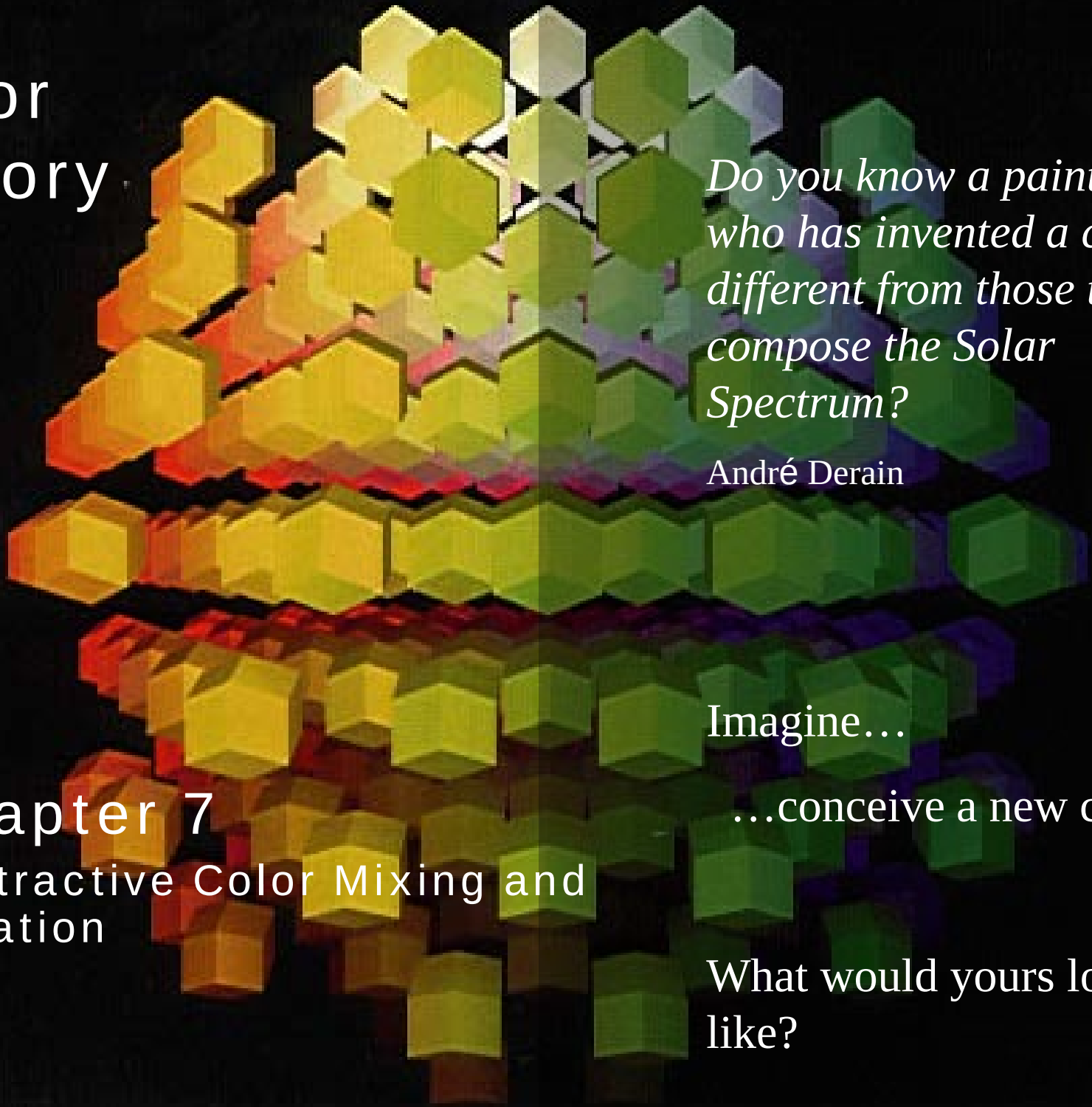
Color Theory



Do you know a painter who has invented a color different from those that compose the Solar Spectrum?

André Derain

Imagine…

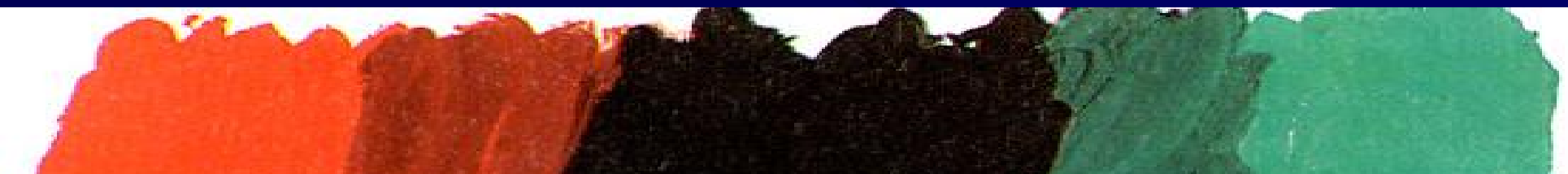
…conceive a new color.

What would yours look like?

- Chapter 7
- Subtractive Color Mixing and Notation

A Review of the Basics of Subtractive Mixing

- The general principles of subtractive color mixing have already been introduced.
- Since *all of your paint-mixing experiences involve subtractive mixing*, you have a great deal of practical experience with the issues involved.
- We'll look at missing pieces — other media and applications that rely on colors mixed by pigments and dyes – *subtractive mixtures.*



In Review:

- Primaries
- Secondaries
- Tertiaries
- Pigments

Chapter 7

- Dyes vs. Pigments
- Color Specification Systems
  - Munsell Notation System
  - C.I.E. System
  - Pantone Matching System
- Mixing Oils and Acrylics
- Ceramic Glazes
- Colored Glass
- Color Printing
- Color Photography
- Fiber Dyes
- Fading of Subtractive Color

Dyes vs. Pigments vs. Lakes

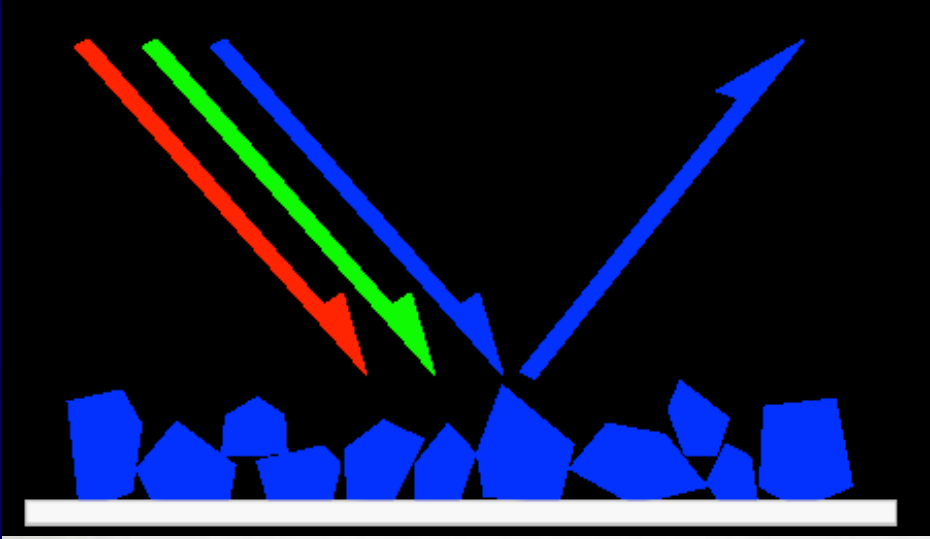
- Each of these are means of introducing color into a medium.
- **Pigments** are bits of power suspended (floating or mixed into) a medium. They tend to be opaque.
- **Dyes** are dissolved into a liquid solvent…in practice dyes are much, much smaller molecules than pigments. They tend to be transparent.
- **Lakes** are a compromise. Many paints need denser, more opaque pigments — traits that dyes to not offer. So dyes are used to stain a white pigment. Then that color pigment (a Lake) is mixed into a medium.

Pigments

- **Pigments** are bits of power suspended (floating or mixed into) a medium. They tend to be opaque.

Pigments

- “A pigment is a material that changes the color of reflected or transmitted light as the result of wavelength-selective absorption.
- “A pigment must have a high tinting strength relative to the materials it colors. It must be stable in solid form at ambient temperatures.
- “…permanence and stability are desirable properties. Pigments that are not permanent are called **fugitive**. Fugitive pigments fade over time, or with exposure to light, while some eventually blacken.
- en.wikipedia.org/wiki/Pigment



Earth Pigments

Earth pigments are literally ground dirt (carefully selected, separated, filtered).

- They are sometimes baked to induce a chemical change (Burnt Umber) …
  … and sometimes not (Raw Umber)

Earth Pigments... natural minerals

"The earliest known pigments were natural minerals. (i.e. earth pigments)

Natural iron oxides give a range of colors and are found in many Paleolithic and Neolithic cave paintings. Two examples include Red Ochre, anhydrous Fe_2O_3, and the hydrated Yellow Ochre ($Fe_2O_3.H_2O$).

"Charcoal, or carbon black, has also been used as a black pigment since prehistoric times."

