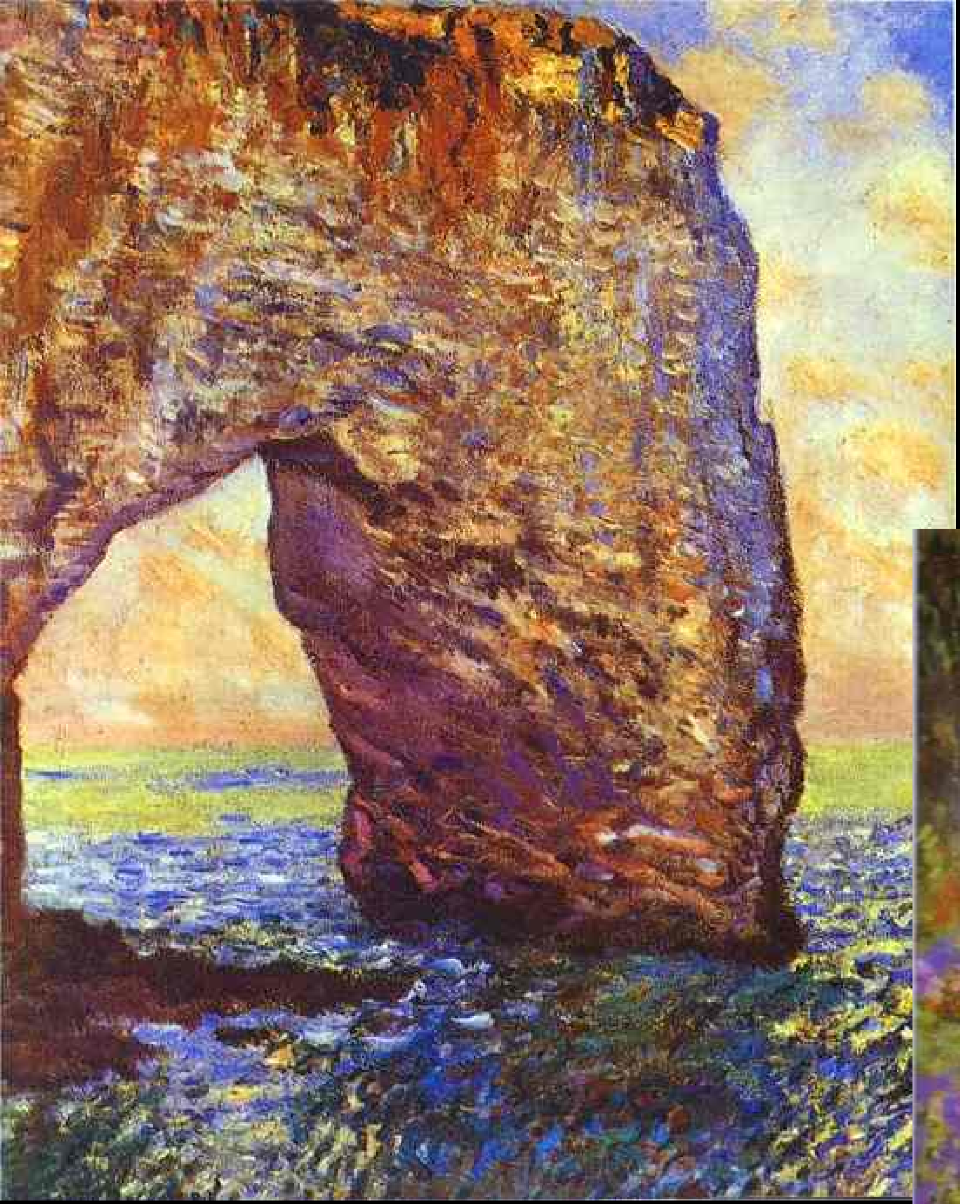
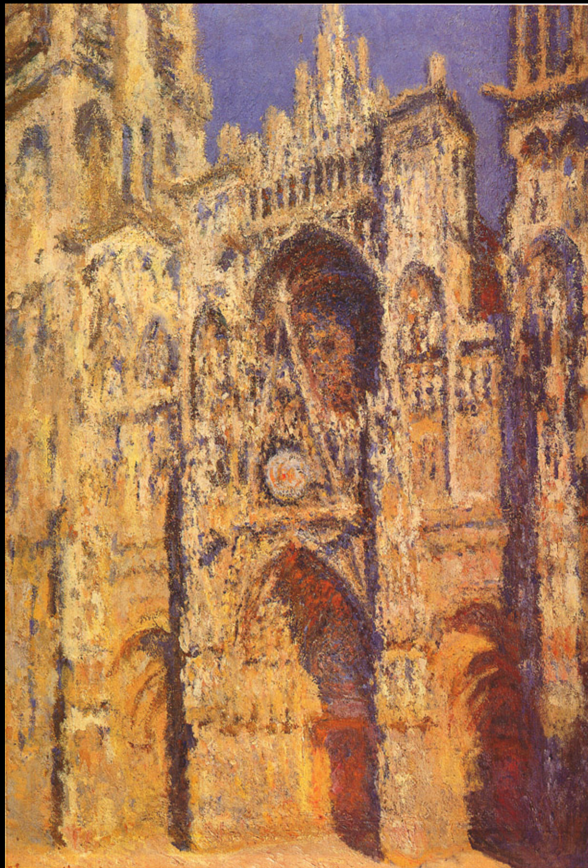
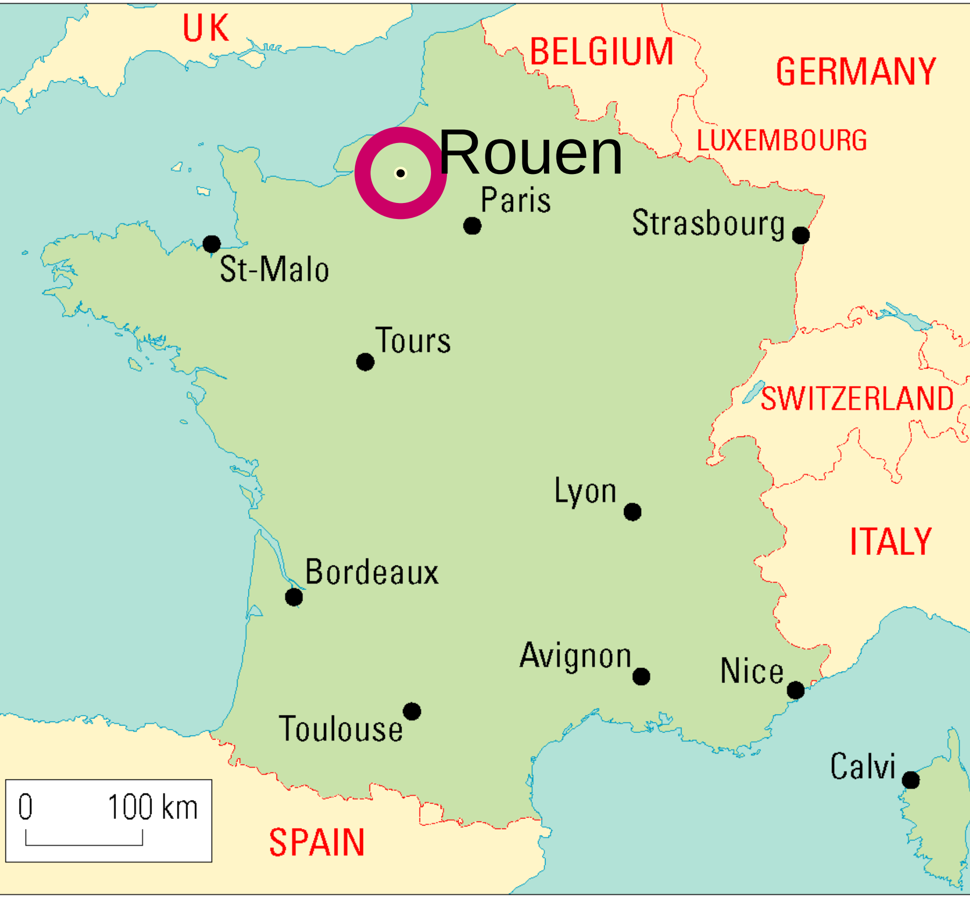



- Monet - Rouen Cathedral series.

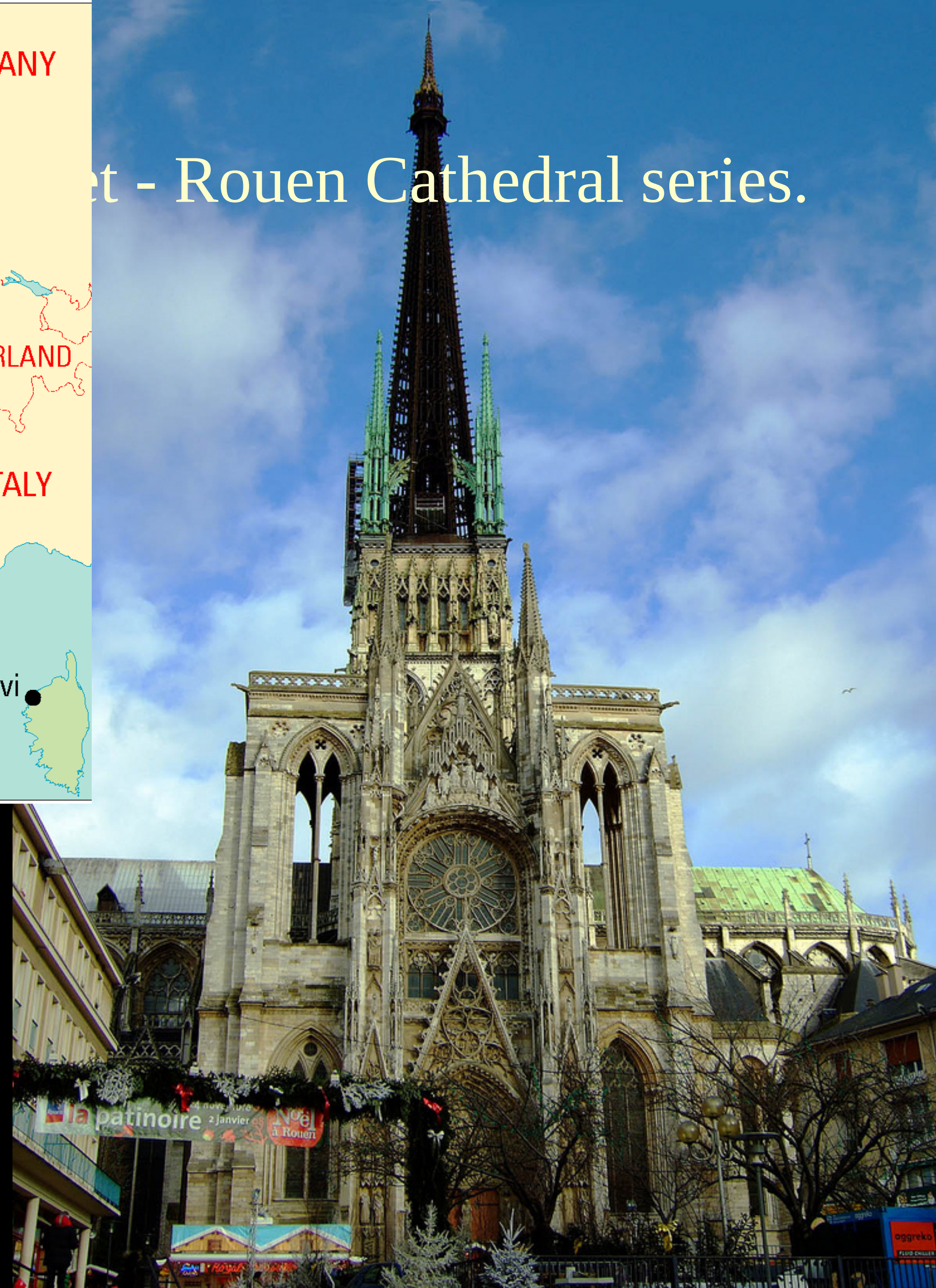



t - Rouen Cathedral series.

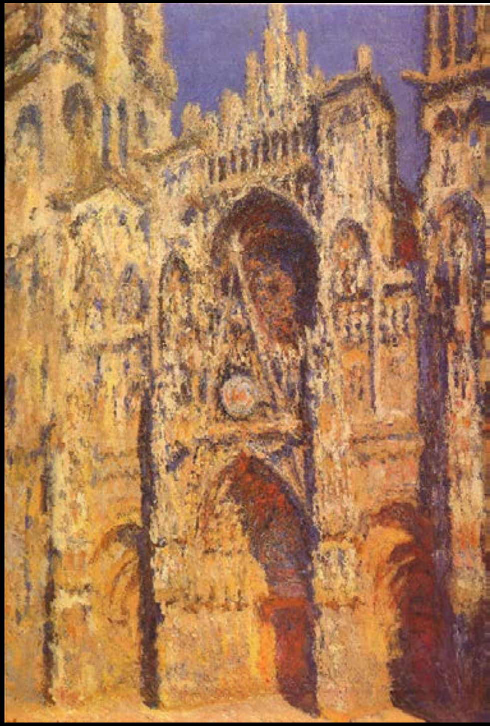


Rouen is about 60miles WNW of Paris.

Here’s the south entrance, at the transept, showing the tower above the crossing.



- **Monet** Rouen Cathedral series 1893-1894



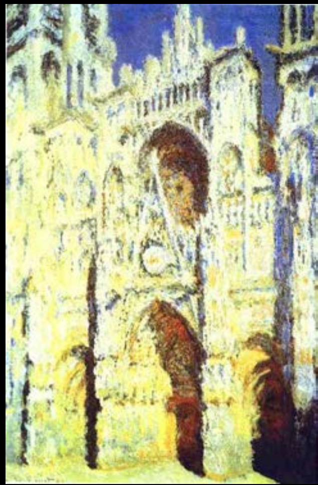
Rouen was long the capital city of France — Joan of Arc was burned here. The Cathedral is the seat of the Archbishop of Rouen. Rouen Cathedral contains a tomb of Richard the Lionheart which contains his heart. It was the tallest building in the world (151 m) from 1876 to 1880.

•**Monet** Rouen Cathedral series 1893-1894

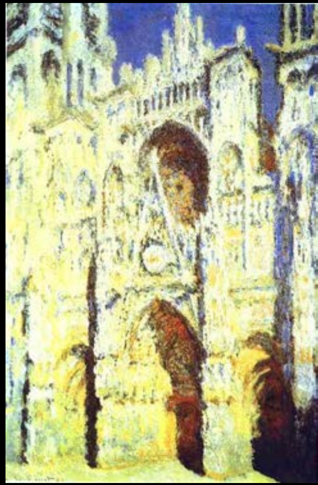
Here' s the Tourist Office in Rouen — it sits across the plaza from the cathedral. The front of the cathedral is on the east side, and this building is on the west.

It was one of 3 studios Monet used in Rouen to paint the cathedral series. This was his second location. His rented studio space on first floor of what was a draper's shop.

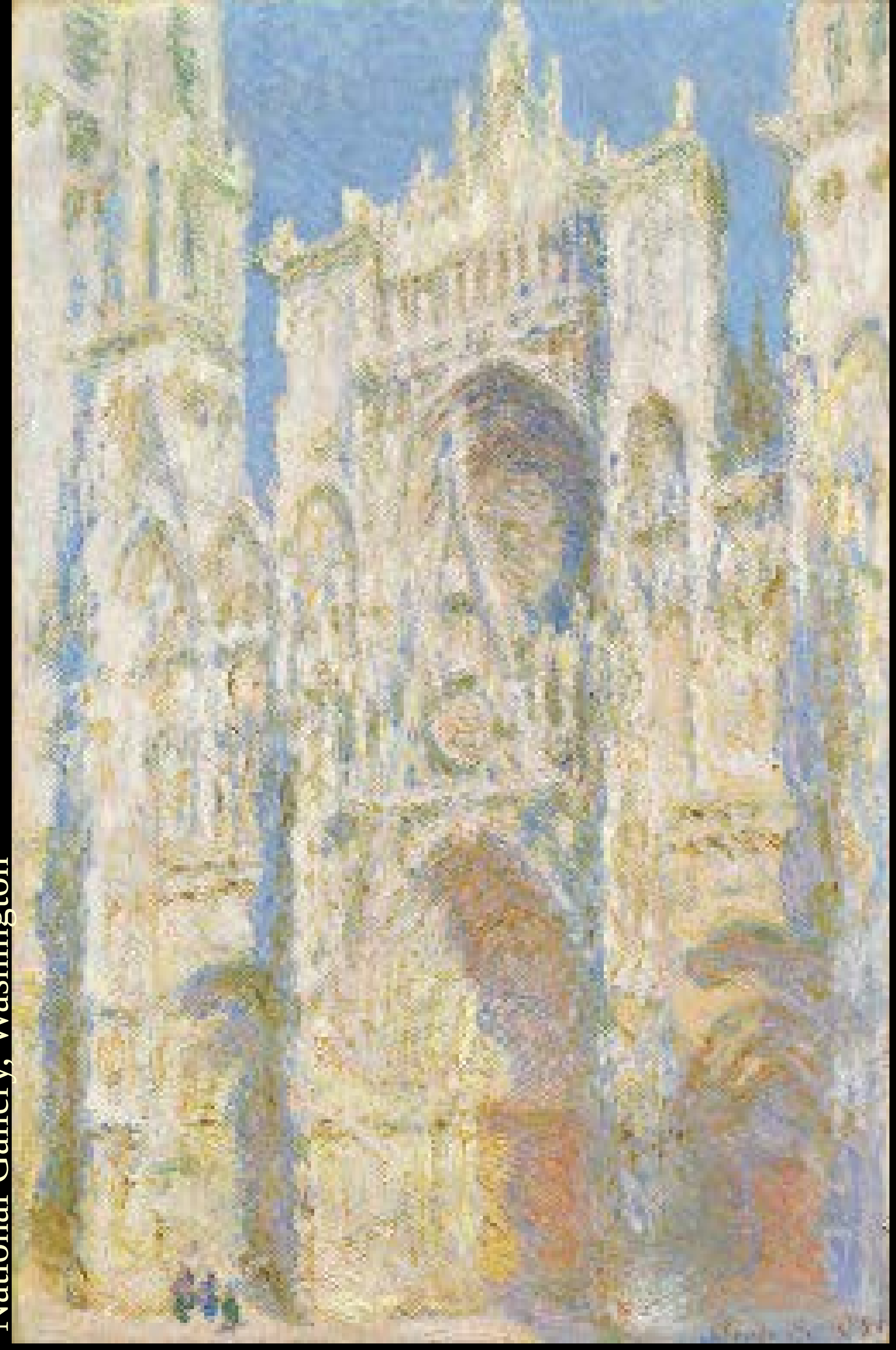
- **Monet** Rouen Cathedral series 1893-1894