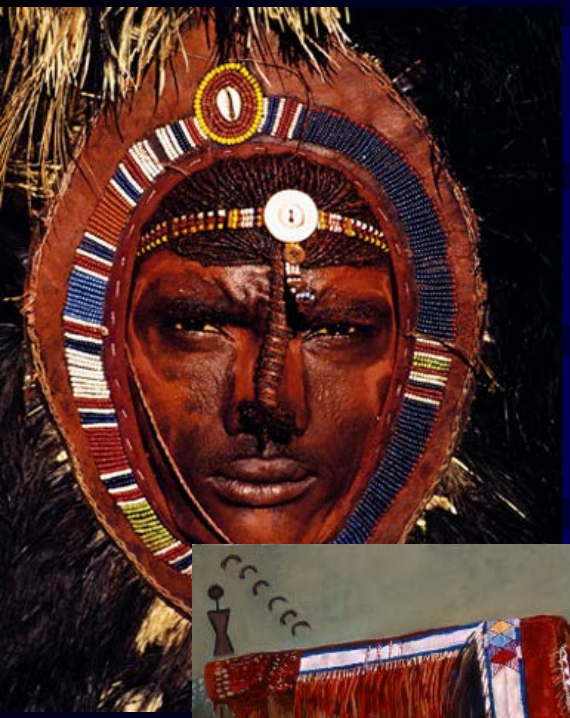
en.wikipedia.org/wiki/Pigment

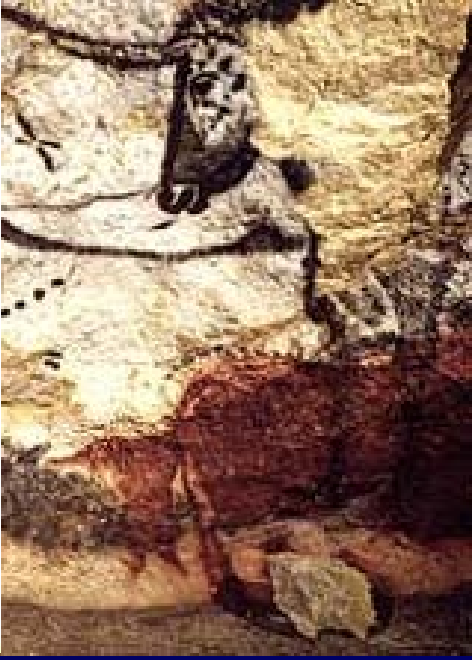
Cave painting of auroches in Lascaux, France.
Est. 30,000 b.c.e.

Reproduction of cave of Altamira, Spain in "Deutsches Museum", Munich. Original c. 18,000 b.c.e.

Red Ochre

Red Ochre, for instance, has been used by native cultures cross the globe.





Rousillon, France, in the Provencal region, is famous for its magnificent red cliffs and ochre quarries

Pigments

Batches of earth pigments tend to vary — each sample of minerals/dirt will have its own subtly distinctive color traits.
(no two shovelfuls of dirt are identical…right?)

- Several traditional earth pigments are now available in synthetic forms, offering color-consistent alternatives to traditional earth pigments.

Synthetic Pigments

"The Industrial and Scientific Revolutions brought a huge expansion in the range of synthetic pigments, pigments that are manufactured or refined from naturally occurring materials, available both for manufacturing and artistic expression. Because of the expense of Lapis Lazuli, much effort went into finding a less costly blue pigment.

"Prussian Blue was the first modern synthetic pigment, discovered by accident in 1704.

"By the early 19th century, synthetic and metallic blue pigments had been added to the range of blues, including French ultramarine, a synthetic form of lapis lazuli, and the various forms of Cobalt and Cerulean Blue. In the early 20th century, organic chemistry added Phthalo Blue, a synthetic, organometallic pigment with overwhelming tinting power."

en.wikipedia.org/wiki/Pigment

Sculpture by Yves Klein with a strong use of ultramarine blue.

Natural ultramarine pigment in powdered form

Synthetic ultramarine pigment is chemically identical to natural ultramarine

Synthetic Pigments

Where would we be without synthetic blue?

Really.

Dyes

- **Dyes** are dissolved into a liquid solvent…in practice dyes are much, much smaller molecules than pigments. They tend to be transparent.

Dyes are a preferred colorant in media where transparency is important.

Watercolors.

Acrylics/Oils when glazing is prevalent.

Dyes

- **The varying degrees of transparent/opacity offered by dye-based media can offer rich, vibrant hues and graceful transitions between colors.**

Dyes

- **…and some pretty bizarre and utterly fun fashion statements.**

Lakes

- **Lakes** are a compromise.
- Many paints need denser, more opaque pigments — traits that dyes to not offer.
- Dyes offer a vast range of hue and often intense chroma. So dyes are used to stain a white pigment. Then that color pigment (a Lake) is mixed into a medium.
- (I don't have info to verify this, but the powers in the photo are almost certainly Lakes rather than authentic pigments.)

Lakes

- A lake pigment is a pigment created when a dye is fixed ("stuck onto") to a powder, which is then mixed with a binder to create paint.

- Rose madder is an example of a lake pigment; the color comes from a dye created from madder root.

- Look out for the word "lake" on the label of the paint tube. It's not always mentioned in the name, but the pigment information may tell you. Also check the lightfastness rating of the color as some lake pigments are fugitive (the dyes fade when exposed to light).

Historical Lakes

- Indigo lake was originally produced from the leaves of woad, and was known in ancient Egypt.
- “Today, indigo is also produced by the bacterium E. coli through genetic engineering.”
- Required for true Denim blue.
- “To prepare the dye, freshly cut plants were soaked until soft, packed into vats and left to ferment. It was then pressed into cakes for use as a watercolor or dried and ground into a fine powder for use as an oil paint..”
- http://www.webexhibits.org/pigments/indiv/recipe/indigo.html

Historical Lakes

- Indigo lake in henna tattoos. Some folks have skin sensitivity issues with indigo. Color changes over time.

Historical Lakes

- Rose madder lake, originally from the root of the madder plant, is also known as alizarin crimson in its synthetic form. Since rose madder is fugitive when exposed to light, its use has been largely superseded, even in synthetic form, by quinacridone pigments.

- "Cloth dyed with madder root dye was found in the tomb of the Pharaoh Tutankhamun and in the ruins of Pompeii and ancient Corinth."

Illustration of the process:

making alizarin in the laboratory:

The solution of sodium carbonate is poured into the solution of aluminum sulfate

Precipitate of aluminum hydroxide

alizarin mixed with castor oil

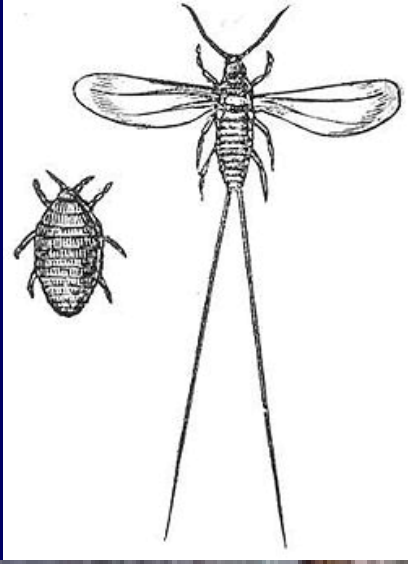
alizarin is added to the aluminum hydroxide

Reaction mixture after heating for one hour

Historical Lakes

- Carmine lake was originally produced from the cochineal insect, native to Central and South America. It is also called crimson lake.

- When the Spanish conquered the Aztec Empire (1518-1521), they encountered Aztec warriors garbed in an unknown crimson color. Cochineal became their second most valuable export from the New World, after silver, and the Spanish zealously guarded the secret of its production for centuries



From Craft to Manufacture

hand-made to mass-produced

Studio-art to printing-house production

- Artists and Designers historically have mixed their own paints/colors.
- *19th century industrialism* changed that.
- Mass production, scientific research methods, new means of testing and new sources of materials coalesced to *produce predictable and available pigments*, paints, dyes, and inks.

Communicating Color

- Production Demands *Quality Control*
- One of the goals of color suppliers, manufacturers and businesses is to assure that *the color you want is the color you get – first time, every time*.

Color Specification Systems

- The goal is a *system for describing a VERY specific color*.
- All visual design professions need to describe & control the colors produced *by others*.
- It doesn't matter if the design looks great on your computer screen when you designed it, it must look good in the *finished product*.

The Professional Concerns

- *Designers contract with other professions* to complete the work. The designer must have a way to tell his supporting producers what to produce – therefore there must be some way to *describe* the exact color needed.

The Professional Concerns

- Graphic designers deal with inks and substrates (esp. paper & plastics).
- Interior designers deal with fibers, fabrics, paints, dyes and lighting.

- Availability of materials influences both how we describe our color selections, and the colors available to us.

Color standardization still not conquered

- Yet, color products are *still* not entirely “standardized”.
- If you buy “Cadmium Red” from two different manufacturers, don’t expect the same color.

Production Runs Still Vary

- You cannot order fabric or carpet from two different production runs (even from the same company and same factory) and expect an identical color match.

- Interior designers have to pre-order adequate fabric/carpet for an entire job – which can mean buying more fabric/paper/carpet than is needed, just to be safe.

Human color discernment

- One challenge is that, despite sensitive testing instruments and accurate pigment recipes, the human eye is capable of very fine color distinctions.

- Under good lighting, an average human can distinguish **up to seven million different colors**.

Standard Viewing Conditions

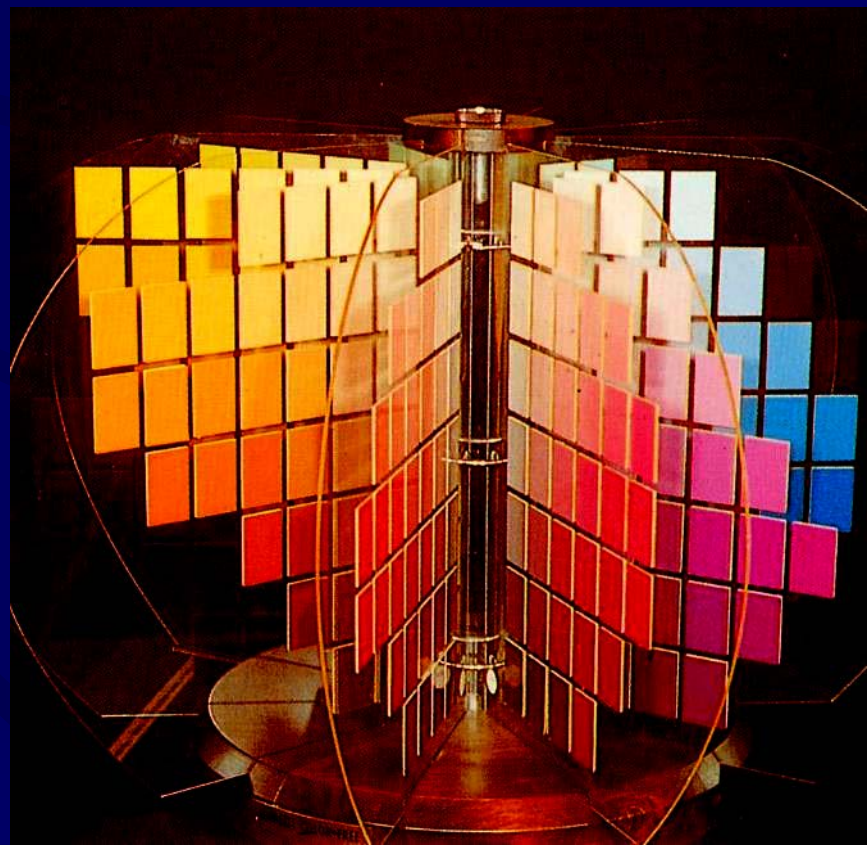
- *Controlled lighting conditions* help with color matching.
- Light boxes offer varied light sources for comparison.

Munsell Color Notation System

- Widely accepted international professional standard for color notation.

- TWO hue-notation options:
- 100-hue system
- 10-hue-group system

  (15/8/11 = 5YR/8/11)
- See text p. 73

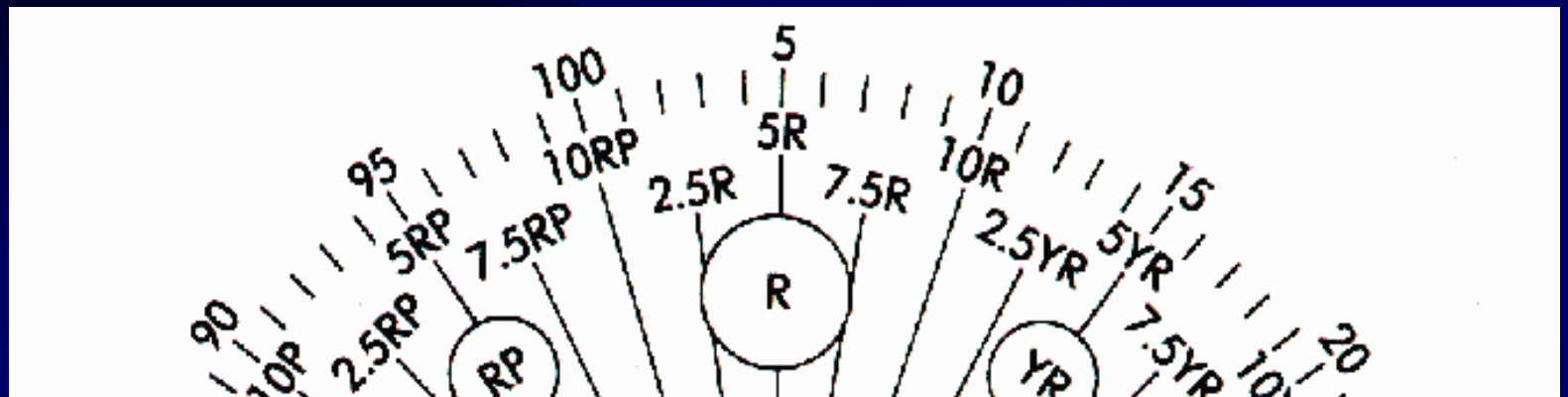


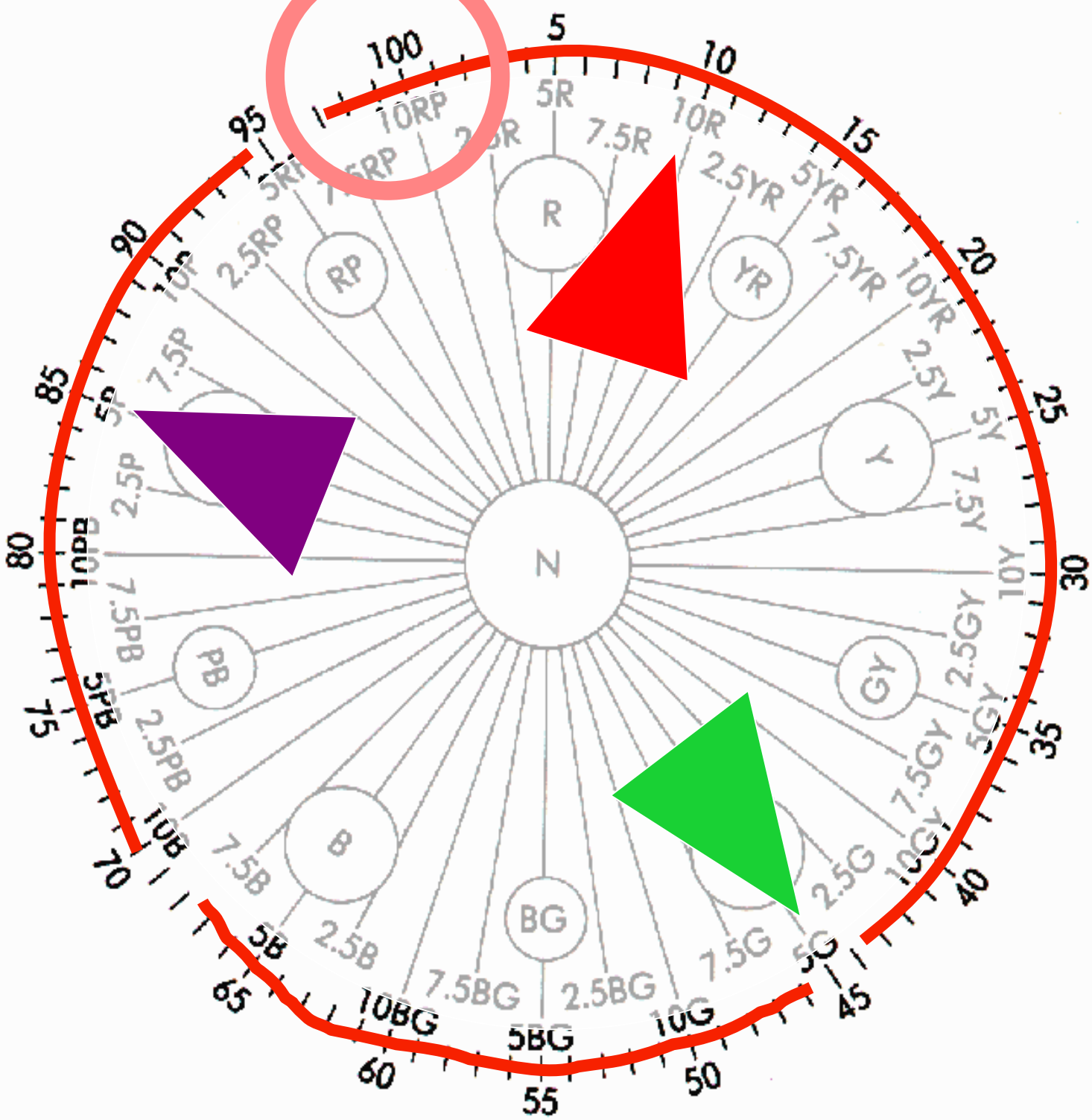
Munsell Color Notation System

- **100-hue system**
- Each hue described *by number only*: 1-to-100 clockwise from RRV.

A Hue of 50 would be a blue-green -- “6 o’ clock” on the wheel.

- (0-100 system not used so often by artists, but handy for digital systems.)