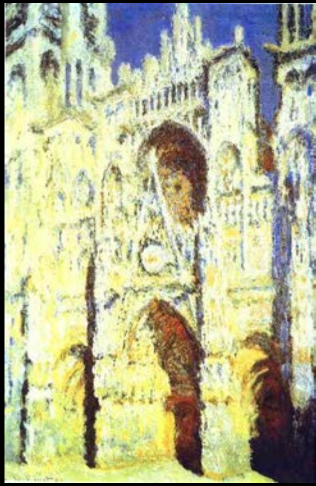
- **Monet** Rouen Cathedral series 1893-1894

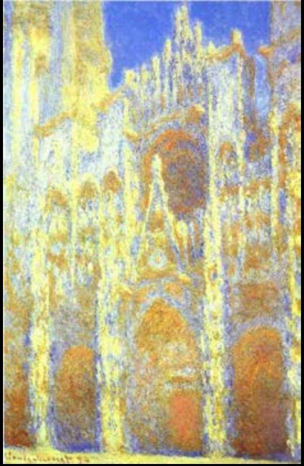


National Gallery, Washington

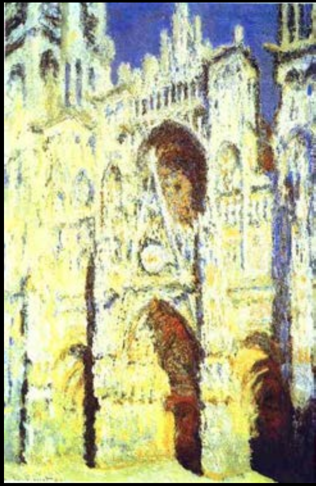


- **Monet** Rouen Cathedral series 1893-1894





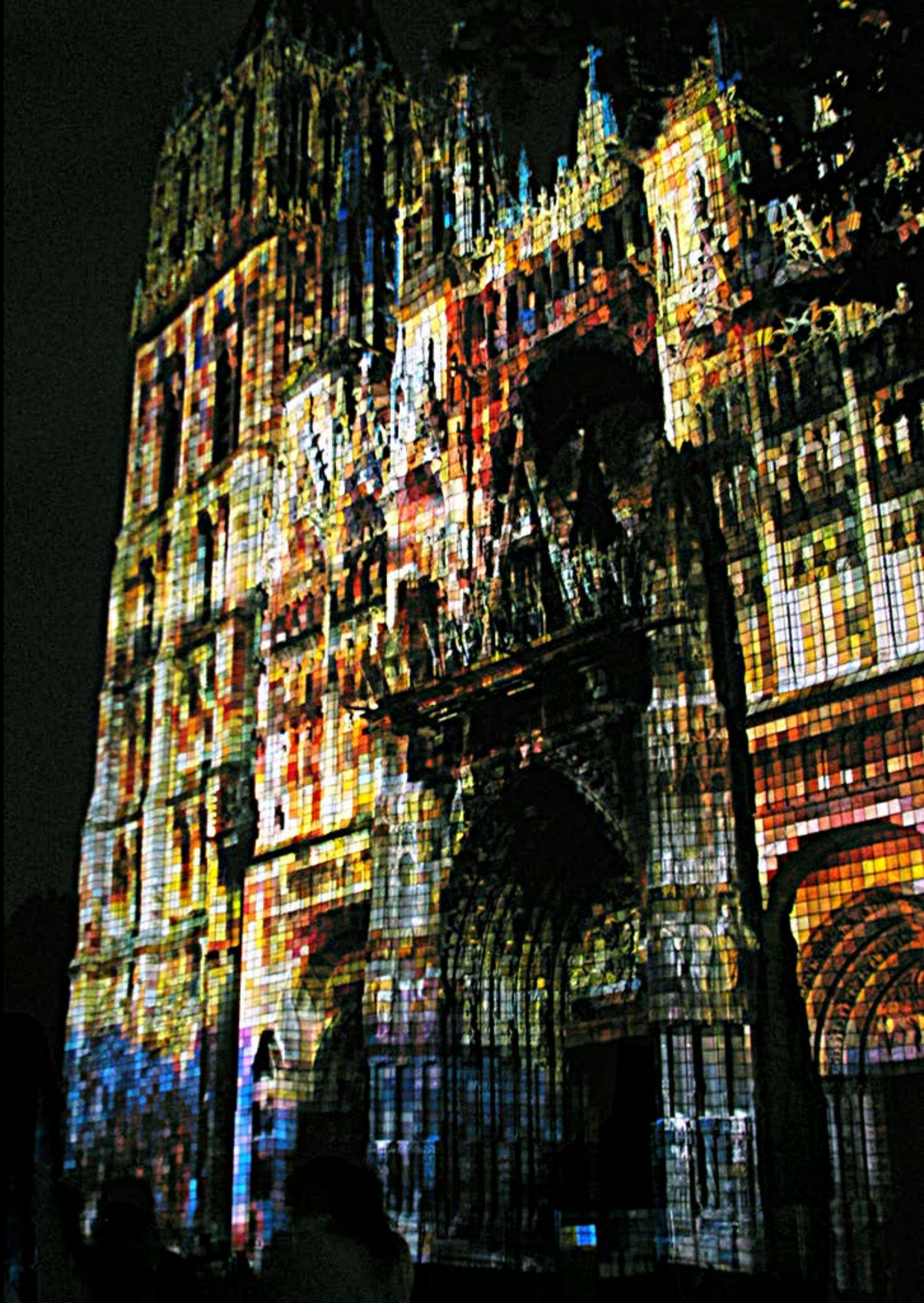
- **Monet**
Rouen Cathedral series 1893-1894



How do you out-color Monet?
How do you alter appearance via light still *more*?

Several cathedrals, including Rouen, here, have begun a late-evening tradition of projecting images and colors on their facades — night-time light shows using the cathedral as a huge, undulating backdrop.

This is an (unaltered) photo of one of the Cathedral projections.

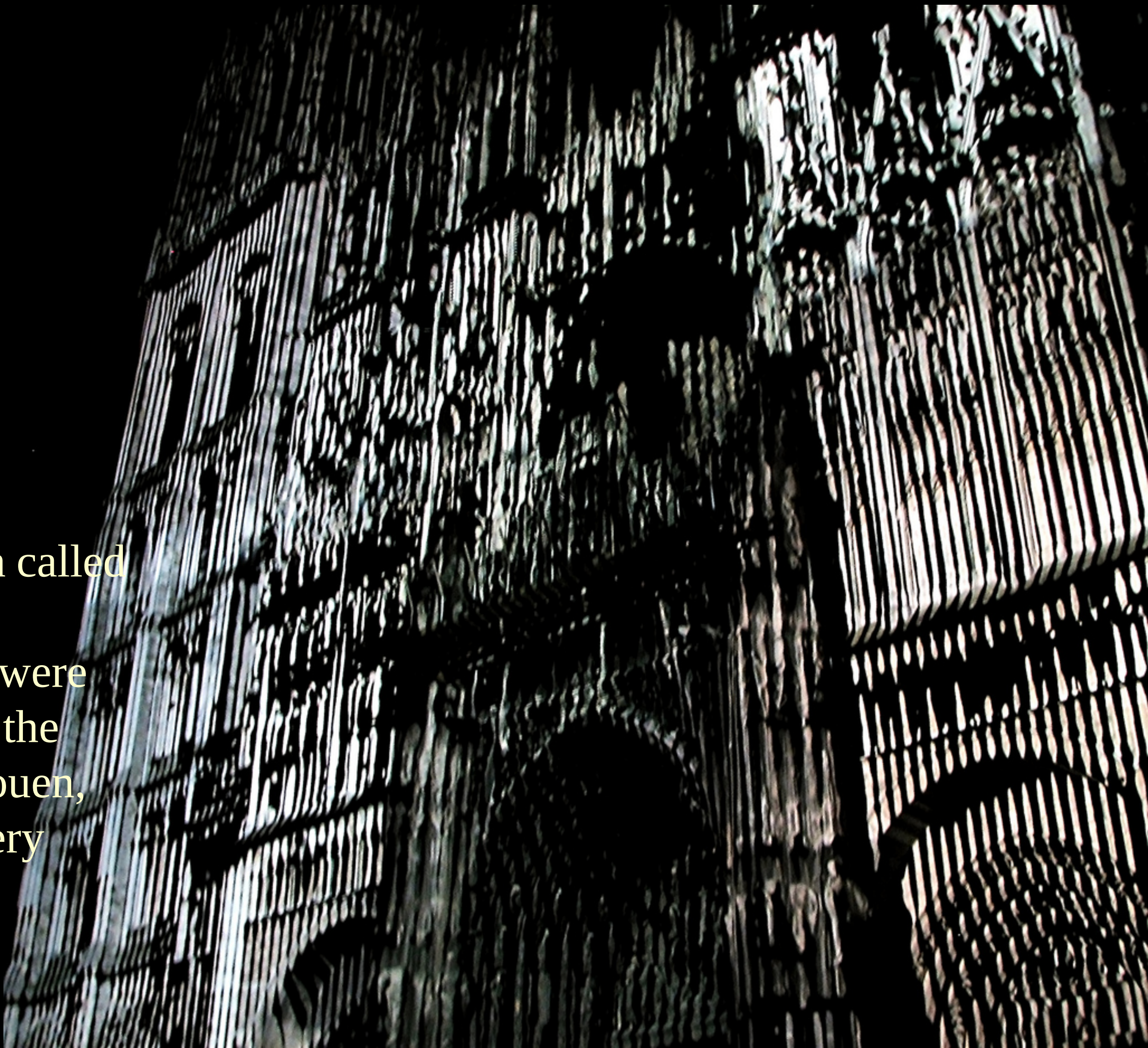


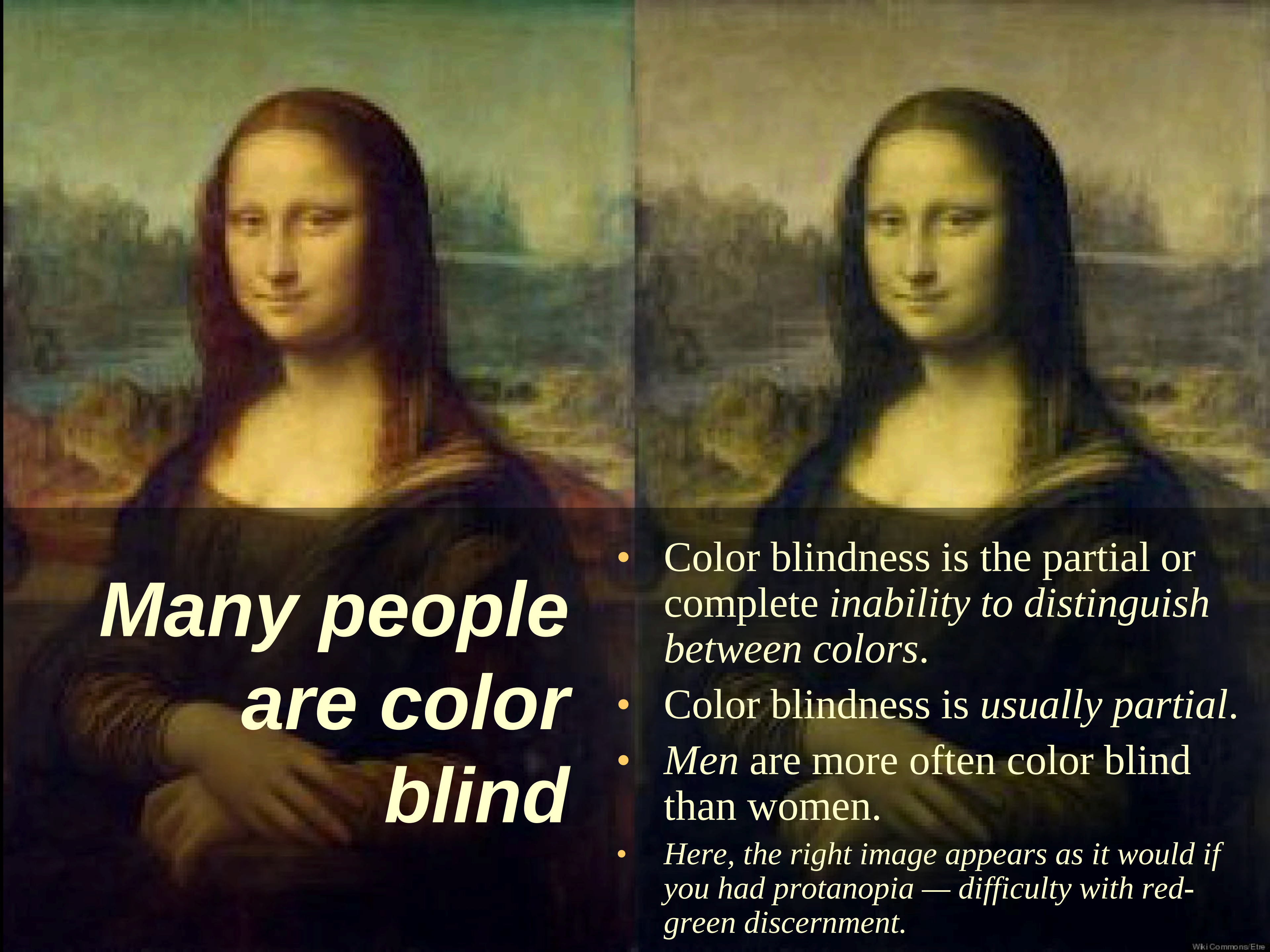
Here a Monet Cathedral painting is being projected onto the cathedral he painted.

Here a Monet Cathedral painting is being projected onto the cathedral he painted.

• Rouen Cathedral

Taken during an exhibition called "Monet aux pixels" where pixelised Monet paintings were projected onto the front of the impressive Cathedral at Rouen, France ….along with an eery soundtrack





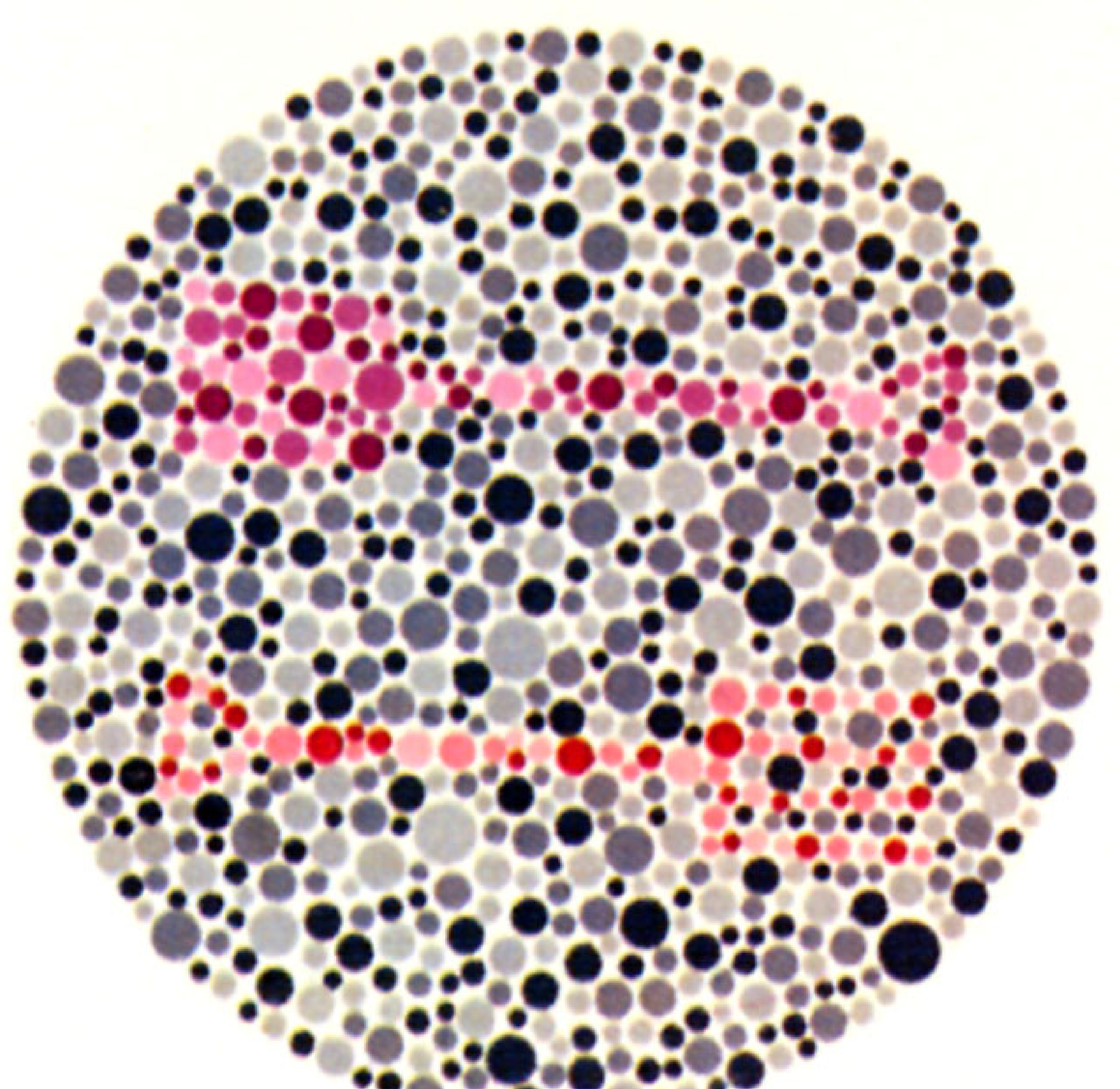
Wiki Commons/Etre

Many people are color blind

- Color blindness is the partial or complete *inability to distinguish between colors*.
- Color blindness is *usually partial*.
- *Men* are more often color blind than women.
- *Here, the right image appears as it would if you had protanopia — difficulty with red-green discernment.*

Color Blindness

- Red deficiency
- People with red-deficient color vision will see only spots



Color Blindness — Design Implications

"Color codes present particular problems for color blind people as they are often difficult or impossible for color blind people to understand."