Munsell 100-hue Circle

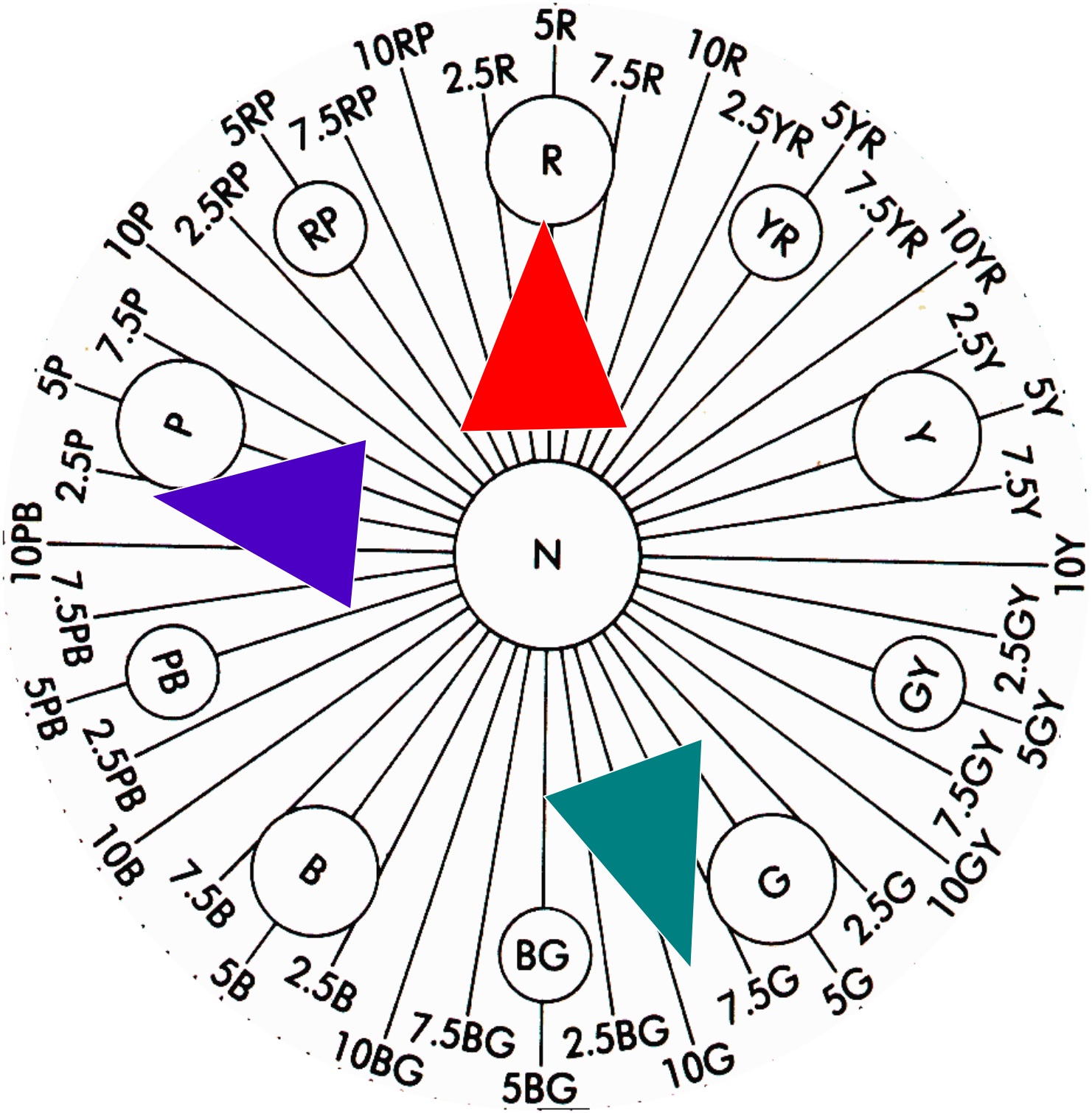
100-hue notation system

5 =Red

45=Green

85=Purple

100 & 0 at same location.



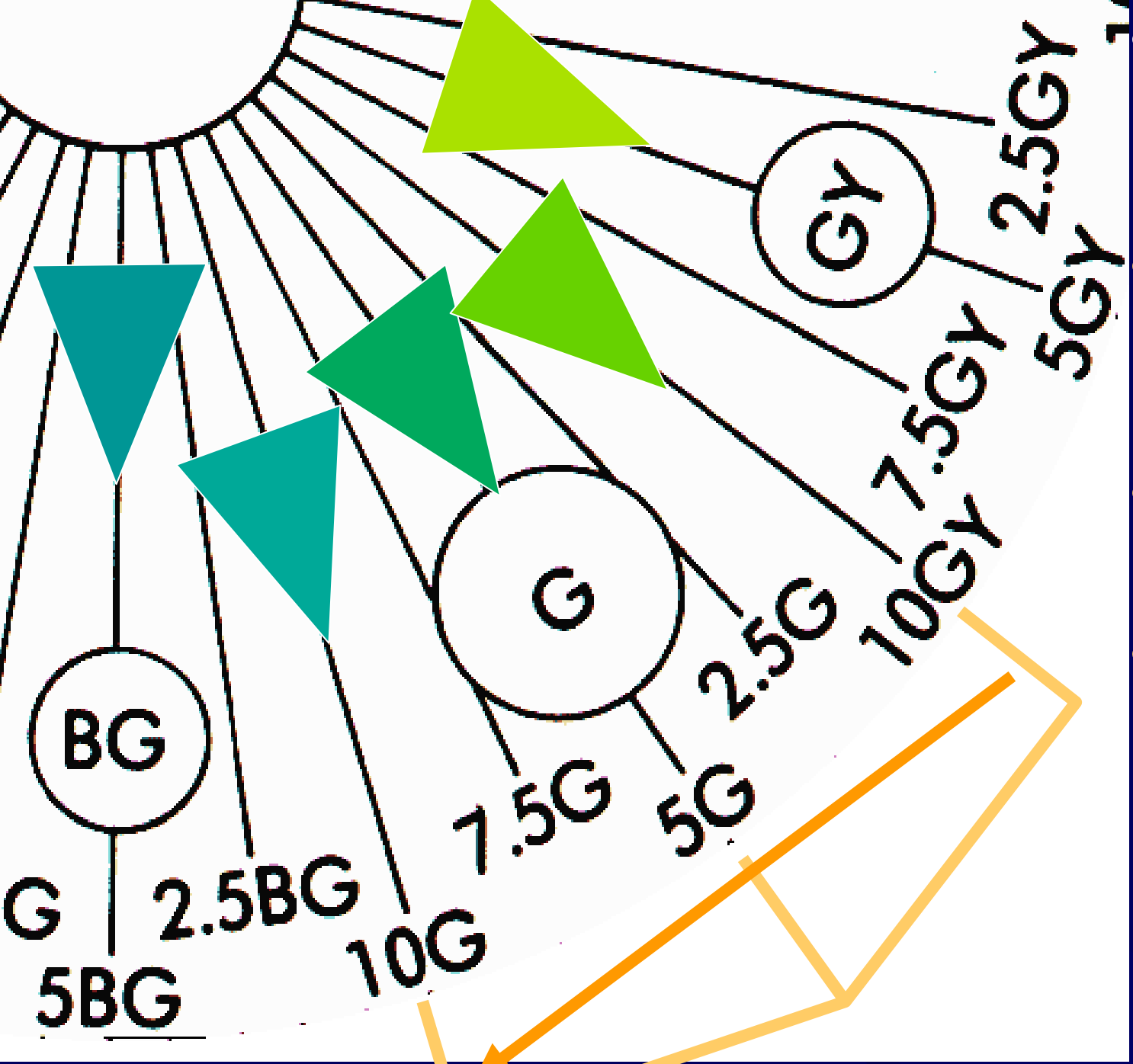
Munsell 100-hue Circle

10-hue group system

5R - “pure” red

9G - (BG)G

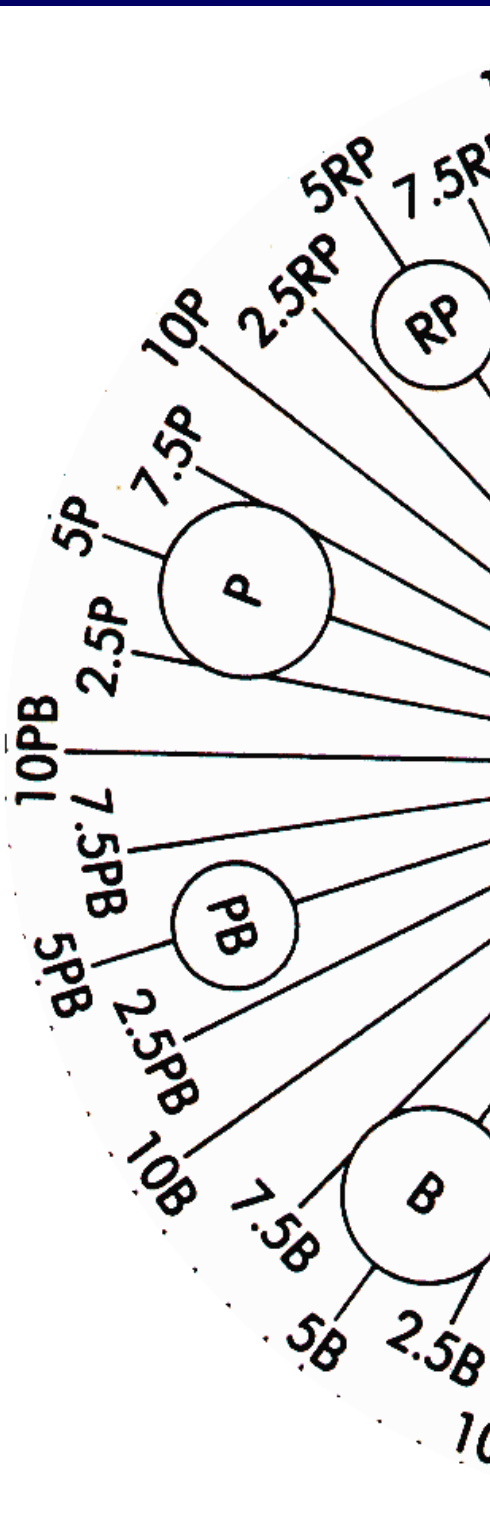
2P (BP)P



- Munsell “Greens”
- 0G - YG (=10YG)
- 5G - G
- 10G - BG (=0BG)