"Good graphic design avoids using color coding or color contrasts ***alone*** to express information, as this not only helps color blind people, but also aids understanding by normally sighted people."

www.spiritus-temporis.com/color-blindness/design-implications-of-color-blindness.html

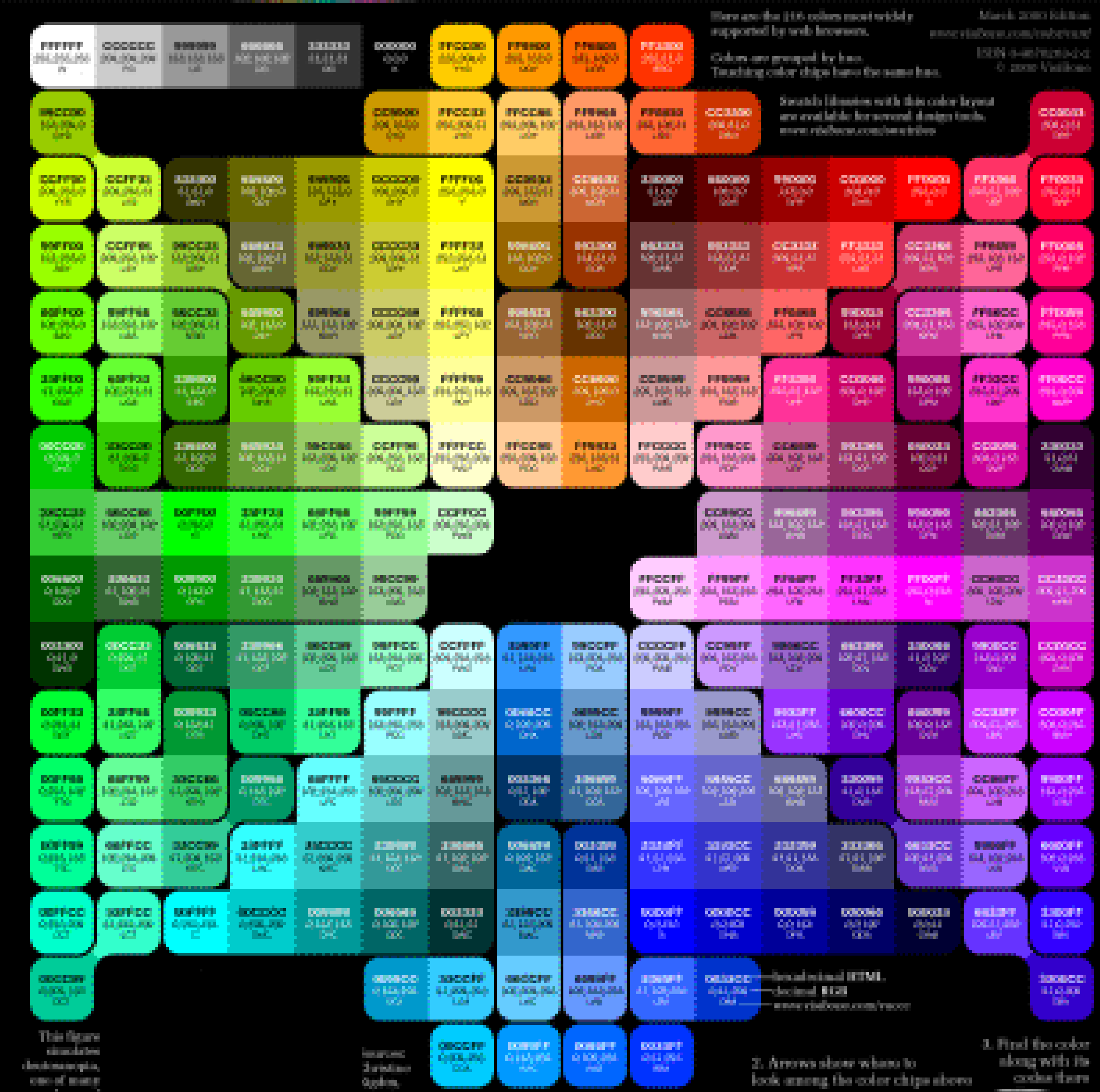
Color Blindness — Design Implications

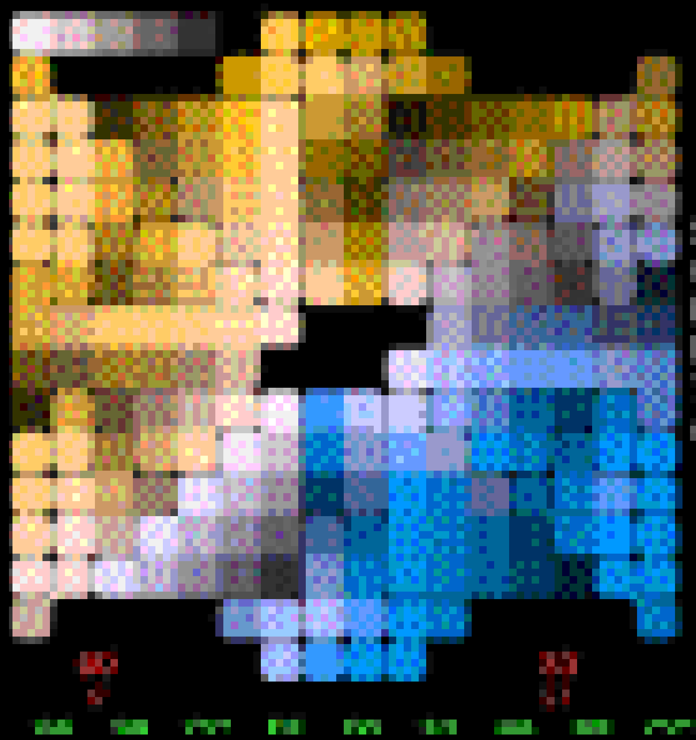
Web Design

"The use of Cascading Style Sheets on the world wide web allows pages to be given an alternative color scheme for color-blind readers."
www.spiritus-temporis.com/color-blindness/design-implications-of-color-blindness.html

Adobe Photoshop offers tools that enable a designer to see what their design will look like to a color blind viewer/user.

Web Colors & Simulated R-G Blindness

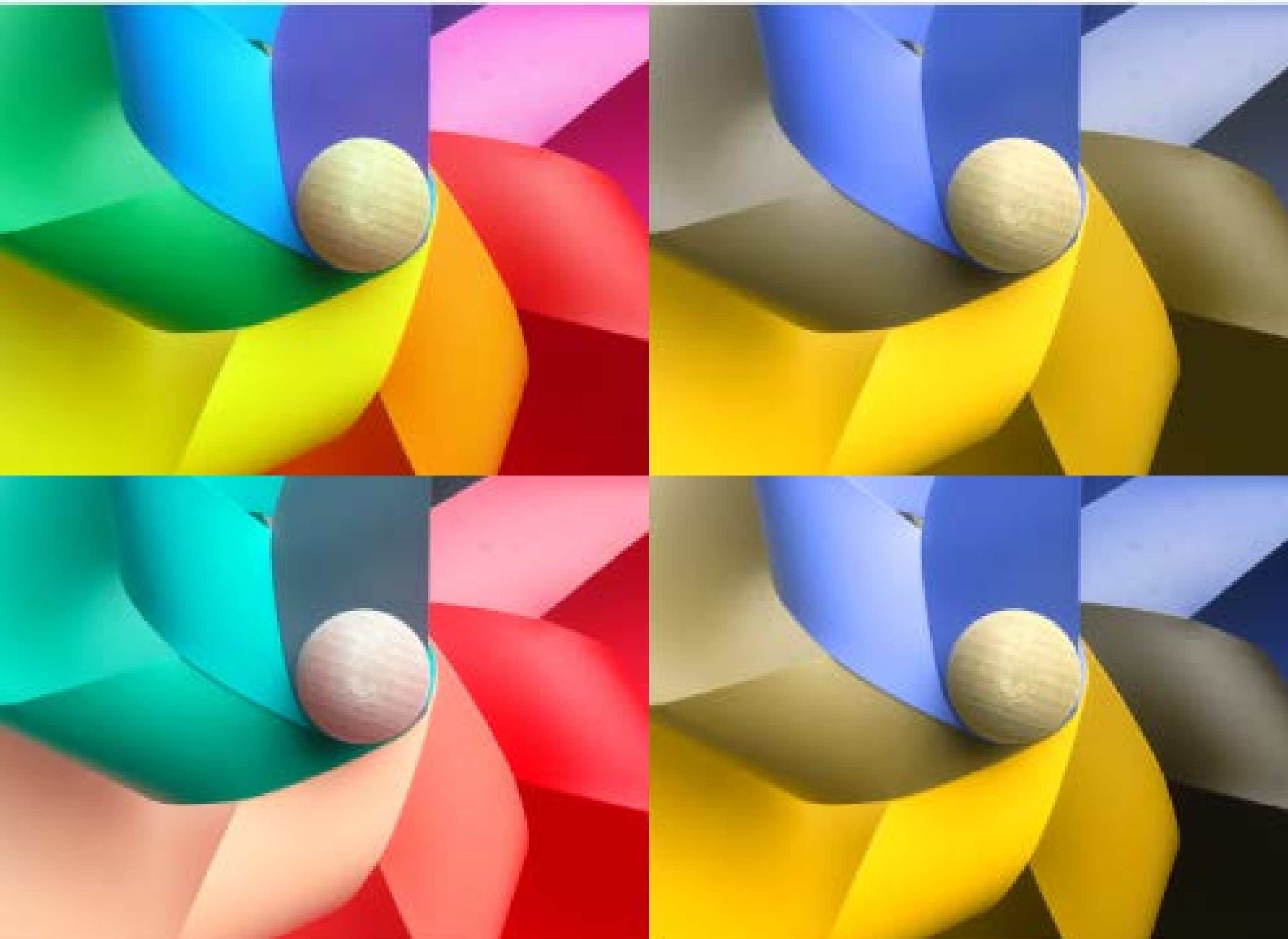




- Red and Green are indistinguishable — other component colors remain.

"normal" color vision

green-blindness (deuteranopia)



blue-blindness (tritanopia)

red-blindness (protanopia)

Normal vs Protonopia

Normal vs Protonopia

Normal vs Protonopia

Normal vs Protonopia

Normal vs Deuternopia

Normal vs Deuternopia

Normal vs Deuternopia

Normal vs Deuternopia

Japanese Color Scholar proposes that Vincent Van Gogh was color blind.

As painted

Protan simulated

Kazunori Asada viewed prints of van Gogh’s paintings in the “Color Vision Experience Room” at the Hokkaido Color Universal Design Organization.

The viewing room “…uses illumination that is optically filtered to provide a modified spectrum of light. Under this filtered light, a person who has normal color vision sees color much the same as the person who has protan or deutan color vision.”

“Vincent van Gogh has, is well known, a somewhat unusual way to use color. Although his use of color is rich, we see lines of diverse colors existing concurrently. Sometimes a point of entirely different color suddenly is interjected. Some people conjecture that van Gogh had color vision deficiency.”

http://asada0.tumblr.com/post/11517603099/the-day-i-saw-van-goghs-genius-in-a-new-light

Vincent Van Gogh color blind?

As painted

Protan simulated

Note the greens painted, but lost in the protan version.
The reflections on the left become consistent with the wall reflected.

http://asada0.tumblr.com/post/11517603099/the-day-i-saw-van-goghs-genius-in-a-new-light

Vincent Van Gogh color blind?

As painted

Protan simulated

Note the greens painted, but lost in the protan version.
The more typical, or expected golden sky is present on the right.

http://asada0.tumblr.com/post/11517603099/the-day-i-saw-van-goghs-genius-in-a-new-light

Color Blindness — Design Implications

Type Design

Selecting type colors that contrast by hue only is a poor practice. Instead, always use value contrast to distinguish foreground from background colors.

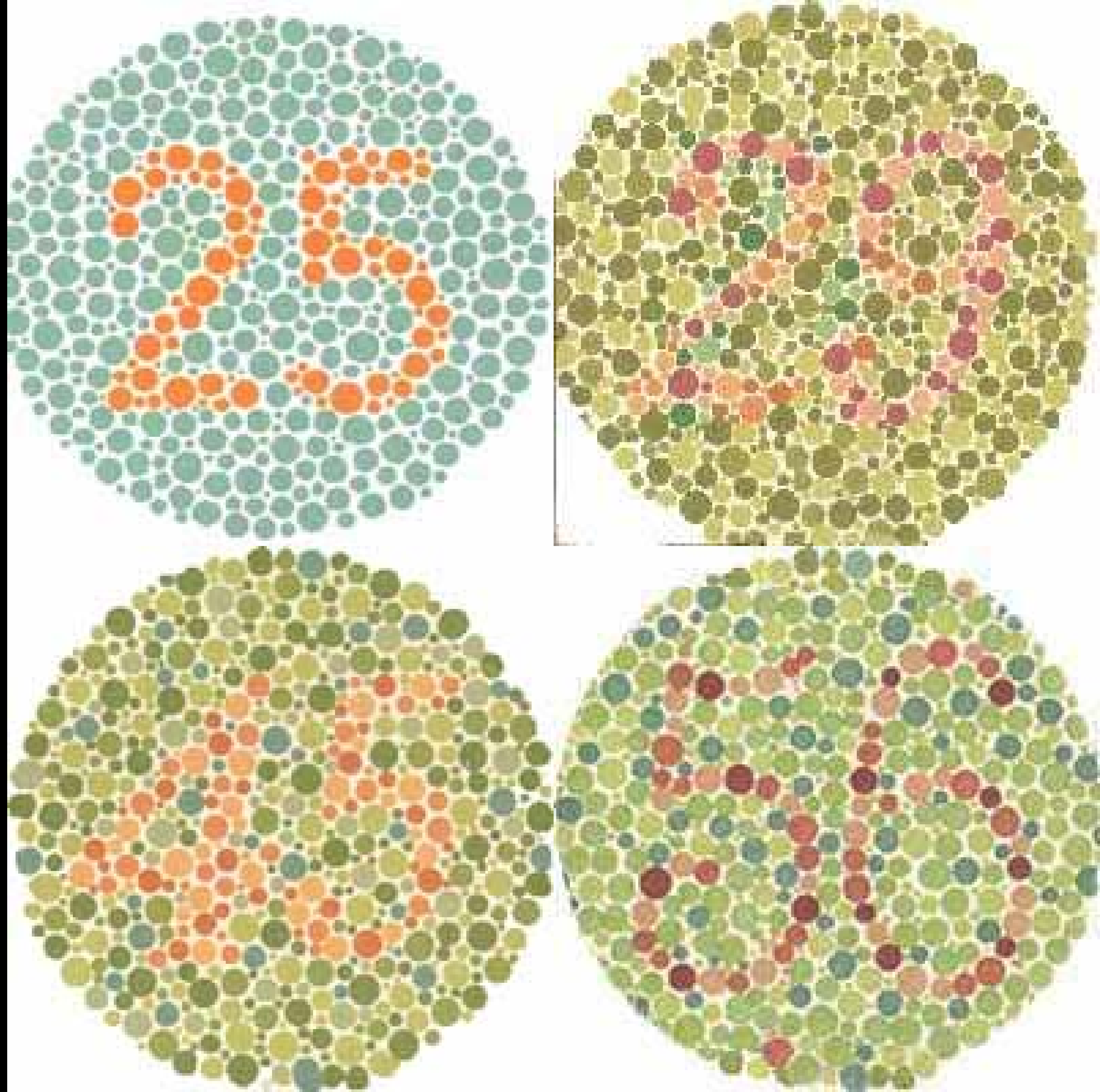
This helps readability for *both* color blind, *and* normal vision.

(note the headings on these pages uses green and red of roughly the same value. Very bad tactic. (though here, intentional))

Hue Contrast	***Value Contrast***
Hue Contrast	***Value Contrast***
Hue Contrast	***Value Contrast***
Hue Contrast	***Value Contrast***

Red-Green Tests

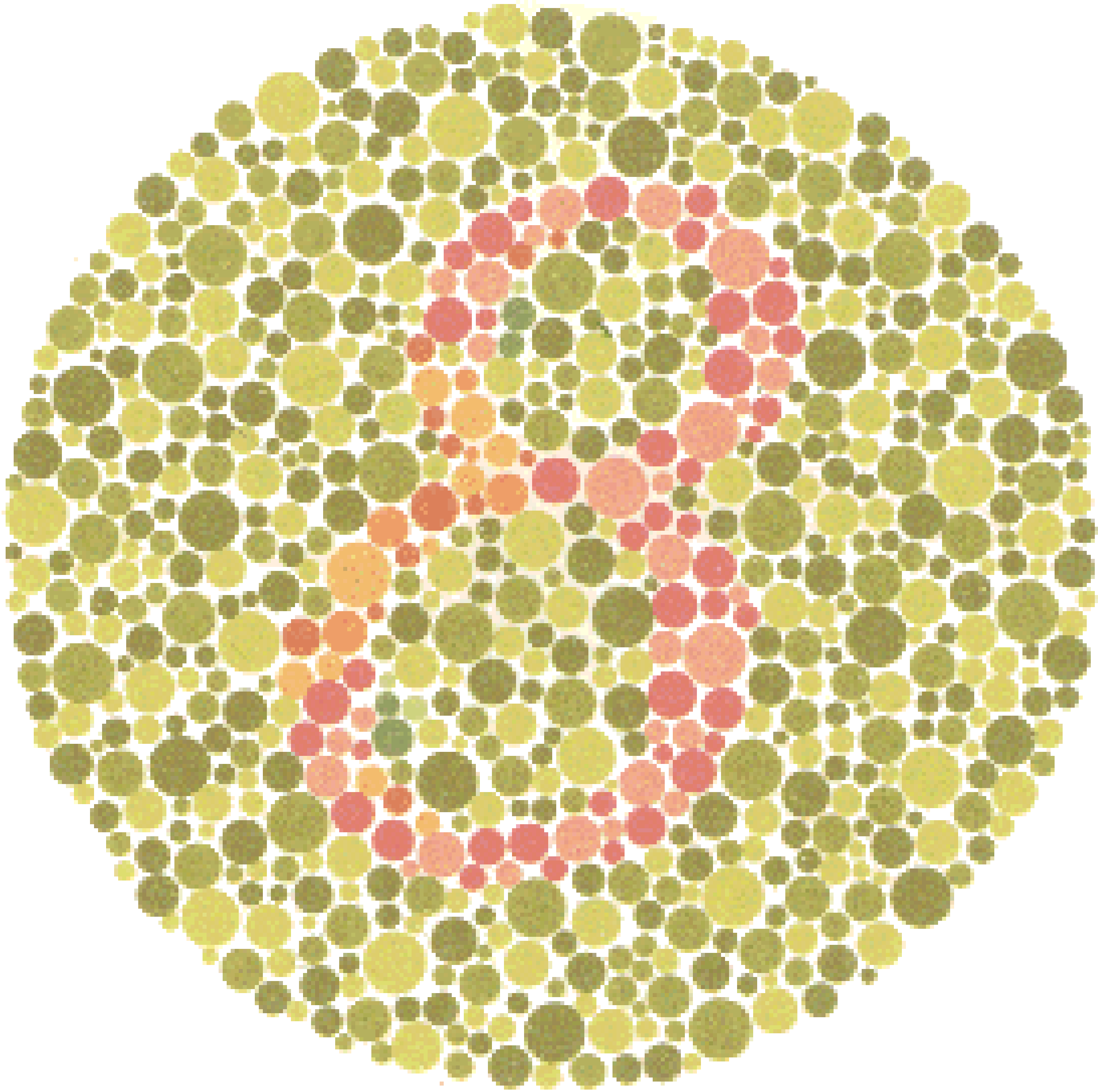
People with red-green deficient color vision will see only spots in one or more of these.



Color Vision Test

What patterns, letters or numbers do you see?

http://www.kcl.ac.uk/teares/gktvc/vc/lt/colourblindness/plate2.htm



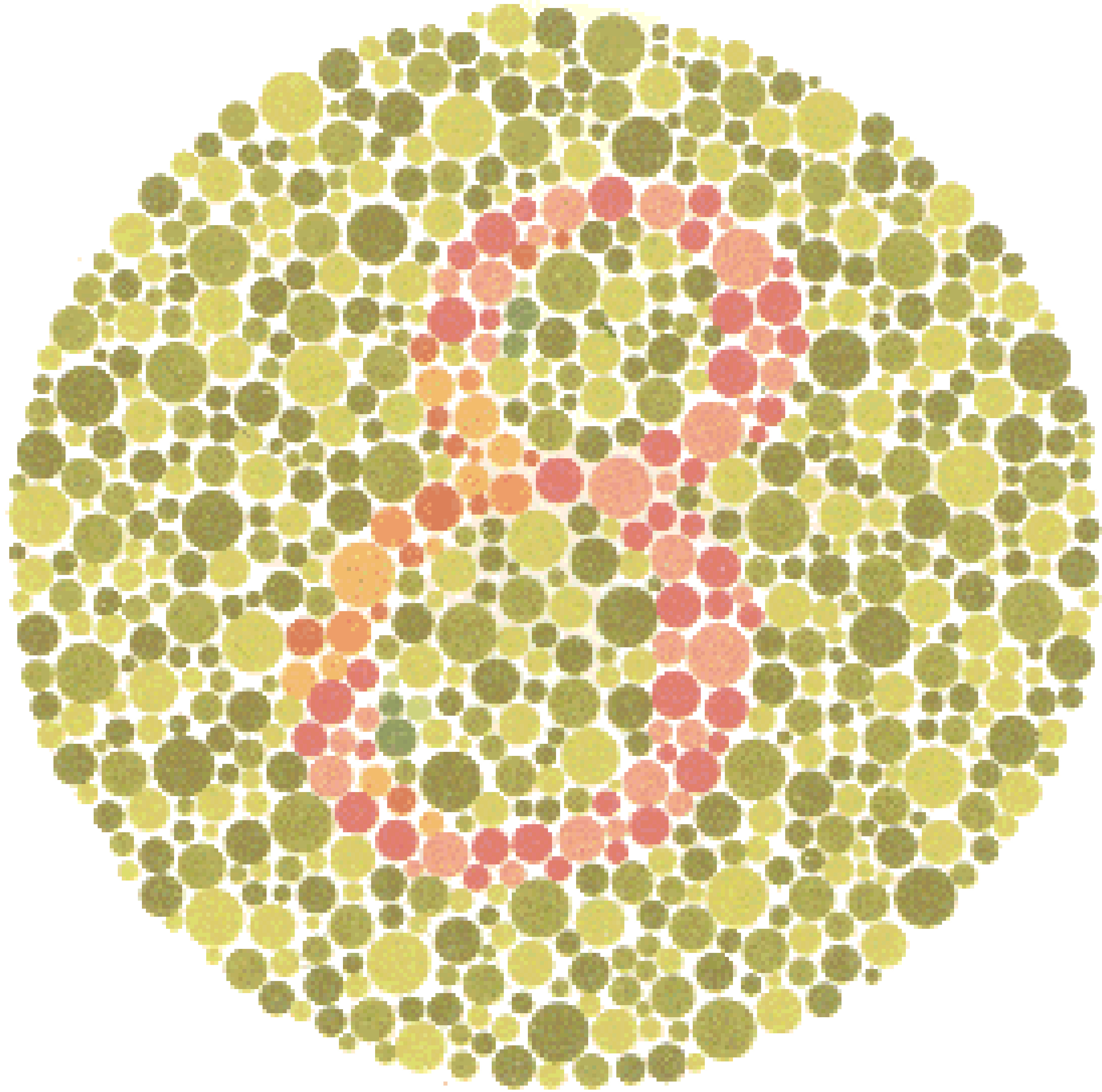
Color Vision Test

Those with normal colour vision should read the number 8.

Those with red-green colour vision deficiencies should read the number 3.

Total colour blindness should not be able to read any number.

http://www.kcl.ac.uk/teares/gktvc/vc/lt/colourblindness/plate2.htm

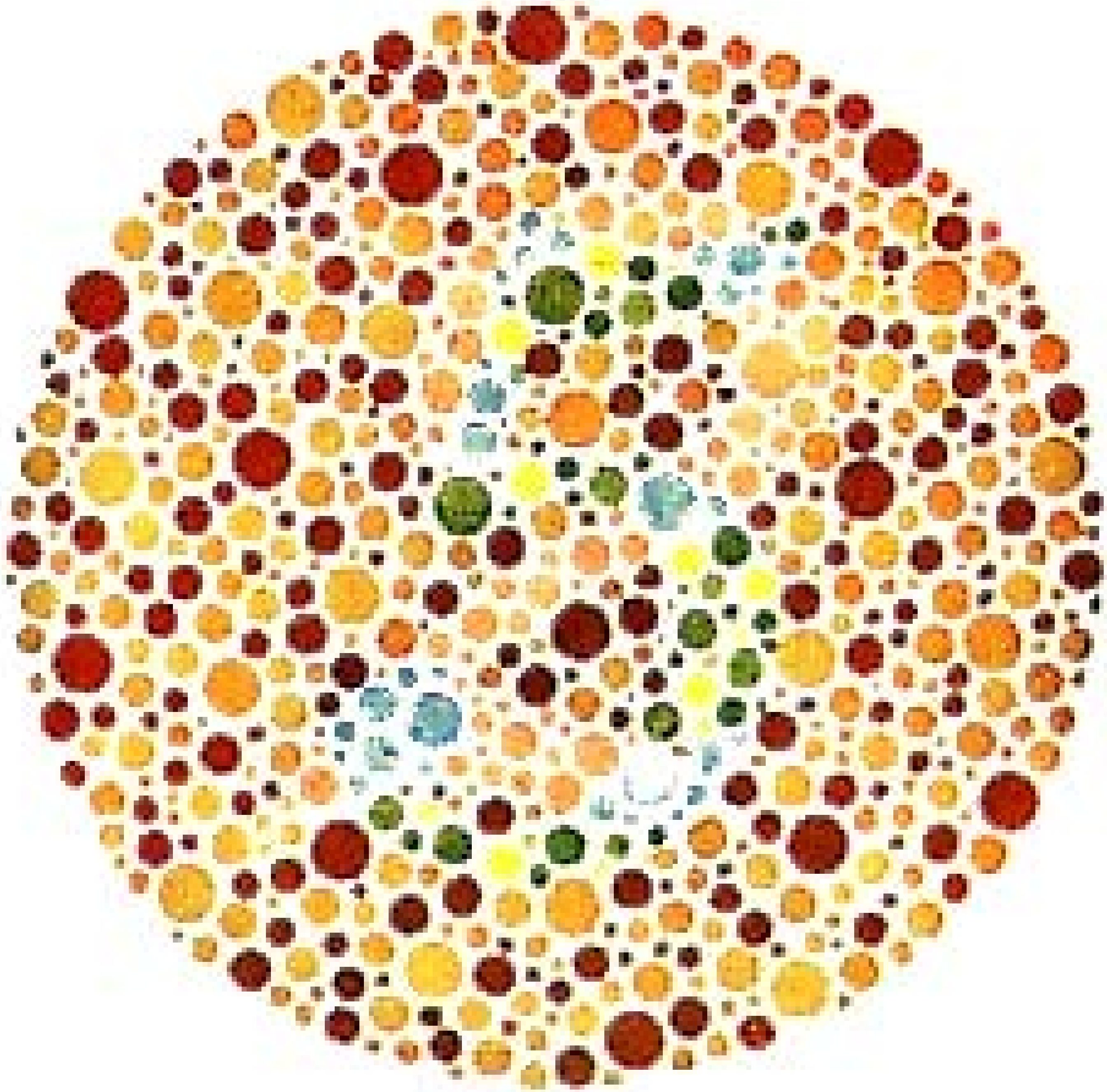


Color Vision Test

What number do you see?

The individual with **normal color vision** will see a **5** revealed in the dot pattern.

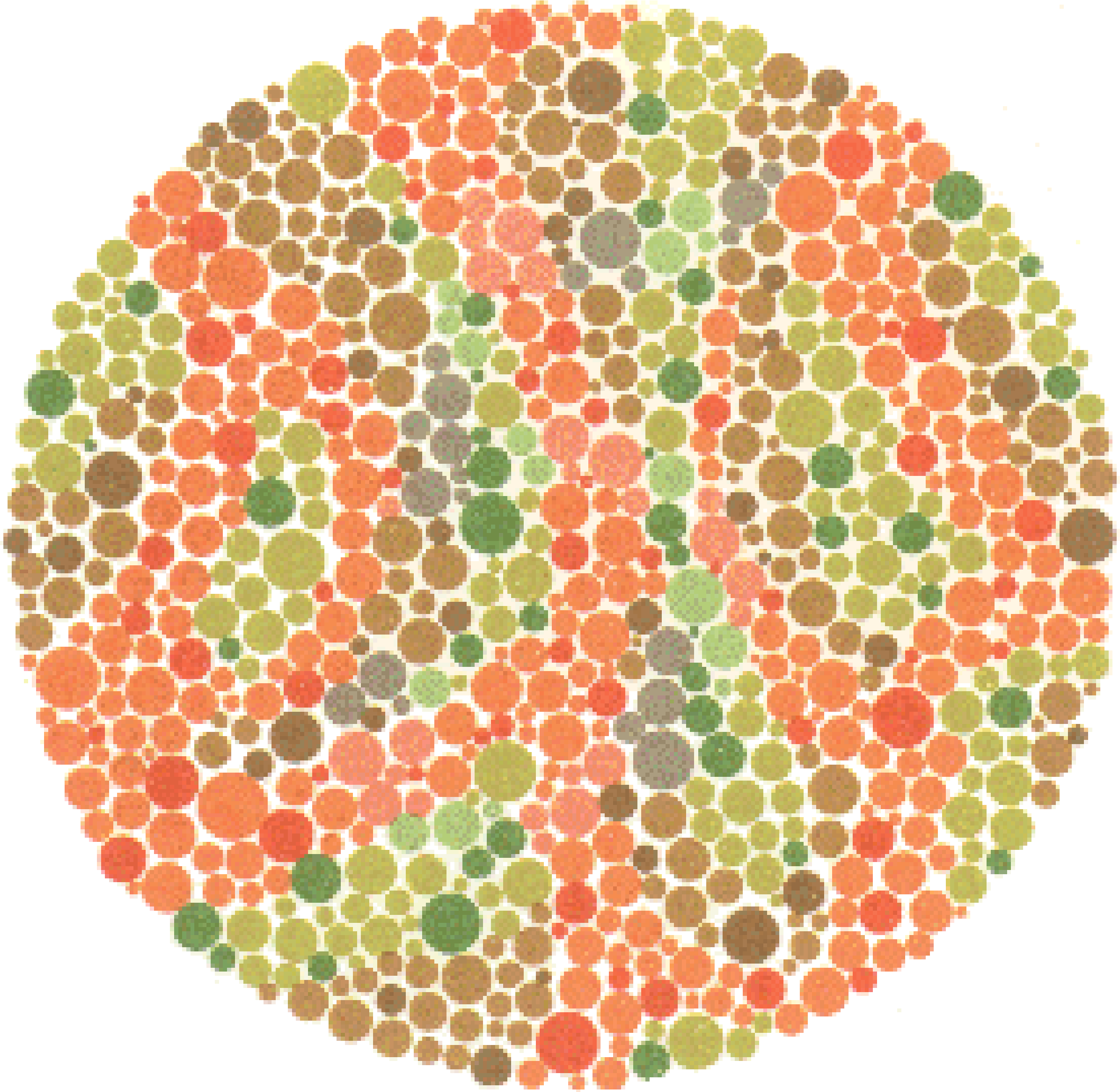
An individual with **Red/Green** (the most common) color blindness will see a **2** revealed in the dots.



Color Vision Test

What number do you see?

http://www.kcl.ac.uk/teares/gktvc/vc/lt/colourblindness/plate2.htm

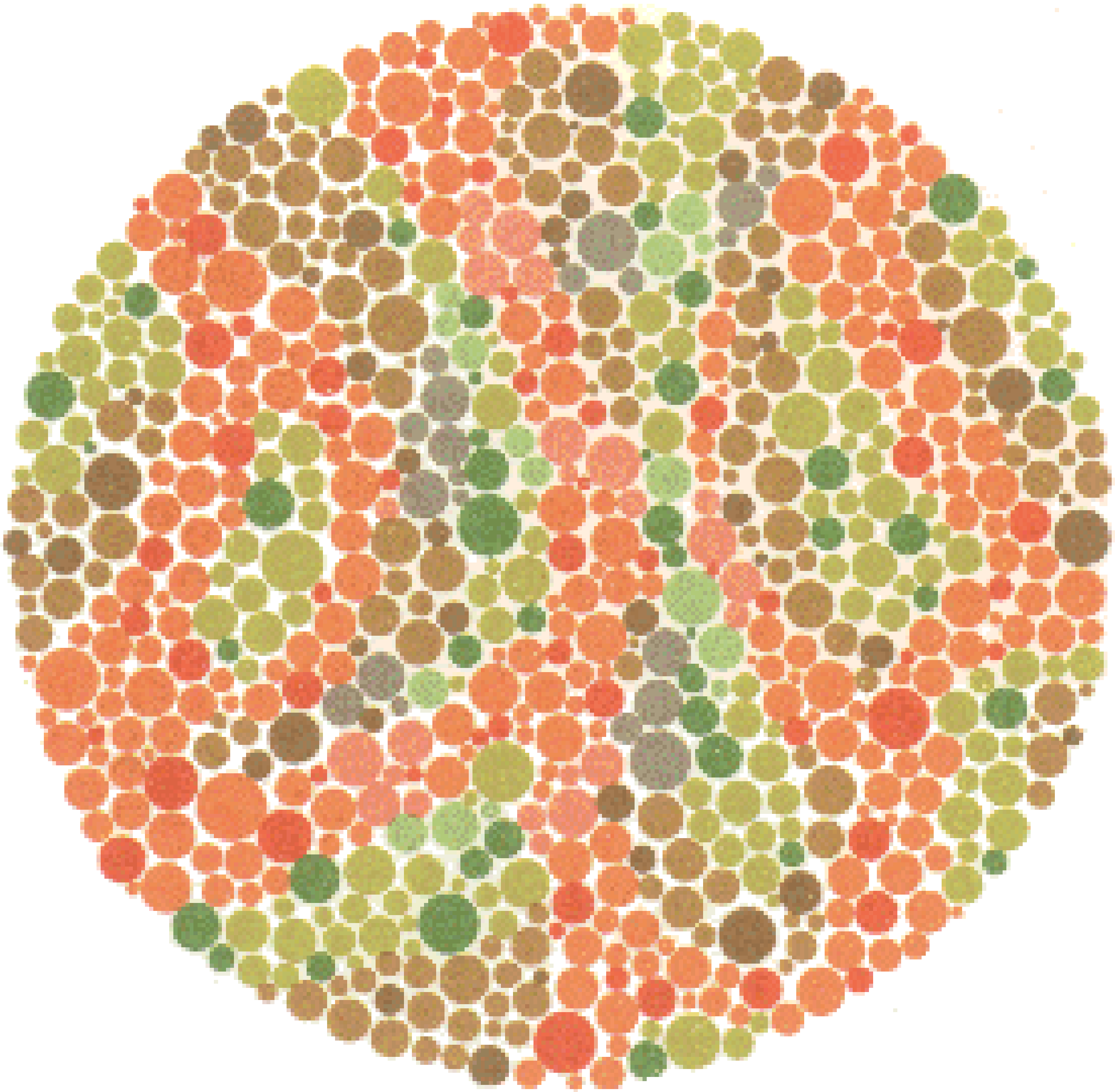


Color Vision Test

Normal colour vision and those with total colour blindness should not be able to read any number.

The majority of those with red-green deficiencies should read the number 5.