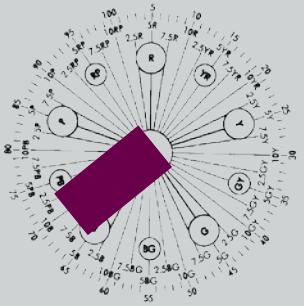
Munsell Hue-Number Notation

- **10-Hue-Group System**:
- a number-letter combination.
- Each of the 10 hues (primaries + secondaries of Munsell's wheel) have a unique acronym (**R, Y, G, B, P** – 5 primaries) (**YR, GY, BG, PB, RP** – 5 secondaries).



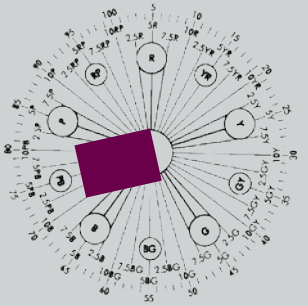
10B9/2 10B9/4
10B8/2 10B8/4 10B8/6 10B8/8
10B7/2 10B7/4 10B7/6 10B7/8 10B7/10 10B7/12
10B6/2 10B6/4 10B6/6 10B6/8 10B6/10
10B5/2 10B5/4 10B5/6 10B5/8
10B4/2 10B4/4 10B4/6 10B4/8
10B3/2 10B3/4 10B3/6
10B2/2 10B2/4
10B1/2

10 B 70



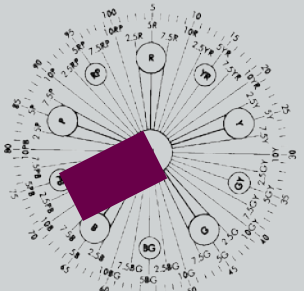
5PB9/2
5PB8/2 5PB8/4 5PB8/6
5PB7/2 5PB7/4 5PB7/6 5PB7/8 5PB7/10
5PB6/2 5PB6/4 5PB6/6 5PB6/8 5PB6/10 5PB6/12 5PB6/14
5PB5/2 5PB5/4 5PB5/6 5PB5/8 5PB5/10 5PB5/12 5PB5/14
5PB4/2 5PB4/4 5PB4/6 5PB4/8 5PB4/10 5PB4/12
5PB3/2 5PB3/4 5PB3/6 5PB3/8 5PB3/10
5PB2/2 5PB2/4 5PB2/6
5PB1/2 5PB1/4 5PB1/6

5 PB 75 Blue-Purple



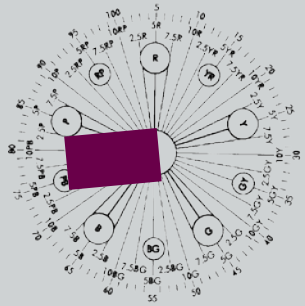
2.5PB9/2
2.5PB8/2 2.5PB8/4 2.5PB8/6
2.5PB7/2 2.5PB7/4 2.5PB7/6 2.5PB7/8 2.5PB7/10
2.5PB6/2 2.5PB6/4 2.5PB6/6 2.5PB6/8 2.5PB6/10 2.5PB6/12
2.5PB5/2 2.5PB5/4 2.5PB5/6 2.5PB5/8 2.5PB5/10
2.5PB4/2 2.5PB4/4 2.5PB4/6 2.5PB4/8 2.5PB4/10
2.5PB3/2 2.5PB3/4 2.5PB3/6 2.5PB3/8
2.5PB2/2 2.5PB2/4 2.5PB2/6
2.5PB1/2 2.5PB1/4

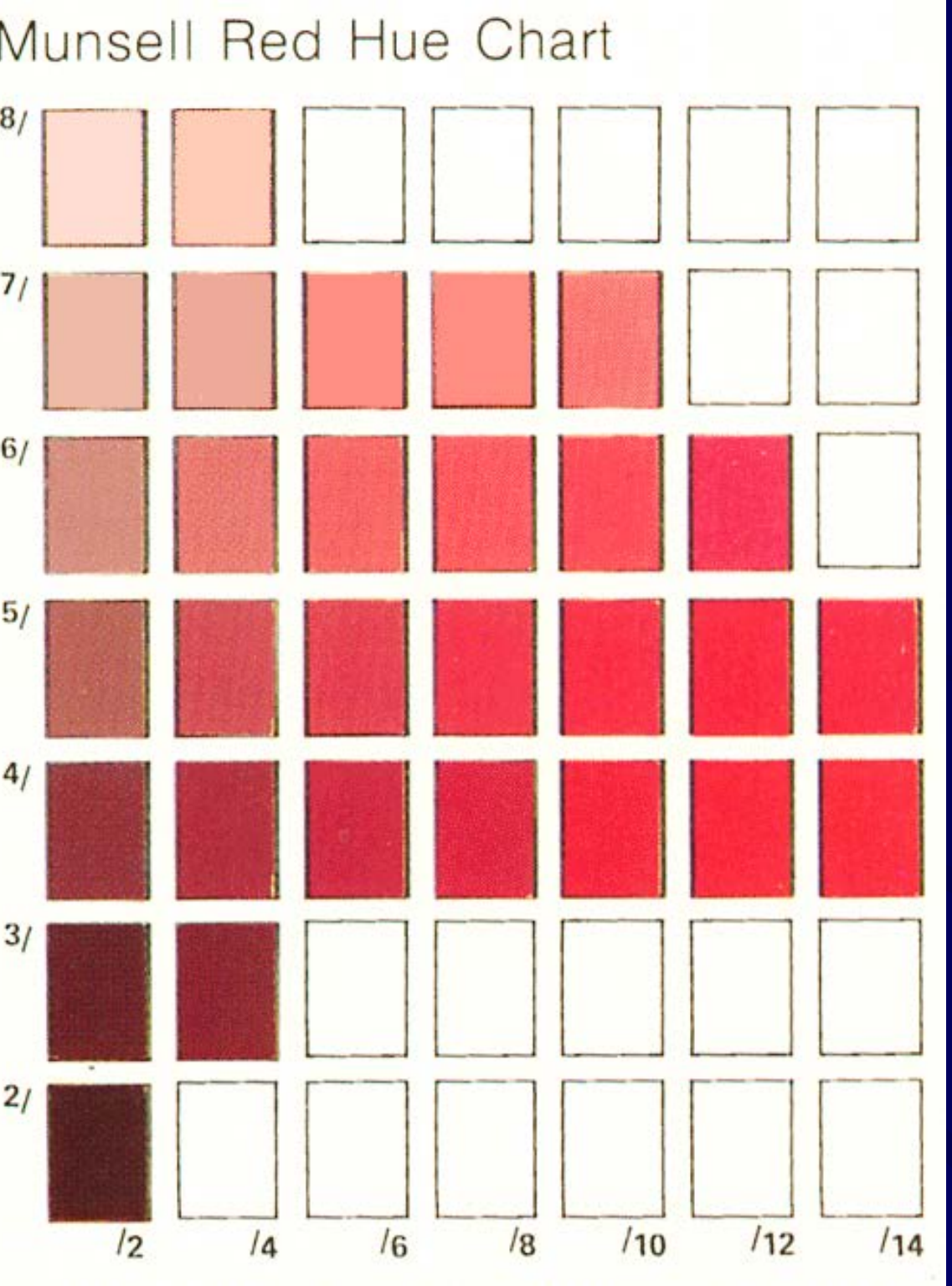
2.5 PB 72.5



7.5PB9/2
7.5PB8/2 7.5PB8/4 7.5PB8/6
7.5PB7/2 7.5PB7/4 7.5PB7/6 7.5PB7/8 7.5PB7/10
7.5PB6/2 7.5PB6/4 7.5PB6/6 7.5PB6/8 7.5PB6/10 7.5PB6/12 7.5PB6/14
7.5PB5/2 7.5PB5/4 7.5PB5/6 7.5PB5/8 7.5PB5/10 7.5PB5/12 7.5PB5/14 7.5PB5/16 7.5PB5/18
7.5PB4/2 7.5PB4/4 7.5PB4/6 7.5PB4/8 7.5PB4/10 7.5PB4/12 7.5PB4/14 7.5PB4/16 7.5PB4/18
7.5PB3/2 7.5PB3/4 7.5PB3/6 7.5PB3/8 7.5PB3/10 7.5PB3/12 7.5PB3/14 7.5PB3/16 7.5PB3/18
7.5PB2/2 7.5PB2/4 7.5PB2/6 7.5PB2/8 7.5PB2/10 7.5PB2/12 7.5PB2/14 7.5PB2/16 7.5PB2/18
7.5PB1/2 7.5PB1/4 7.5PB1/6 7.5PB1/8 7.5PB1/10 7.5PB1/12 7.5PB1/14

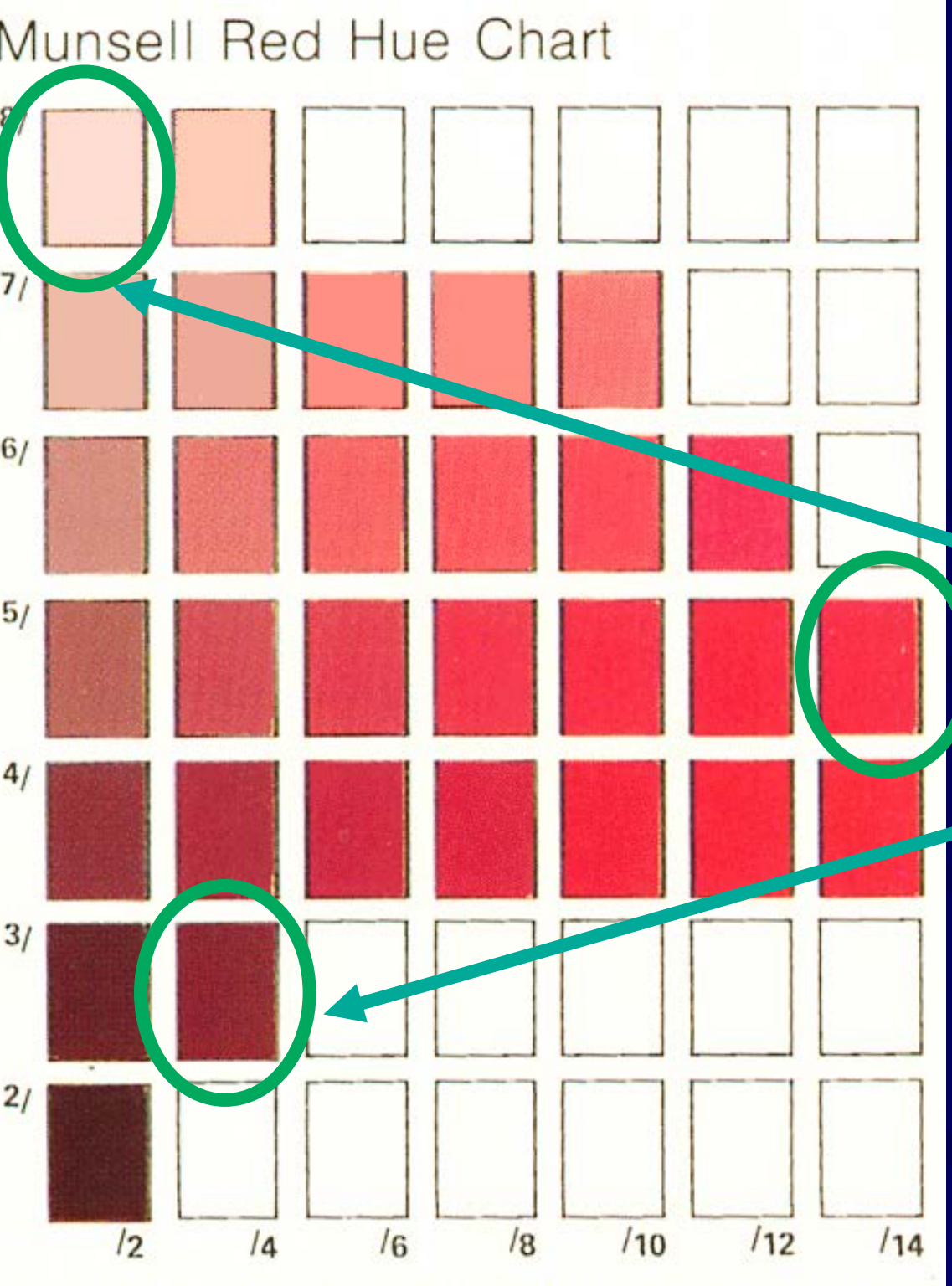
7.5 PB 77.5



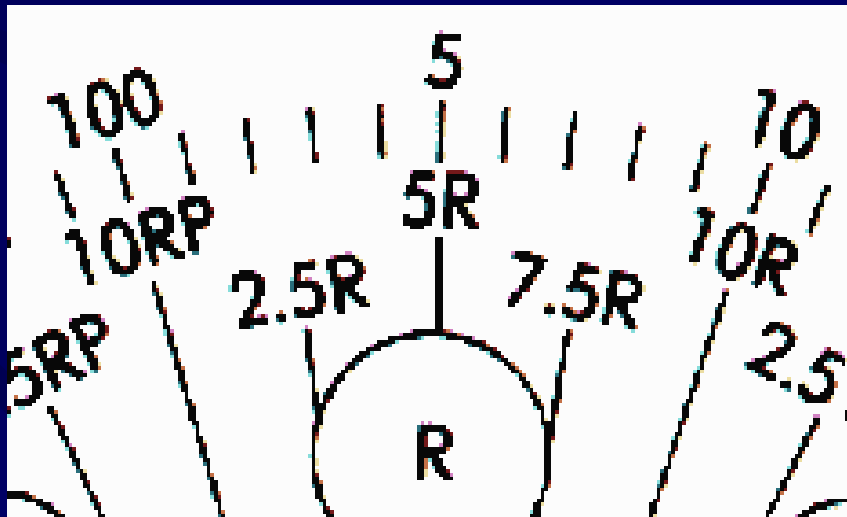


- Munsell
- Hue, value & chroma numbers.

- 5R/8/2
- 5R/5/14
- 5R/3/4

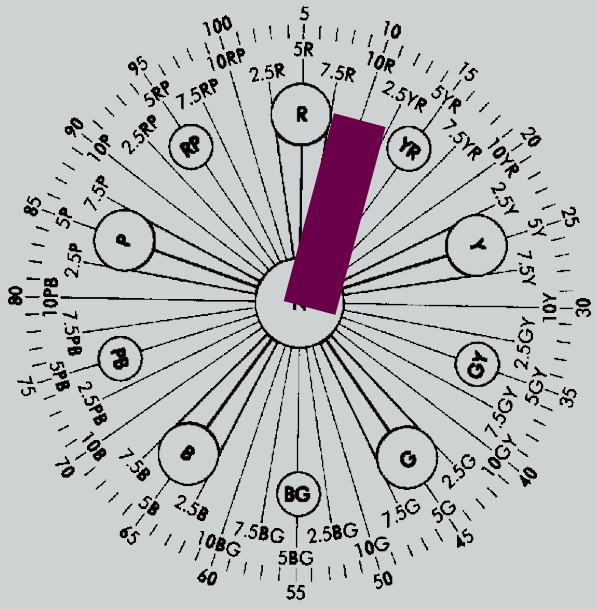


- Munsell Hue, value & chroma notation.
- 5R/8/2
- 5R/5/14
- 5R/3/4



10 RP
10

10R9/2							
10R8/2	10R8/4						
10R7/2	10R7/4	10R7/6	10R7/8	10R7/10			
10R6/2	10R6/4	10R6/6	10R6/8	10R6/10	10R6/12	10R6/14	10R6/16
10R5/2	10R5/4	10R5/6	10R5/8	10R5/10	10R5/12	10R5/14	
10R4/2	10R4/4	10R4/6	10R4/8	10R4/10	10R4/12		
10R3/2	10R3/4	10R3/6	10R3/8	10R3/10			
10R2/2	10R2/4	10R2/6	10R2/8				
10R1/2	10R1/4	10R1/6					