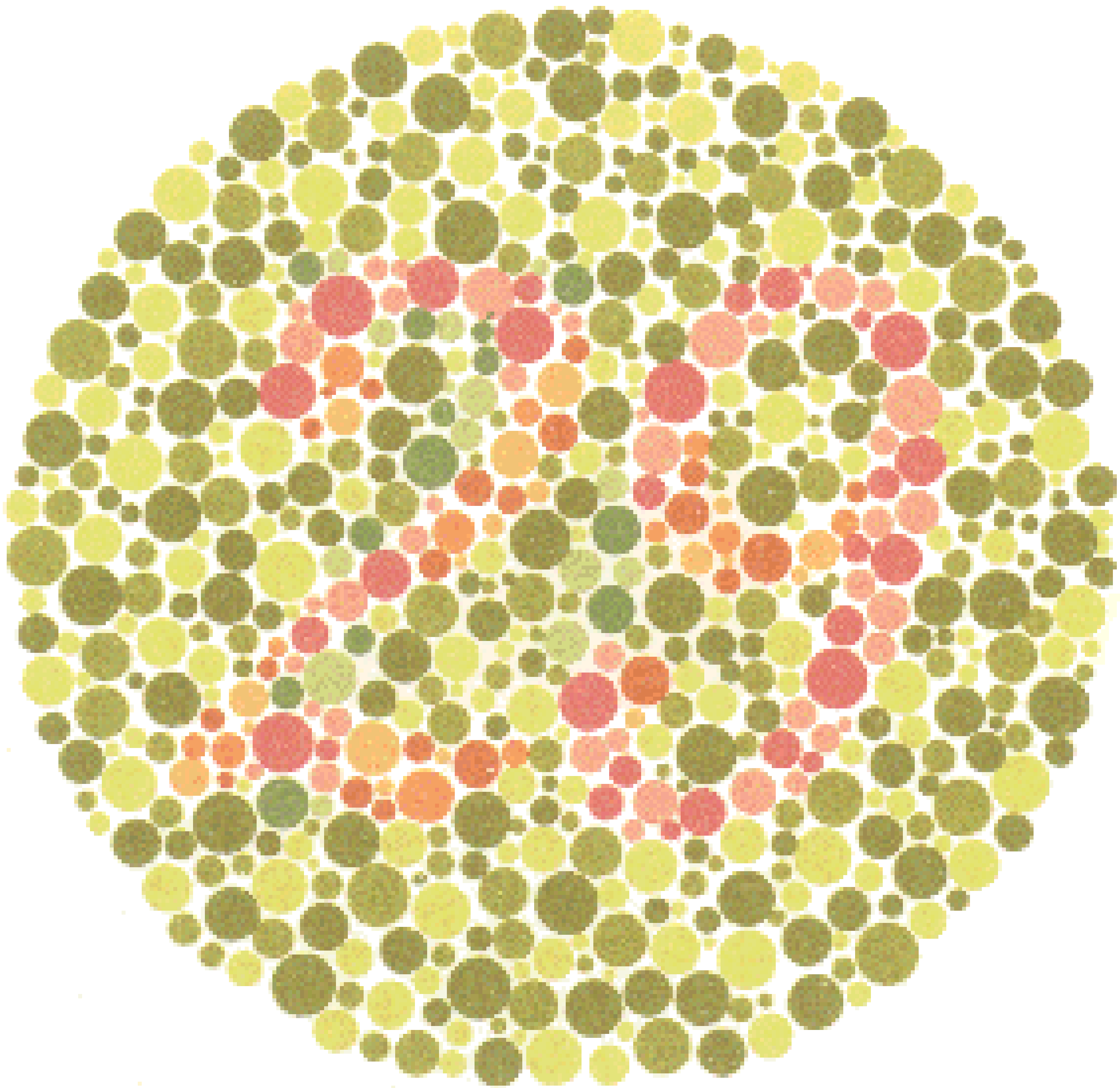
http://www.kcl.ac.uk/teares/gktvc/vc/lt/colourblindness/plate2.htm



Color Vision Test

What do you see?

http://www.kcl.ac.uk/teares/gktvc/vc/lt/colourblindness/plate2.htm



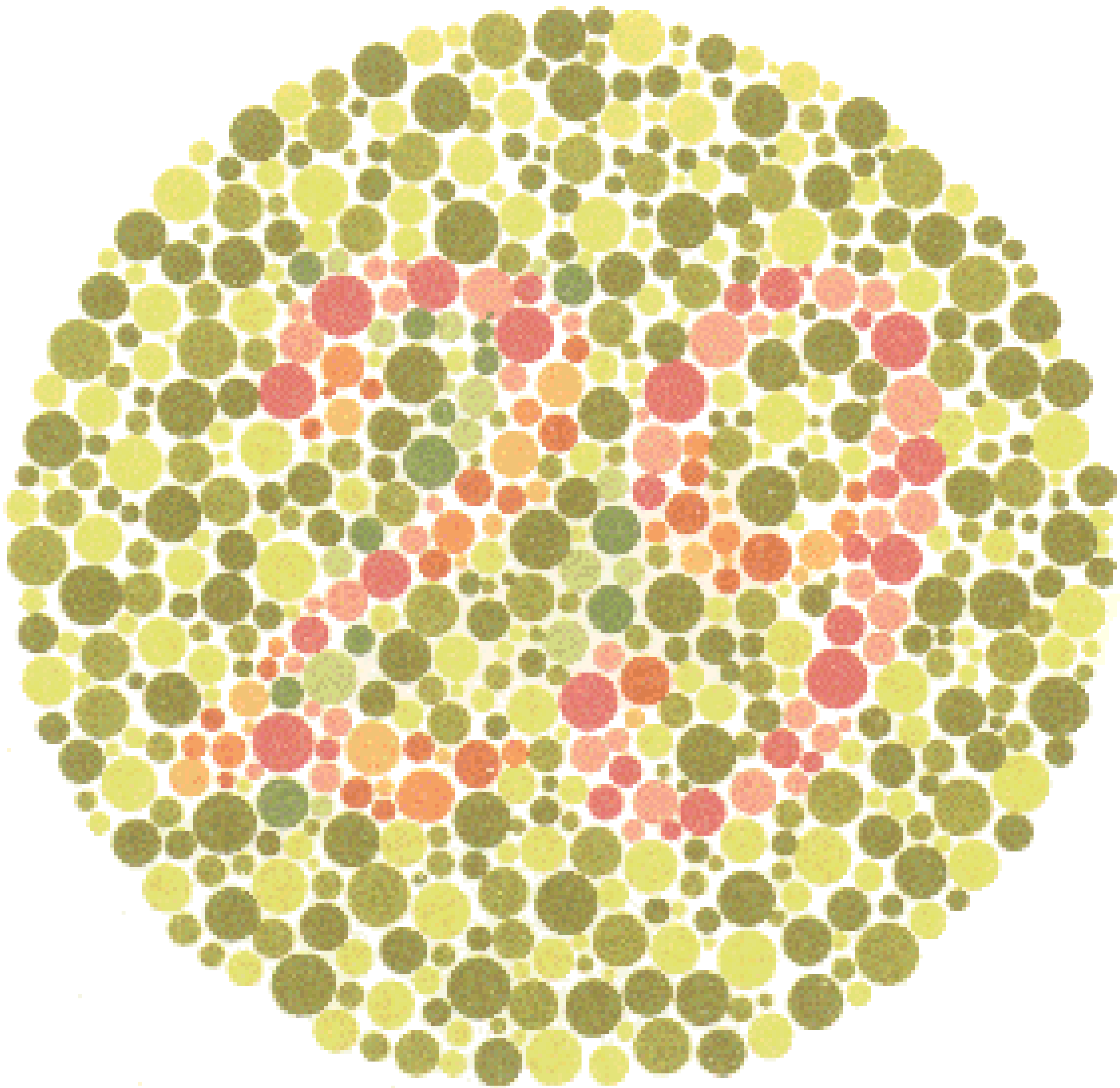
Color Vision Test

Normal vision should read the number 29.

Red-green deficiencies should read the number 70

Total colour blindness should not read any numeral

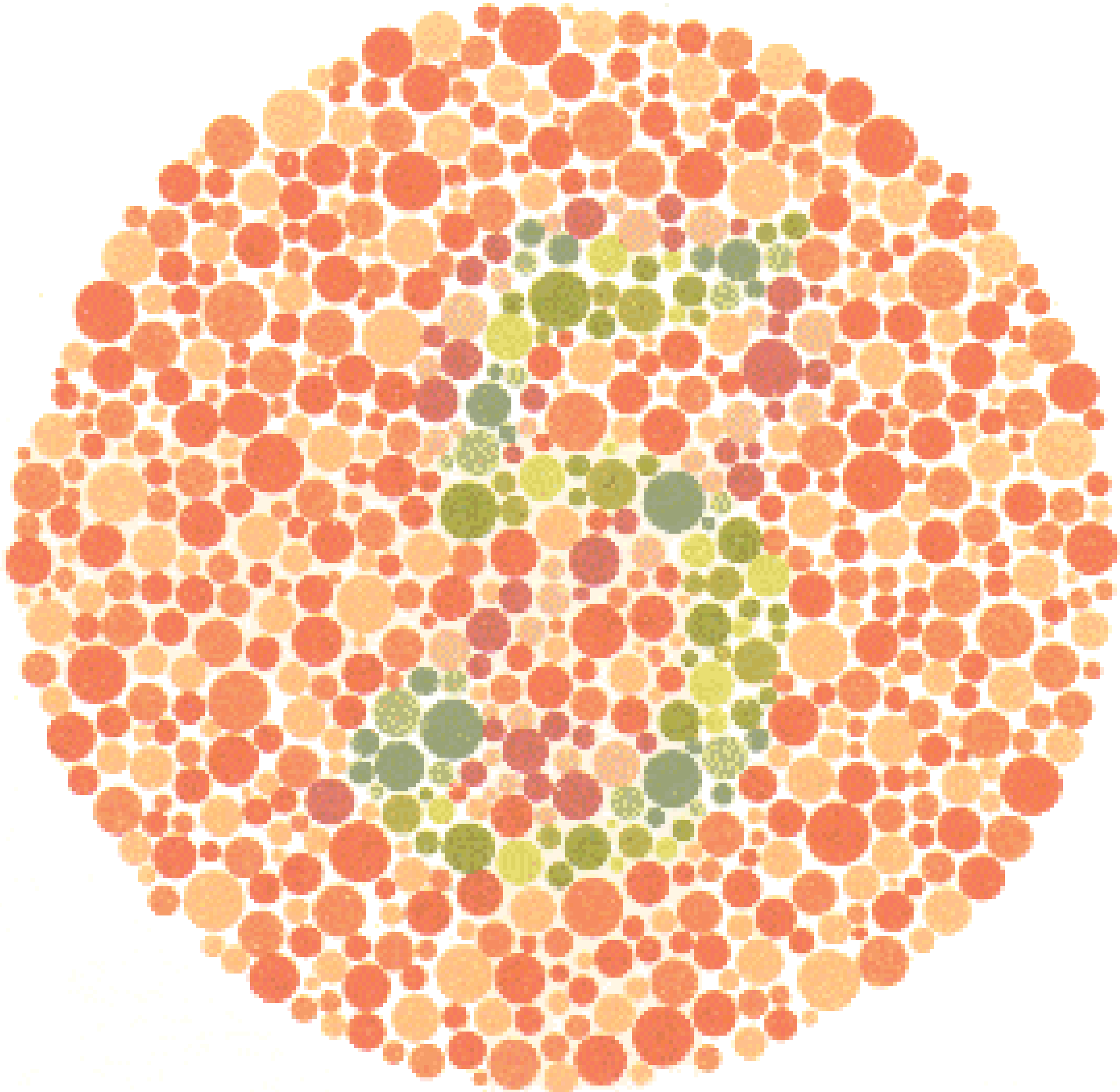
http://www.kcl.ac.uk/tea
res/gktvc/vc/lt/colourblir
dness/plate2.htm



Color Vision Test

What do you see?

http://www.kcl.ac.uk/teares/gktvc/vc/lt/colourblindness/plate2.htm



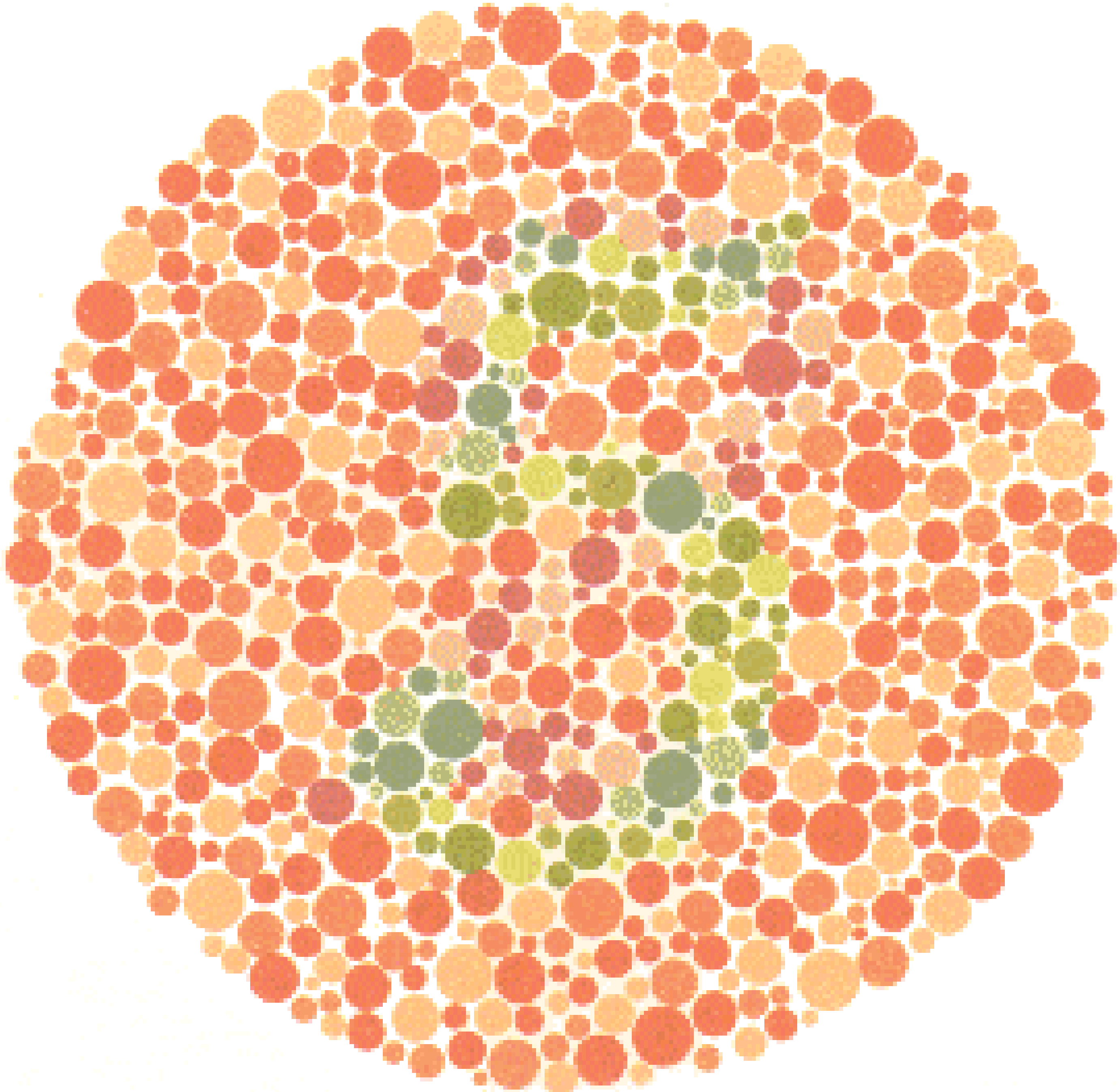
Color Vision Test

Normal colour vision should read the number 5.

Red-Green colour deficiencies should read the number 2.

Total colour blindness should not be able to read any number.

http://www.kcl.ac.uk/teares/gktvc/vc/lt/colourblindness/plate2.htm

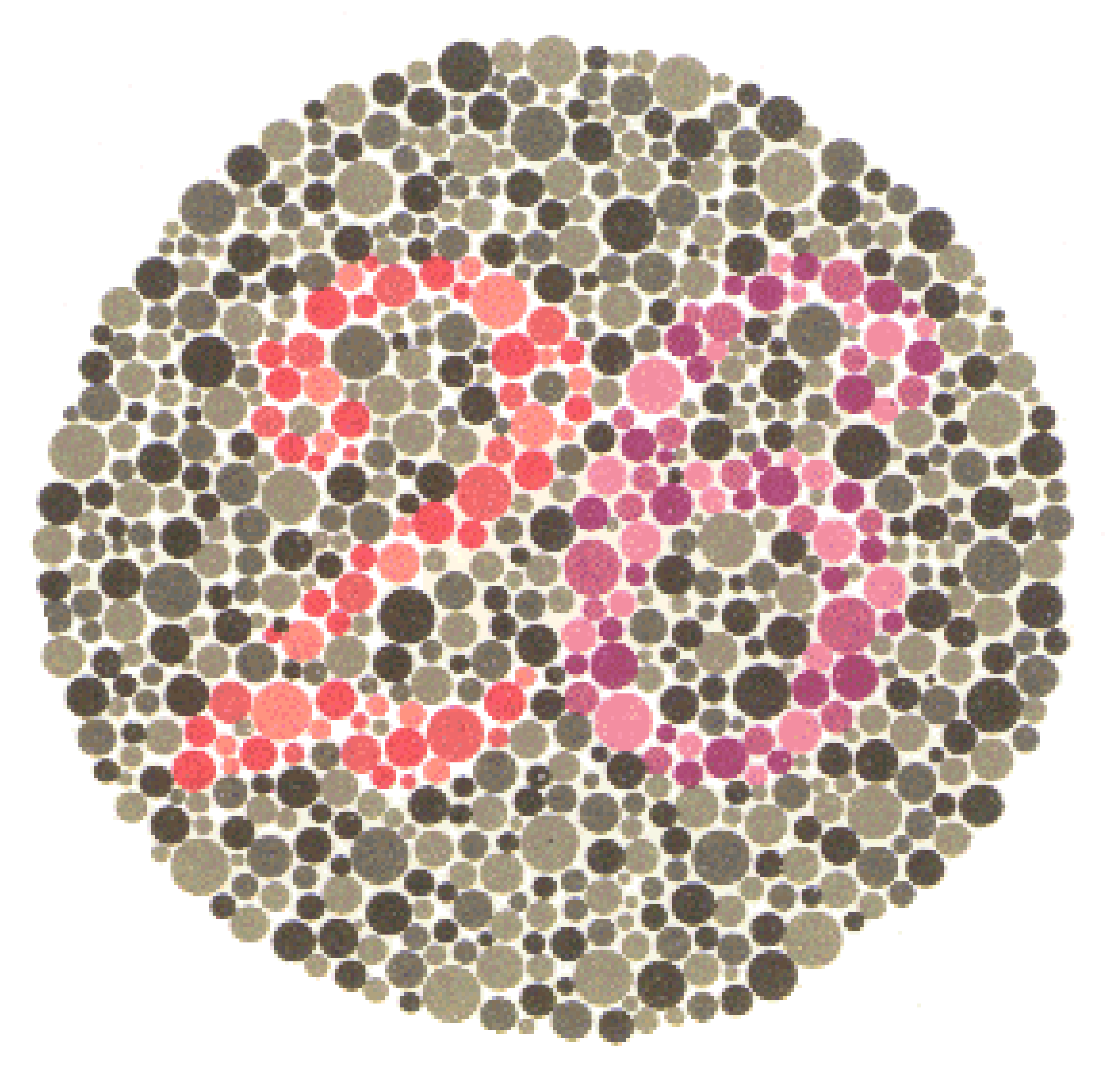


Color Vision Test

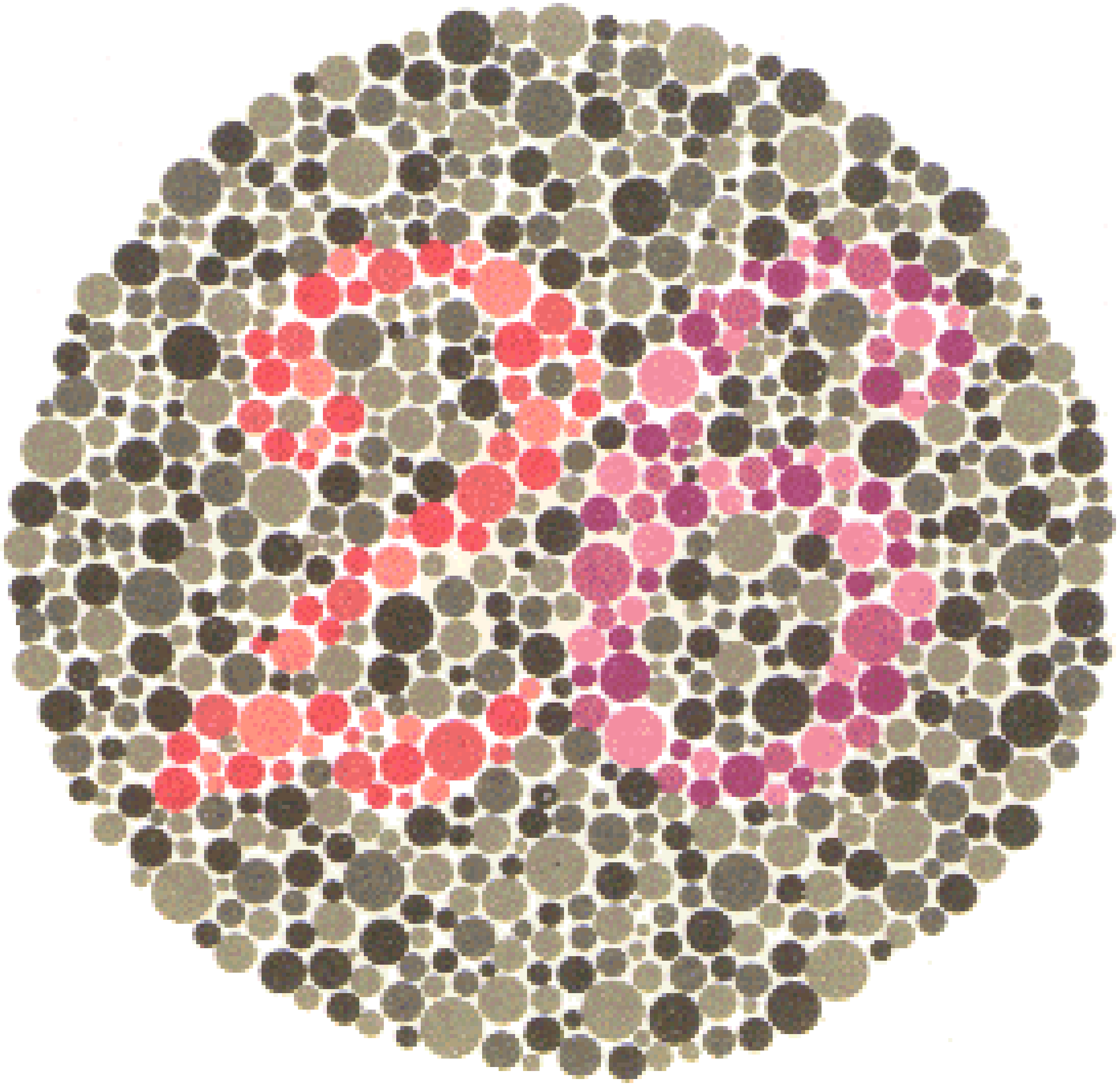
What number do you see?

If you see more than one…which is clearer?

http://www.kcl.ac.uk/teares/gktvc/vc/lt/colourblindness/plate2.htm



Color Vision Test



Normal colour vision should read the number 26.

In protanopia and strong protanomalia the number 6 is read and in mild protanomalia both numerals are read but the number 6 is clearer than the number 2.

protanopia

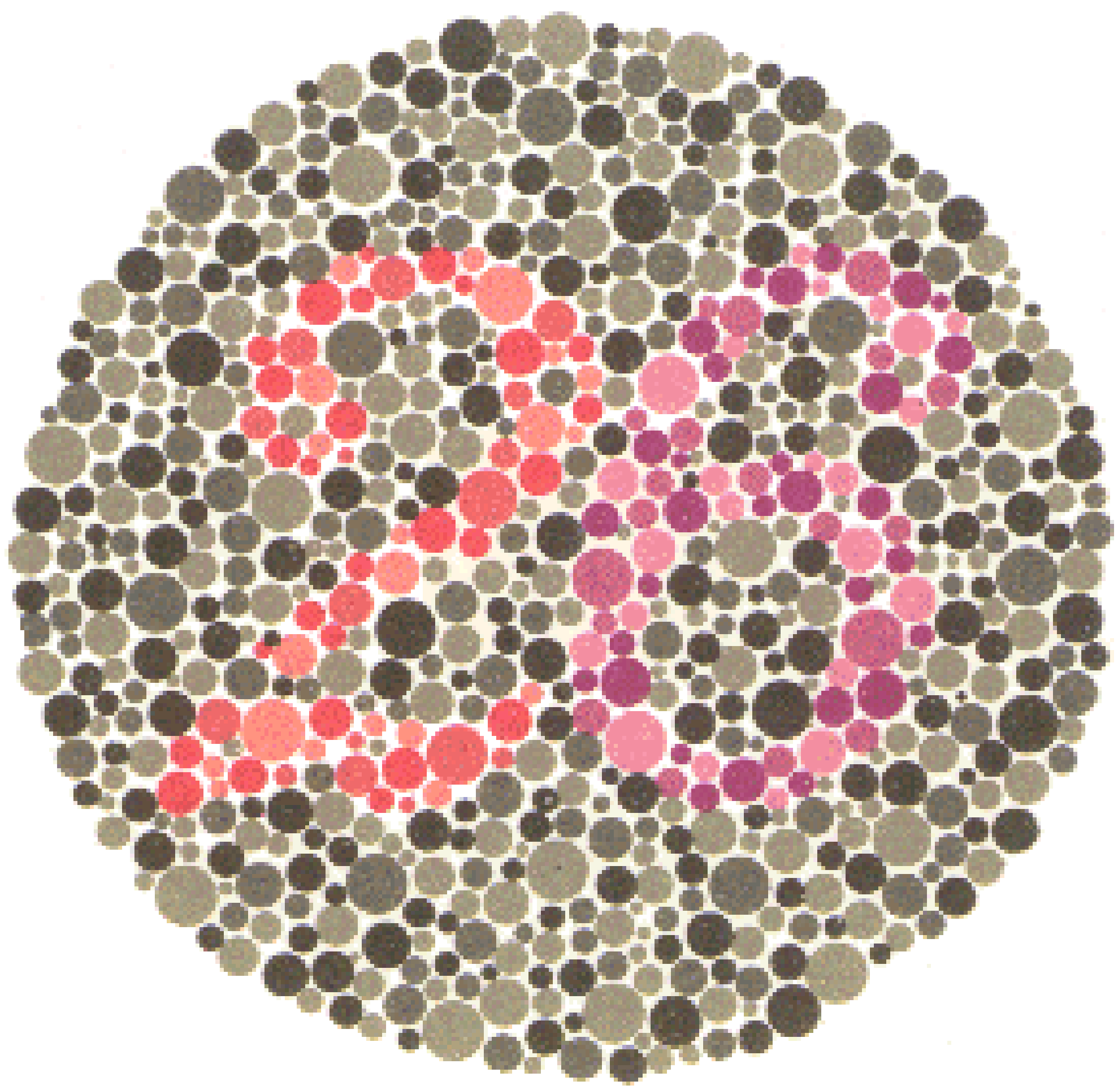
(pro·ta·no·pi·a)
A form of colorblindness characterized by defective perception of red and confusion of red with green or bluish green.

(Red-Green blindness)

http://www.kcl.ac.uk/teares/gktvc/vc/lt/colourblindness/plate2.htm

Color Vision Test

In deuteranopia and strong deuteranomalia only the number 2 is read and in mild deuteranomalia both the number 2 is clearer than the number 6.



deuteranopia

(deu·ter·a·no·pi·a)

A form of colorblindness characterized by insensitivity to green.

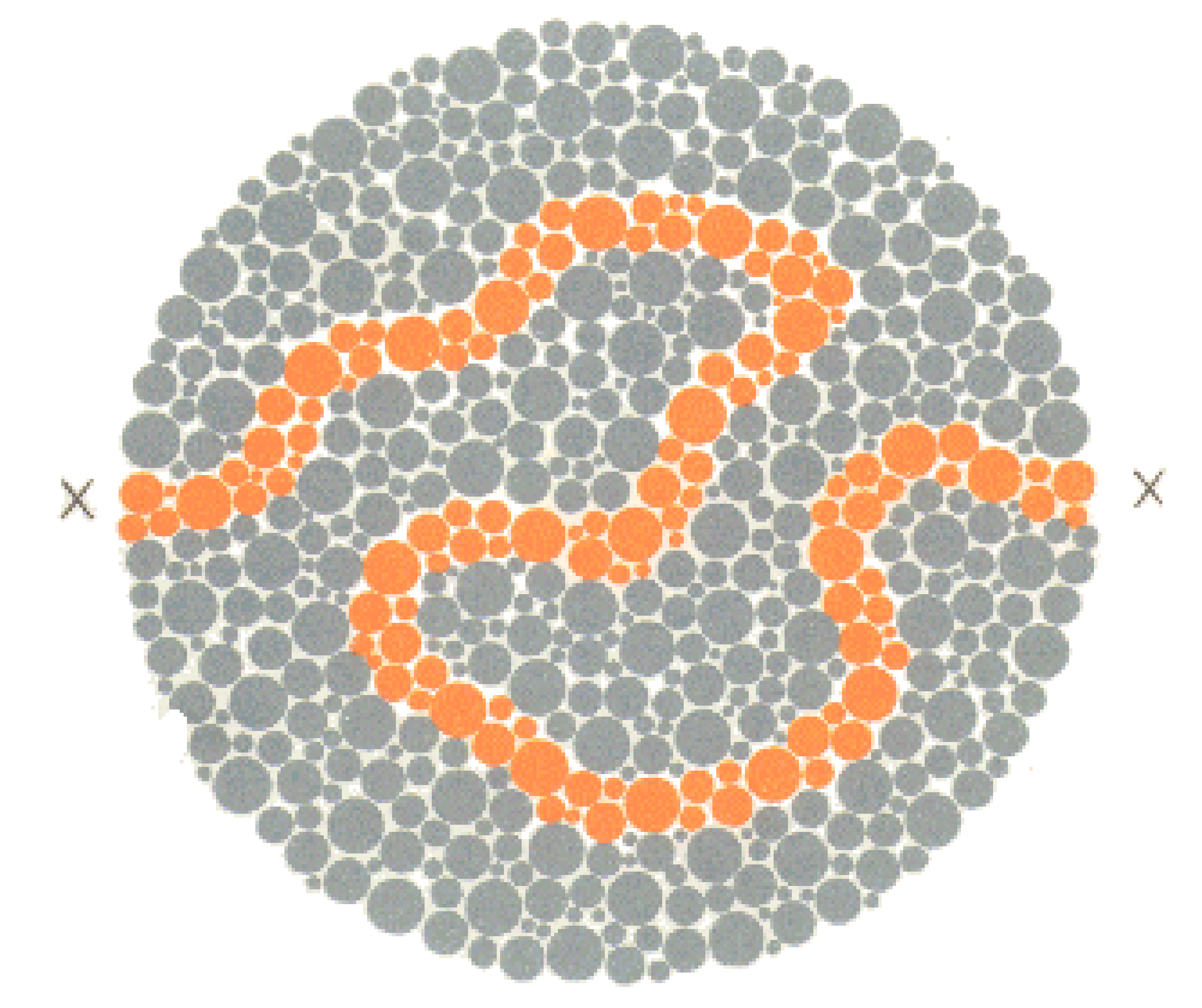
…resulting in an inability to distinguish green and purplish-red

http://www.kcl.ac.uk/teares/gktvc/vc/lt/colourblindness/plate2.htm

Color Vision Test

Trace or draw the path between the X' s.

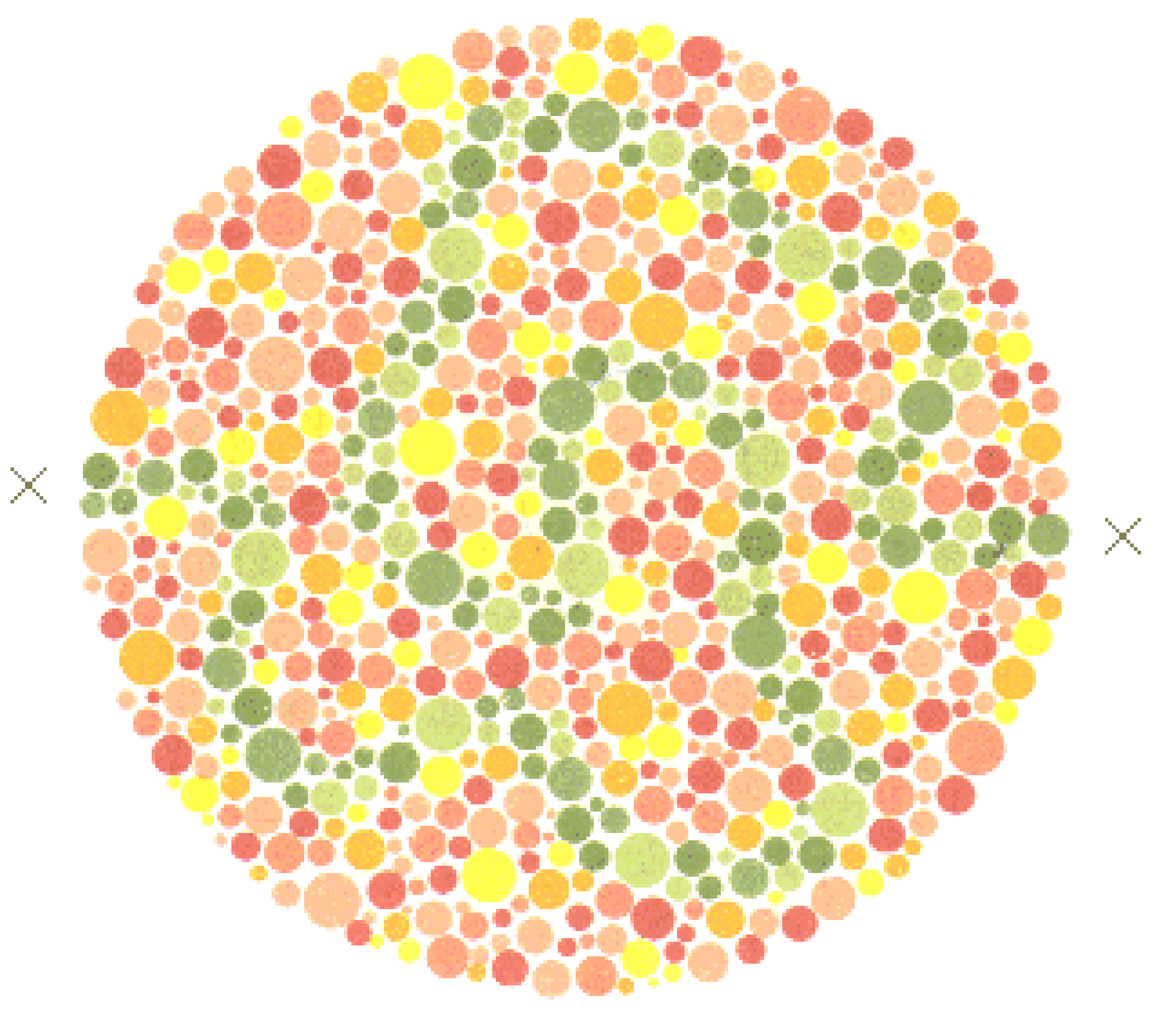
http://www.kcl.ac.uk/teares/gktvc/vc/lt/colourblindness/plate2.htm



Color Vision Test

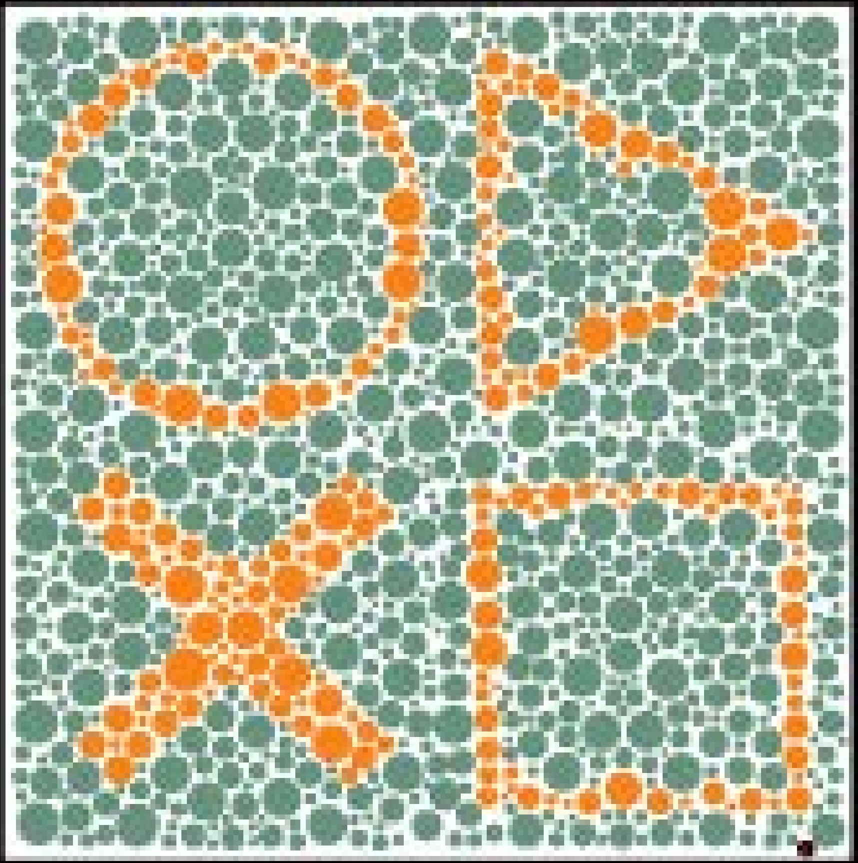
Trace or draw the path between the X's.