10 R
10

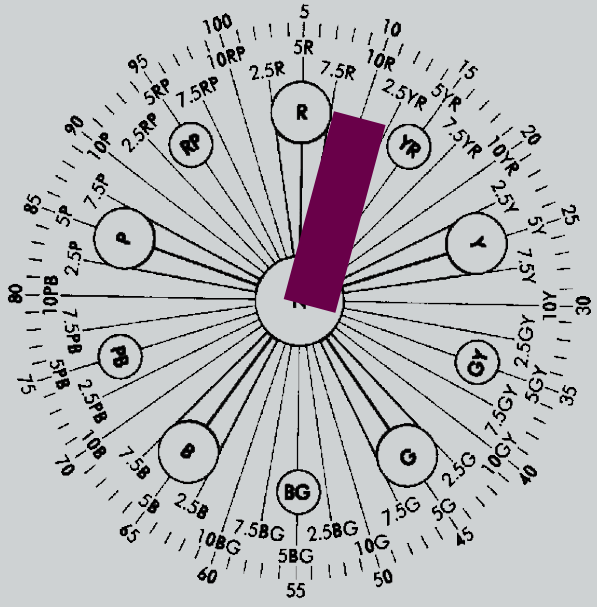
R7/8 10R7/10

R6/8 10R6/10 10R6/12 10R6/14 10R6/16

R5/8 10R5/10 10R5/12 10R5/14

R4/8 10R4/10 10R4/12

R3/8 10R3/10



0R6/12

10R6/14

10R6/16

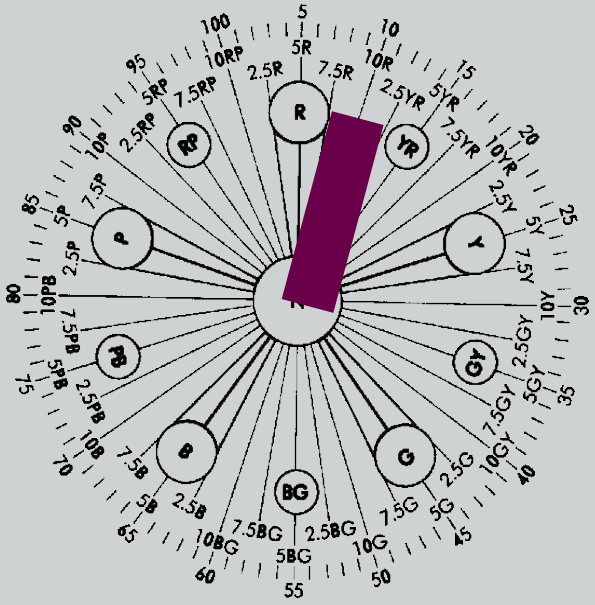
10 R
10

0R5/12

10R5/14

0R4/12

Hue: 10 R
Value: 5
Chroma: 14

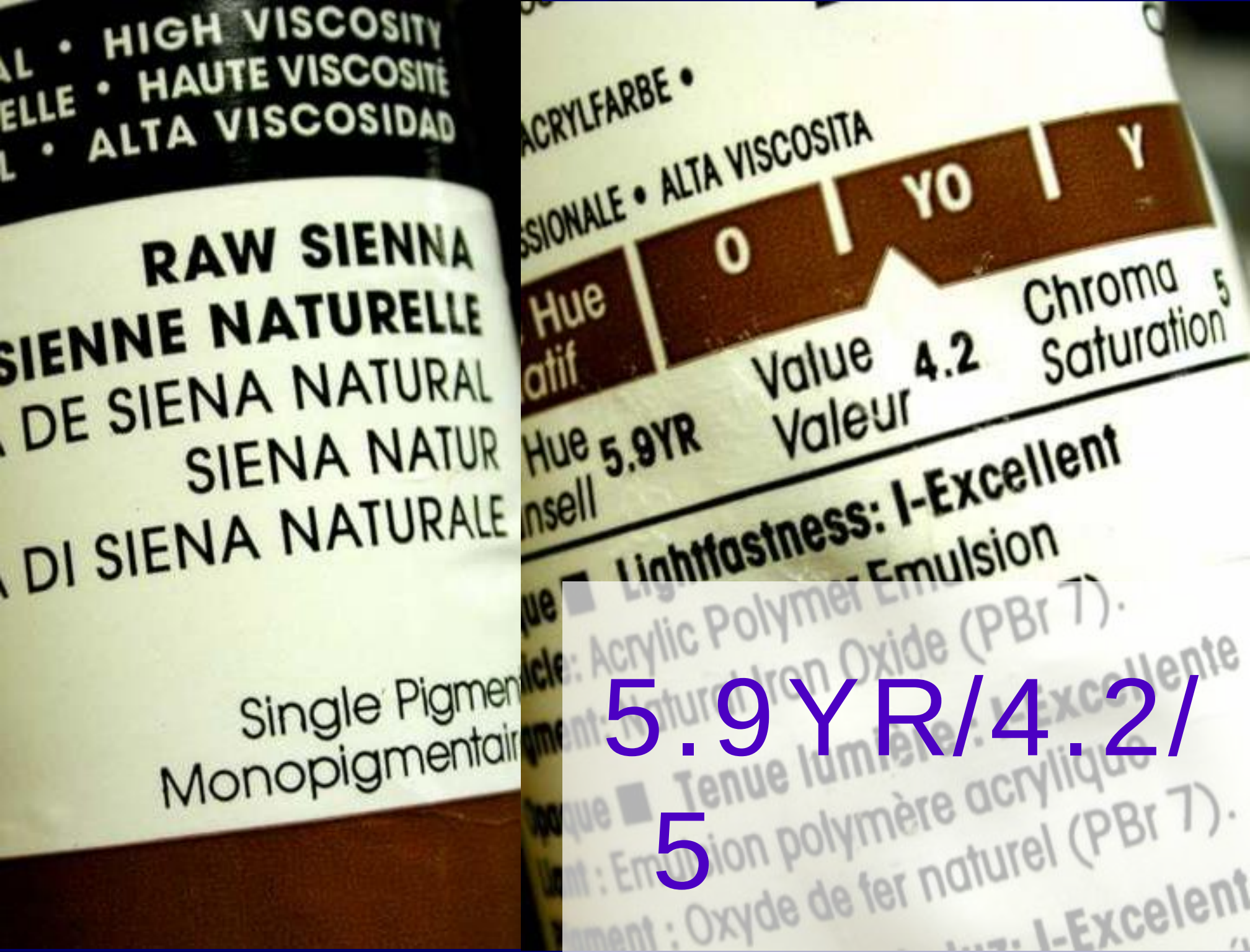


Munsell Value & Chroma Notation

- Values are numbered 0 (black) to 10 (white)

- Chroma is numbered 0 (neutral gray) to however brilliant the color can be – up to 15 or more.
  10 and above are considered high chroma.


BRILLIANT BLUE
(Mixture)
BLEU BRILLANT
AZUL BRILLANTE
8 B/5/9
OPAQUE
T. CLEAN WITH SOAP
SERIES 1
LIGHTFASTNESS:I
OPAQUE
MUNSELL HUE:8.0B
VALUE:5.0
CHROMA:9
BG
B
BP


AL • HIGH VISCOSITY
ELLE • HAUTE VISCOSITÉ
L • ALTA VISCOSIDAD
RAW SIENNA
SIENNE NATURELLE
A DE SIENA NATURAL
SIENA NATUR
A DI SIENA NATURALE
Single Pigmen
Monopigmentair
ACRYLFARBE •
SSIONALE • ALTA VISCOSITA
Hue
atif
O
YO
Y
Hue 5.9YR
nsell
Value 4.2
Valeur
Chroma 5
Saturation
Lightfastness: I-Excellent
Emulsion
5.9YR/4.2/5

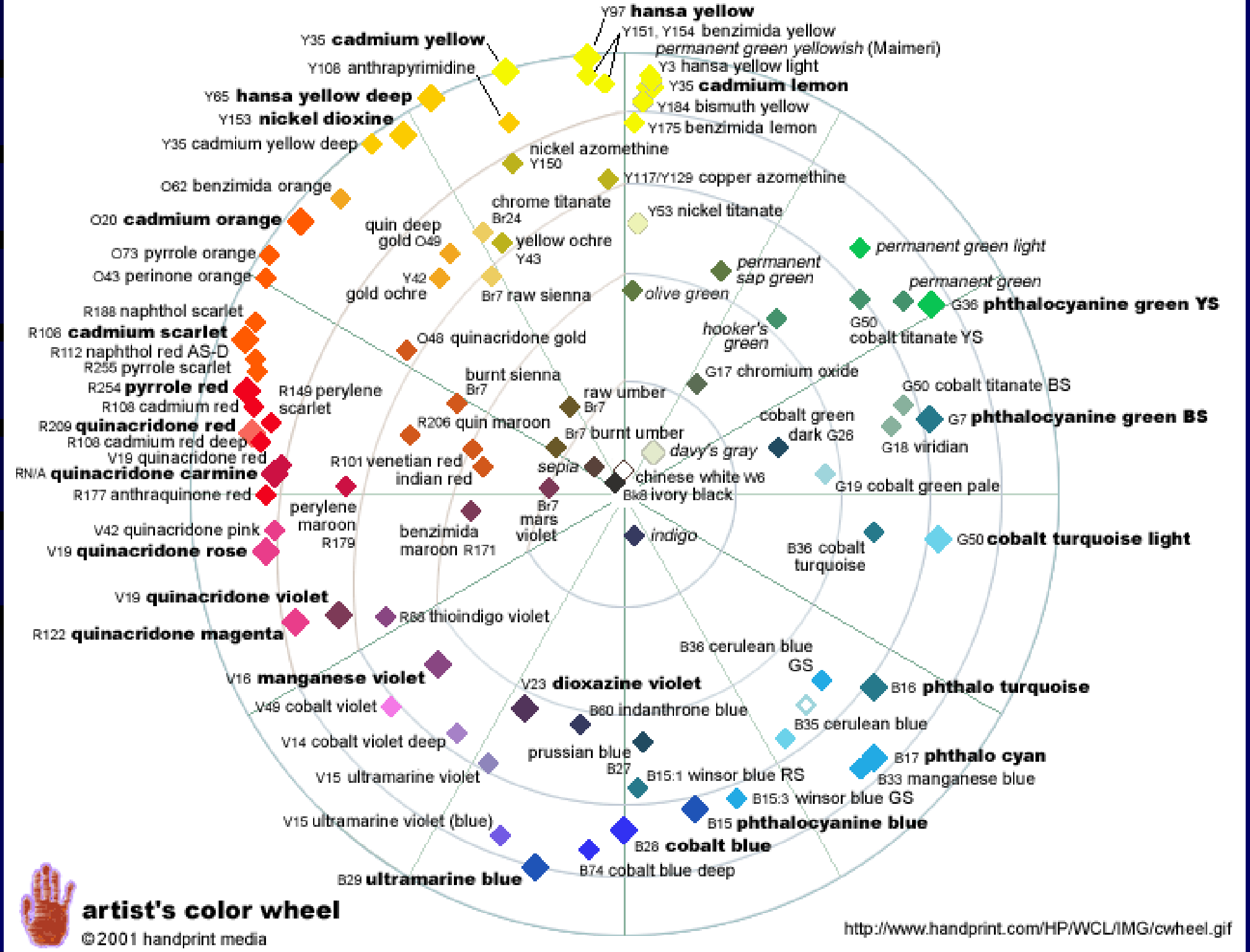
Freedom to Mix with available pigments

- Since C.I.E. color definitions are based on light wavelength characteristics, color producers can mix colors with alternate pigments.
- (some non-CIE color systems such as Pantone, specify particular colors by using recipes of *particular base colors* – so color-matching demands that the press operator has *those* specific inks to start with.)