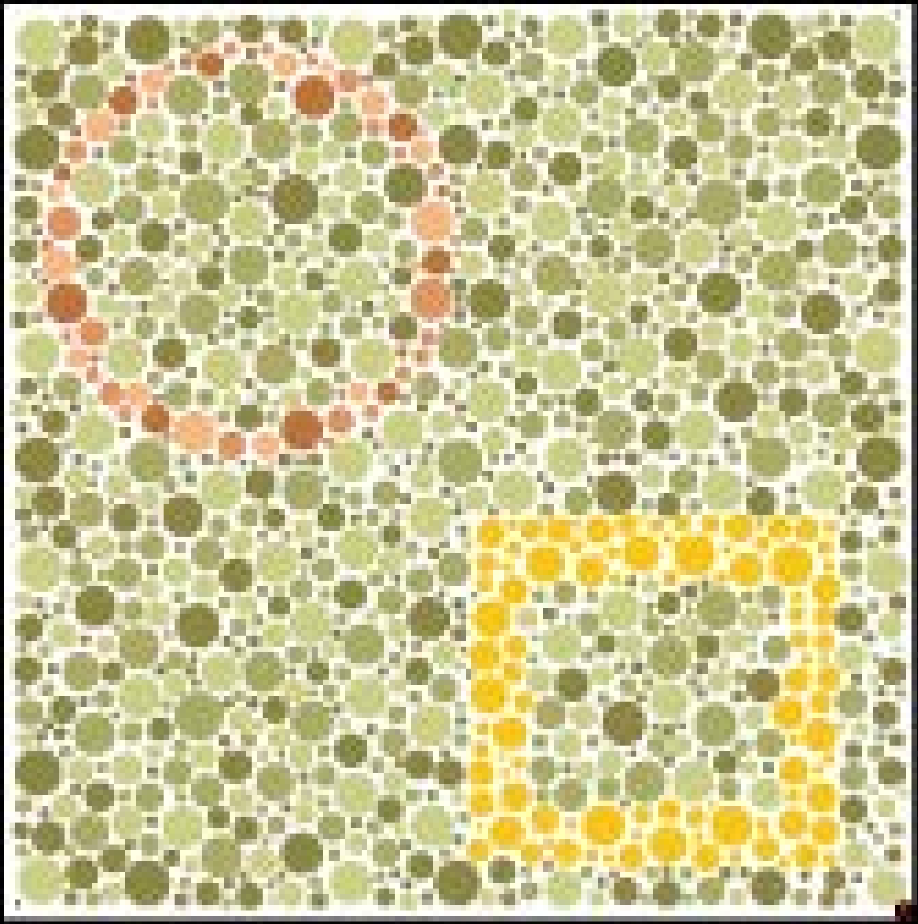
http://www.kcl.ac.uk/teares/gktvc/vc/lt/colourblindness/plate2.htm

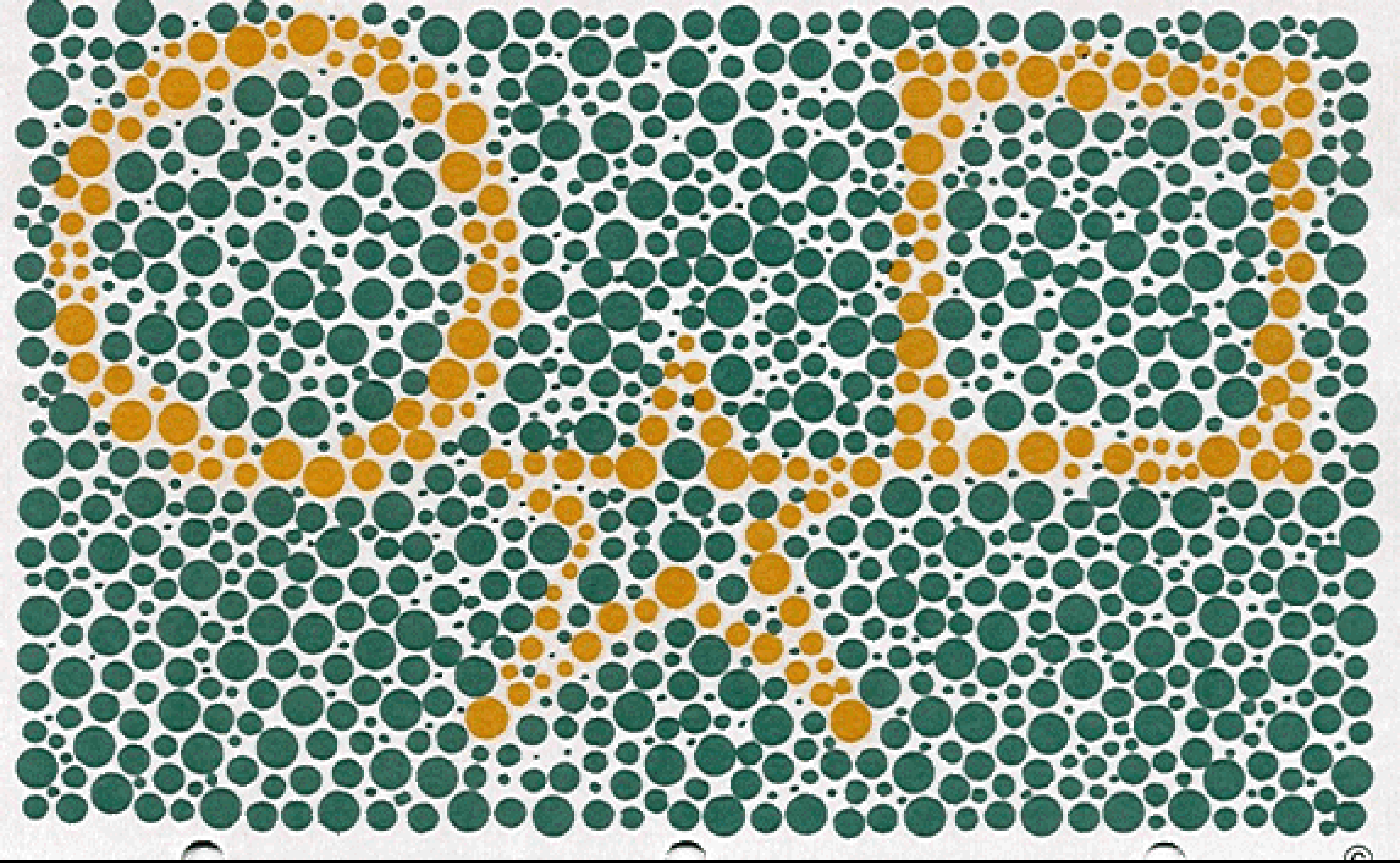


Pediatric Tests

Pediatric test — looks for shapes

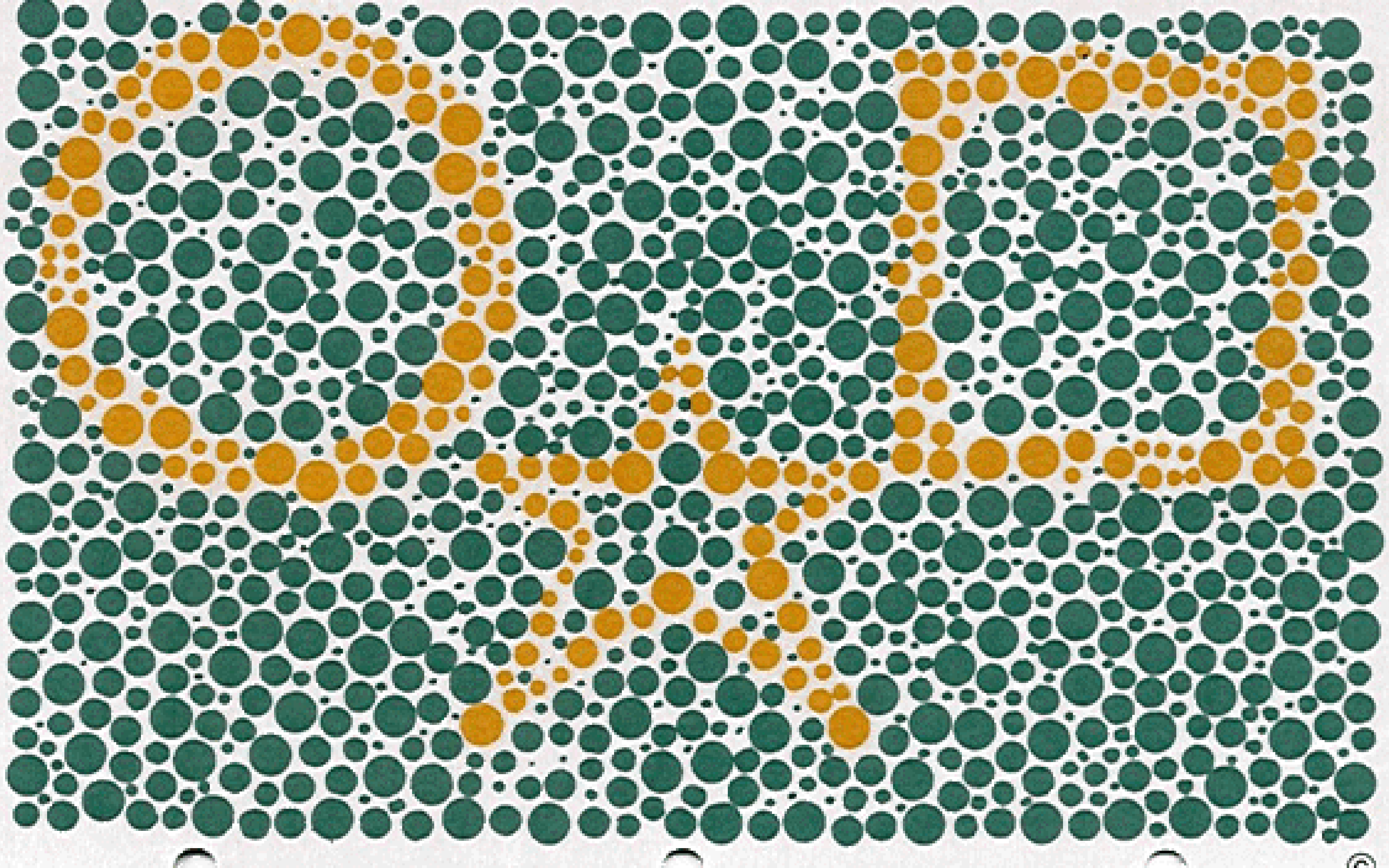






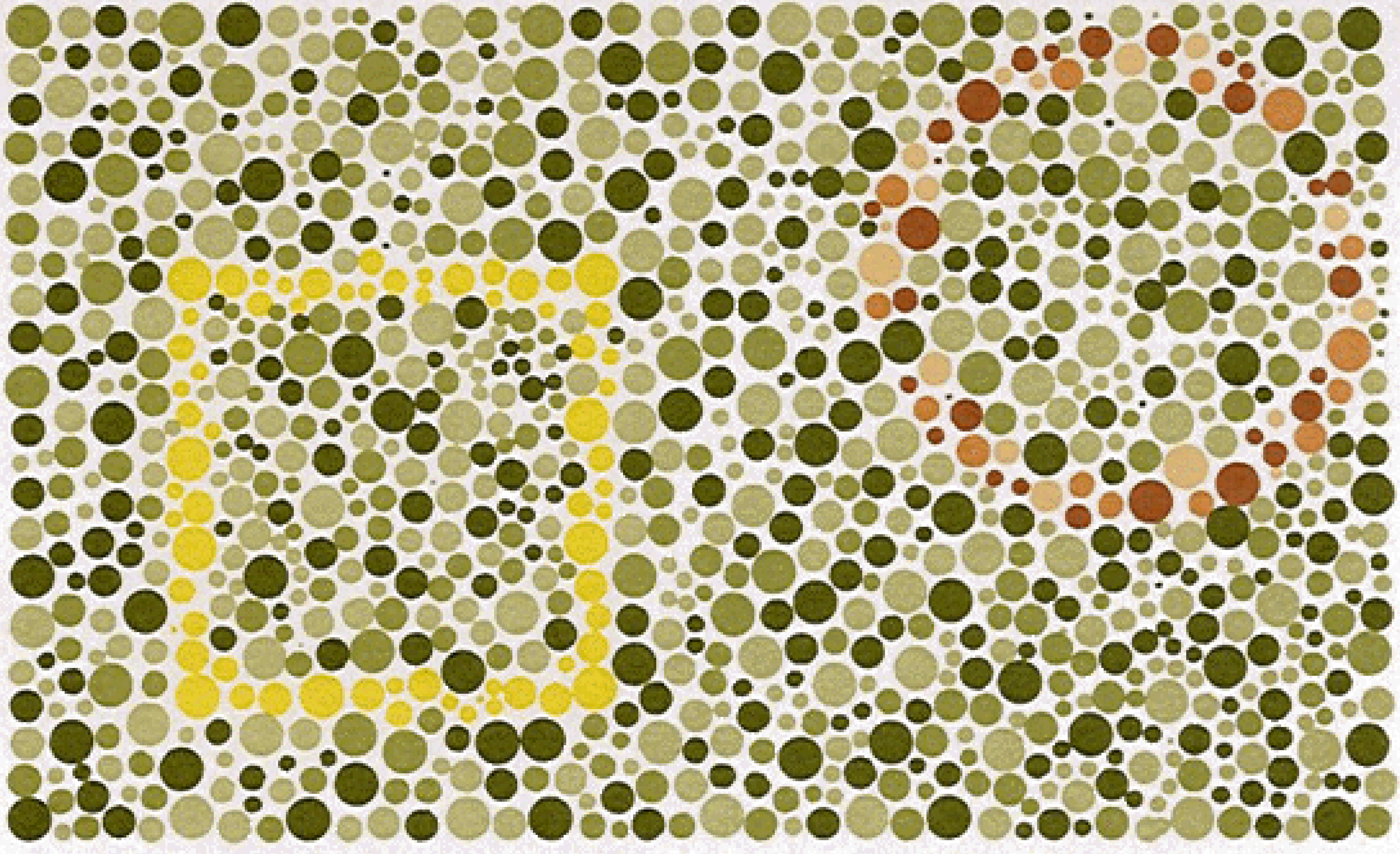
Pediatric Tests

- **Pediatric test — looks for shapes**



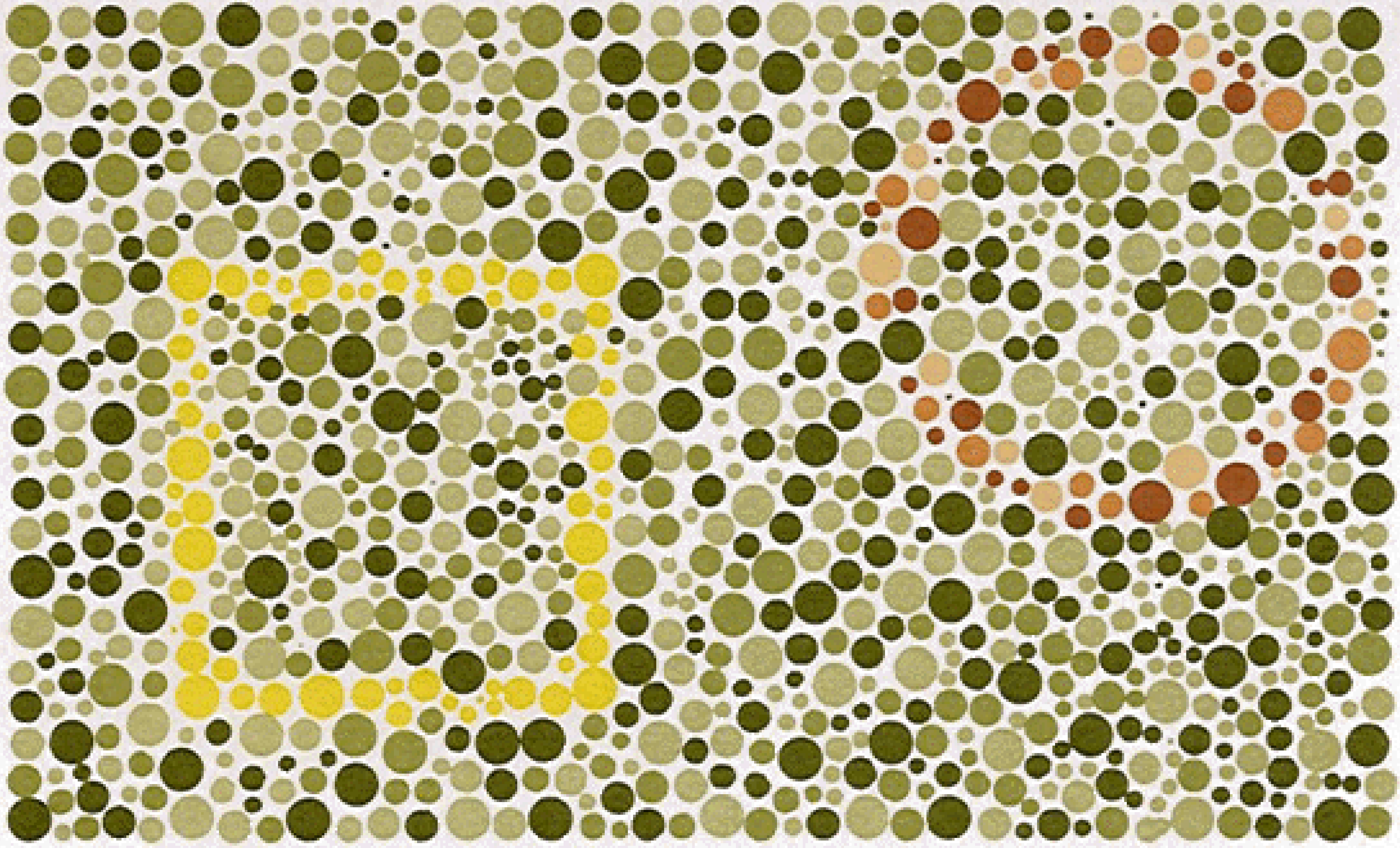
Pediatric Tests

- Everyone should be able to see the circle, square and star on this demonstration plate.



- **look for shapes**

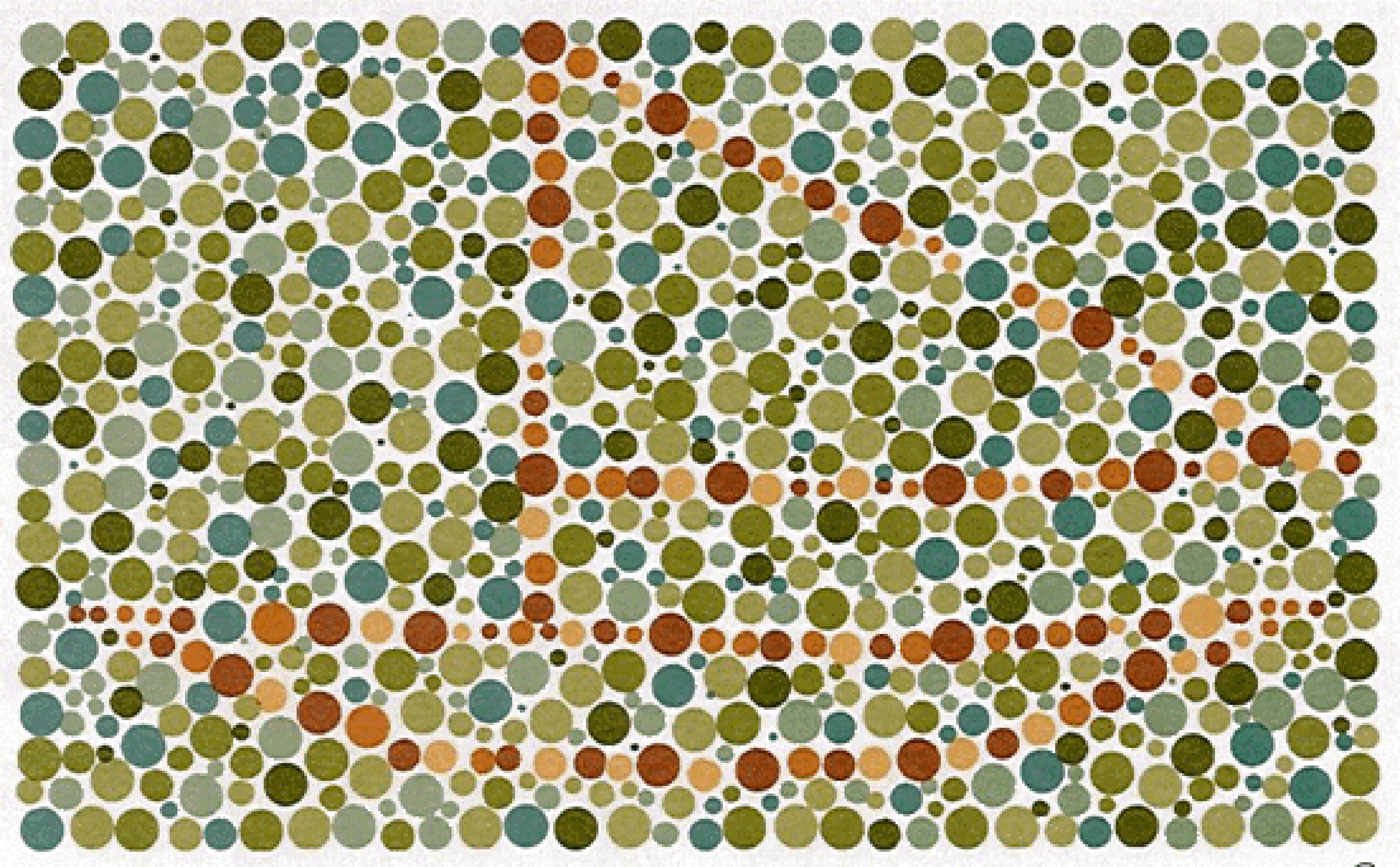
Color Deficiency Test



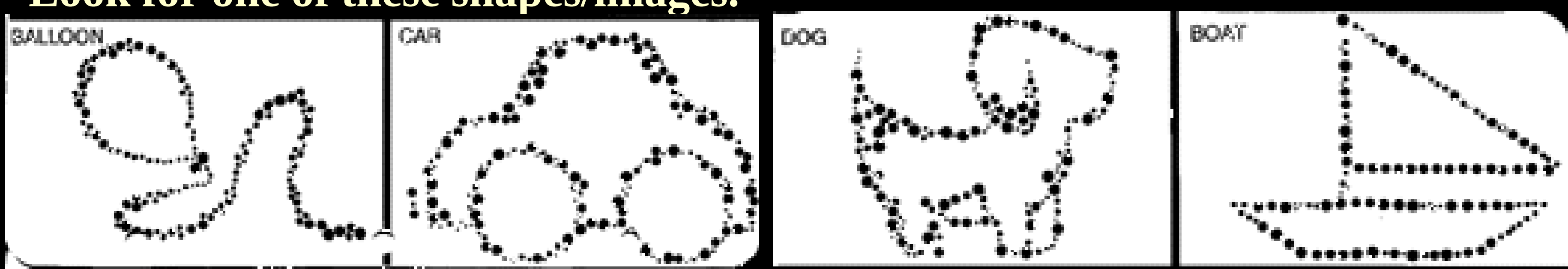
- **Colorblind individuals should be able to see only the yellow square.**
- **Color Normal individuals should be able to see the brown circle.**

Color Deficiency Test

Color Deficiency Test



- Look for one of these shapes/images.



Color Blindness

Many color blindness tests and information on color blindness are available on the web.

- **Web Resources:** **www.toledo-bend.com/colorblind/index.html**
- **colorvisiontesting.com**
- http://www.visualmill.com/
- http://www.kcl.ac.uk/teares/gktvc/vc/lt/colourblindness/cblind.htm

Color Blindness

"Color blindness (color vision deficiency) is a condition in which **certain colors cannot be distinguished**, and is most commonly due to an **inherited condition**.

"Red/Green color blindness is by far the most common form, about 99%, and causes problems in distinguishing reds and greens.

"Another color deficiency Blue/Yellow also exists, but is rare and there is no commonly available test for it."

- **Web Resources:** **www.toledo-bend.com/colorblind/index.html**
- **colorvisiontesting.com**

Color Blindness

“Depending on just which figures you believe, color blindness seems to occur in about 8% - 12% of males of European origin and …

…about one-half of 1% of females.

“Total color blindness (seeing in only shades of gray) is extremely rare.”

Color Blindness

"Color blindness is usually classed as a disability; however…

…in select situations color blind people have advantages over people with normal color vision.

Color blind hunters are better at picking out prey against a confusing background, and…

…the military have found that color blind soldiers can sometimes see through camouflage that fools everyone else.

Monochromats may have a minor advantage in dark vision, but only in the first five minutes of dark adaptation."

www.spiritus-temporis.com/color-blindness/

Color Blindness

"It is most often of genetic nature…

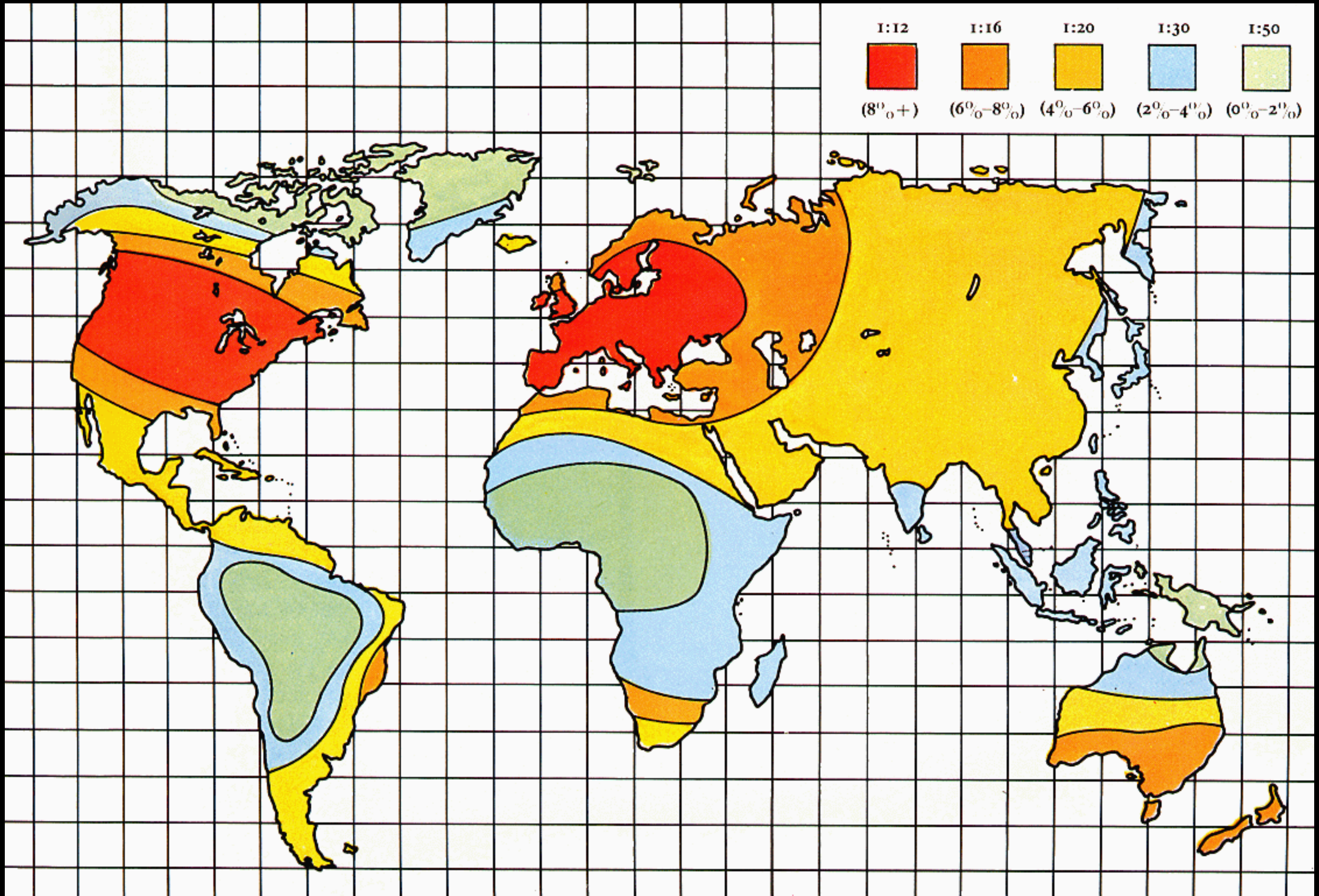
…but may also occur because of eye, nerve, or brain damage…

…or due to exposure to certain chemicals."

www.spiritus-temporis.com/color-blindness/

Color blindness incidence by culture/environment

- Industrialized nations are much more color blind than natives of rural or primitive regions.



Color Blindness

Color blindness varies by ethnicity.

"In Australia, for example, approximately 4% of the population suffers from some deficiency in color perception.

"Isolated communities with a restricted gene pool sometimes produce high proportions of color blindness, including the less usual types. Examples include rural Finland and some of the Scottish islands."

www.spiritus-temporis.com/color-blindness/rates-of-occurrence.html

Color blindness

Web Resources:

Lots of questions about color blindness…

…and a few answers.

wiki.answers.com/Q/FAQ/8070-6

- www.toledo-bend.com/colorblind/index.html

Purported color-blindness correction lenses.

(article/video)

http://www.colormax.org/1062180.html?gclid=COrujqzV_aMCFdFO5wodkDK-JQ

Color Blindness

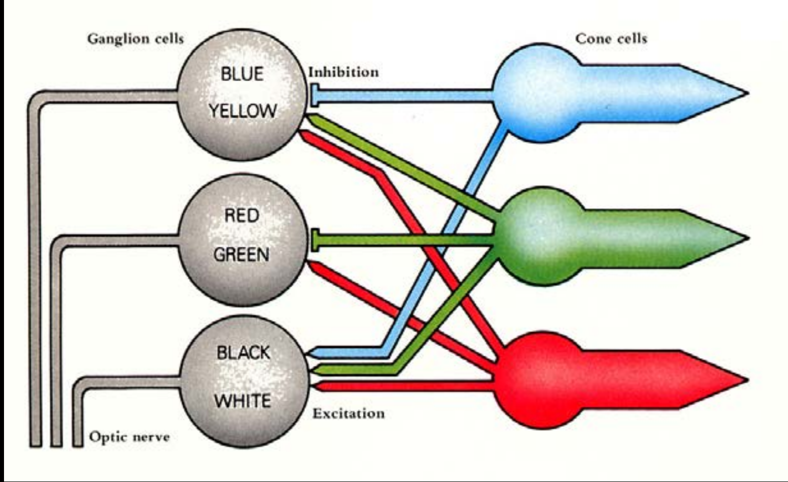
“There is no (well-accepted) treatment for color blindness, nor is it usually the cause of any significant disability. However, it can be very frustrating for individuals affected by it.

“Those who are not color blind seem to have the misconception that color blindness means that a color blind person sees only in black and white or shades of gray. … (complete color blindness) is possible, (but) it is extremely rare.

“Being color blind does keep one from performing certain jobs and makes others difficult.” (e.g. pilots, electricians..)

Forms of color blindness

- There are several forms of color blindness.
- *Red-green* blindness is most common among us. Such a person cannot distinguish a red and green traffic light (except by position.)
- There are varying degrees of color blindness.
- We assume that each particular form of color blindness is do to one of the types of cones being dysfunctional.



Genetics

- "Recent research in molecular biology reveals that a minimal genetic difference between two people…affects the way they see colors… "…there may be an almost infinite variety of ways that people see what is known as 'red.' "
- "Some 7 percent (of men) cannot distinguish red from green."

Culture & Environment

- Each culture appears to be conditioned to see color distinctions that are relevant to their survival…and other distinctions are generalized.

- e.g. Eskimos have twenty different words for "white" -- each with slightly different color traits.
  Why?
  Every color of snow, ice has traits revealed, in part, by color and surface quality. And survival depends on knowing the differences.

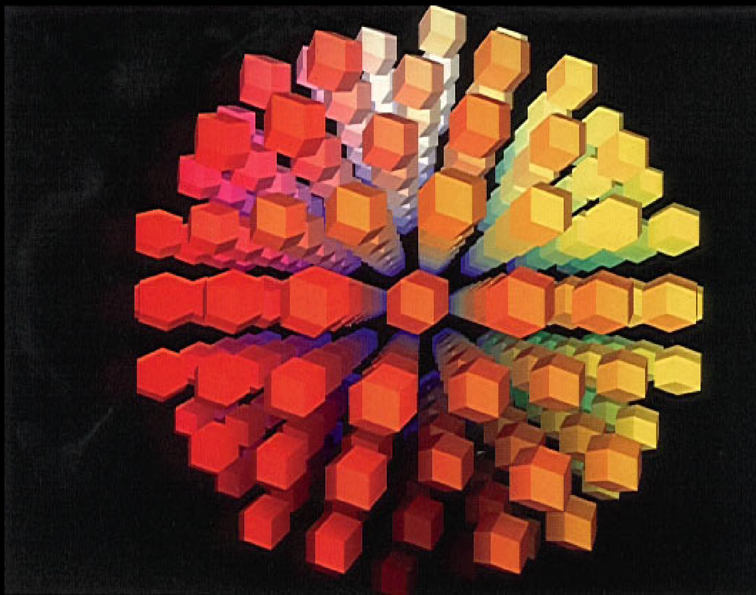
Emotions and Color

- When depressed, we see colors less vividly – more gray, lower chroma. (the blues?)
- Color can be used to induce emotions – gray versus red locker rooms.
  Gray prison spaces.
  Colorful grade school spaces.

Color Theory

- Chapter 3 **Perceiving Color** *(so far)*

- Lens & Iris & Retina
- Rods & Cones x3
- Fovea & Optic Nerve
- Color Afterimage
- Iodopsin & Rhodopsin
- Color Constancy
- Northern Light
- Non-human color vision



Color Theory

- Chapter 3 **Perceiving Color** *(next time)*

- Color Blindness
- Simultaneous Contrast