Mixing Oils and Acrylics

- Liquitex color Mixing chart offers a practical, but not specific, specification and planning aid for painters.
- Liquitex color mixing chart is a variation on a color wheel. Basically its an unrolled cylinder.
- Chroma dimension is NOT dealt with – only hue and value.

LIQUITEX® ACRYLIC COLOR MAP® & MIXING GUIDE

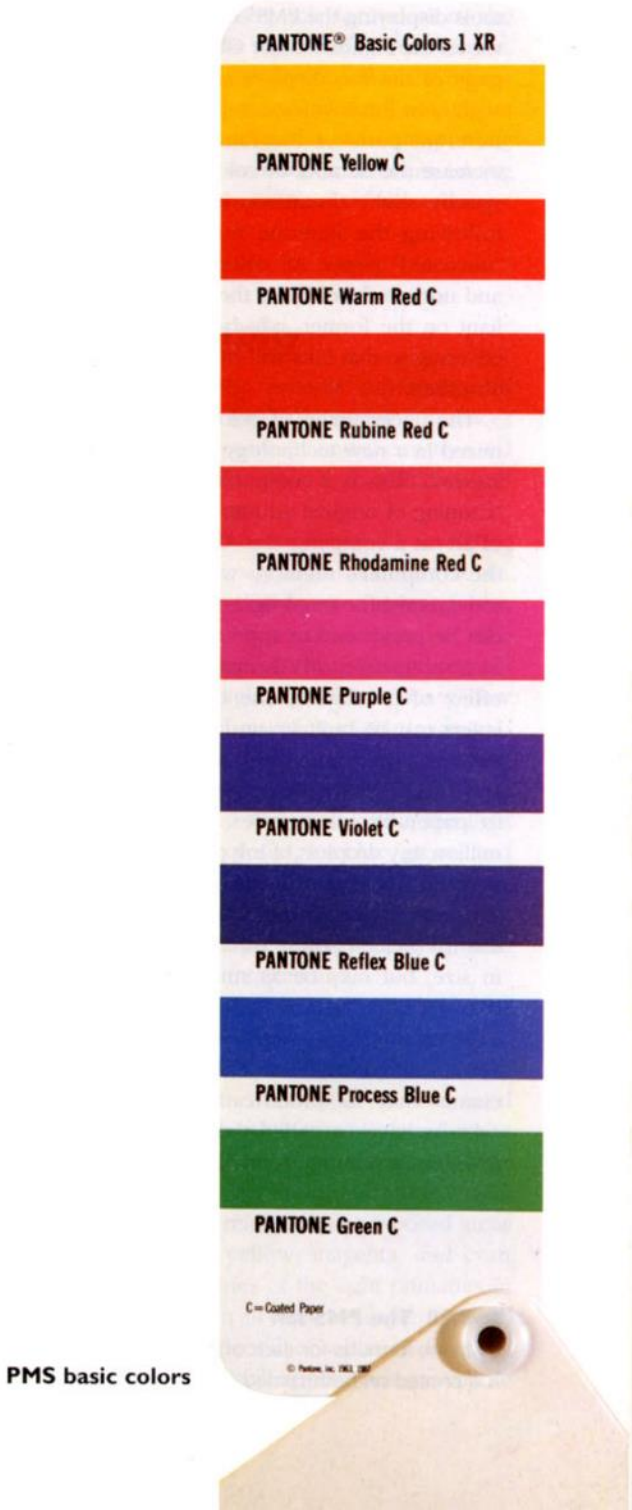

Y97 hansa yellow
Y151, Y154 benzimida yellow
permanent green yellowish (Maimeri)
Y3 hansa yellow light
Y35 cadmium lemon
Y184 bismuth yellow
Y175 benzimida lemon
Y35 cadmium yellow
Y108 anthrapyrimidine
Y85 hansa yellow deep
Y153 nickel dioxine
Y35 cadmium yellow deep
nickel azomethine Y150
Y117/Y129 copper azomethine
O62 benzimida orange
O20 cadmium orange
chrome titanate Br24
Y53 nickel titanate
quin deep gold O49
yellow ochre Y43
permanent green light
permanent sap green
permanent green
G36 phthalocyanine green YS
O73 pyrrole orange
O43 perinone orange
Y42 gold ochre
Br7 raw sienna
olive green
hooker's green
G50 cobalt titanate YS
R188 naphthol scarlet
R108 cadmium scarlet
R112 naphthol red AS-D
R255 pyrrole scarlet
R254 pyrrole red
R108 cadmium red
R209 quinacridone red
R108 cadmium red deep
V19 quinacridone red
RN/A quinacridone carmine
R177 anthraquinone red
O48 quinacridone gold
burnt sienna Br7
raw umber Br7
G17 chromium oxide
G50 cobalt titanate BS
G7 phthalocyanine green BS
G18 viridian
R149 perylene scarlet
R206 quin maroon
Br7 burnt umber
cobalt green dark G26
davy's gray
R101 venetian red
indian red
sepia
chinese white W6
Bk8 ivory black
G19 cobalt green pale
perylene maroon R179
Br7 mars violet
benzimida maroon R171
indigo
B36 cobalt turquoise
G50 cobalt turquoise light
V42 quinacridone pink
V19 quinacridone rose
V19 quinacridone violet
R88 thioindigo violet
R122 quinacridone magenta
B36 cerulean blue GS
V16 manganese violet
V23 dioxazine violet
B16 phthalo turquoise
V49 cobalt violet
B60 indanthrone blue
B35 cerulean blue
V14 cobalt violet deep
prussian blue B27
B17 phthalo cyan
B33 manganese blue
V15 ultramarine violet
B15:1 winsor blue RS
B15:3 winsor blue GS
V15 ultramarine violet (blue)
B15 phthalocyanine blue
B28 cobalt blue
B29 ultramarine blue
B74 cobalt blue deep
artist's color wheel
©2001 handprint media
http://www.handprint.com/HP/WCL/IMG/cwheel.gif

Pantone
—offset print “palette”

- Current Pantone Spot color formulations are based on 14 basic colors (source colors), plus transparent and opaque white and black. These 14 colors offer a wide color gamut.

- Individual *spot colors* are mixed from these basic colors.

- Each PMS color has a formula or ‘recipe’ using these colors as ingredients.



PMS basic colors

Pantone
—samples for process color

- Pantone also offers a **Process Color System Chips and Guides** to provide a comprehensive palette of more than 3,000 colors achievable in four-color (CMYK) process printing.

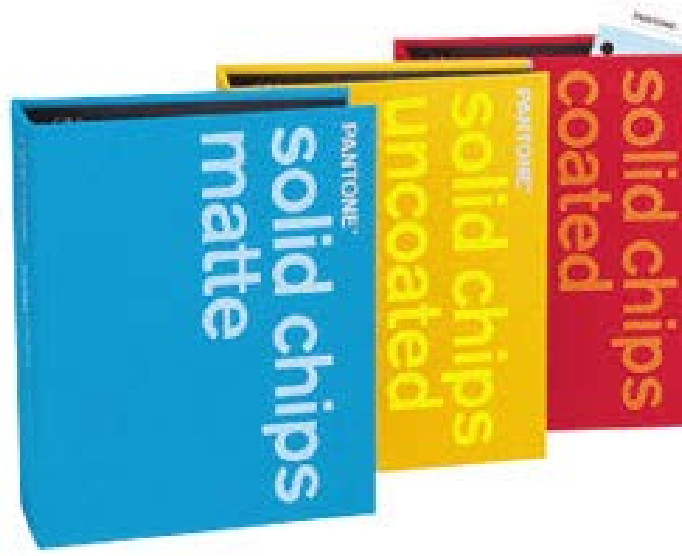
  The Pantone solid to process guide **compares a solid Pantone Color to the closest possible match in CMYK four-color process** that can be achieved on a computer monitor, output device or printing press.

- http://www.signindustry.com/computers/articles/2002-02-15--JL-pantone.php3

Pantone
—samples for other ink/color sets and substrates

- Other Pantone color reference guides for the graphic arts include metallics, pastels, tints, duotones, film and foil.

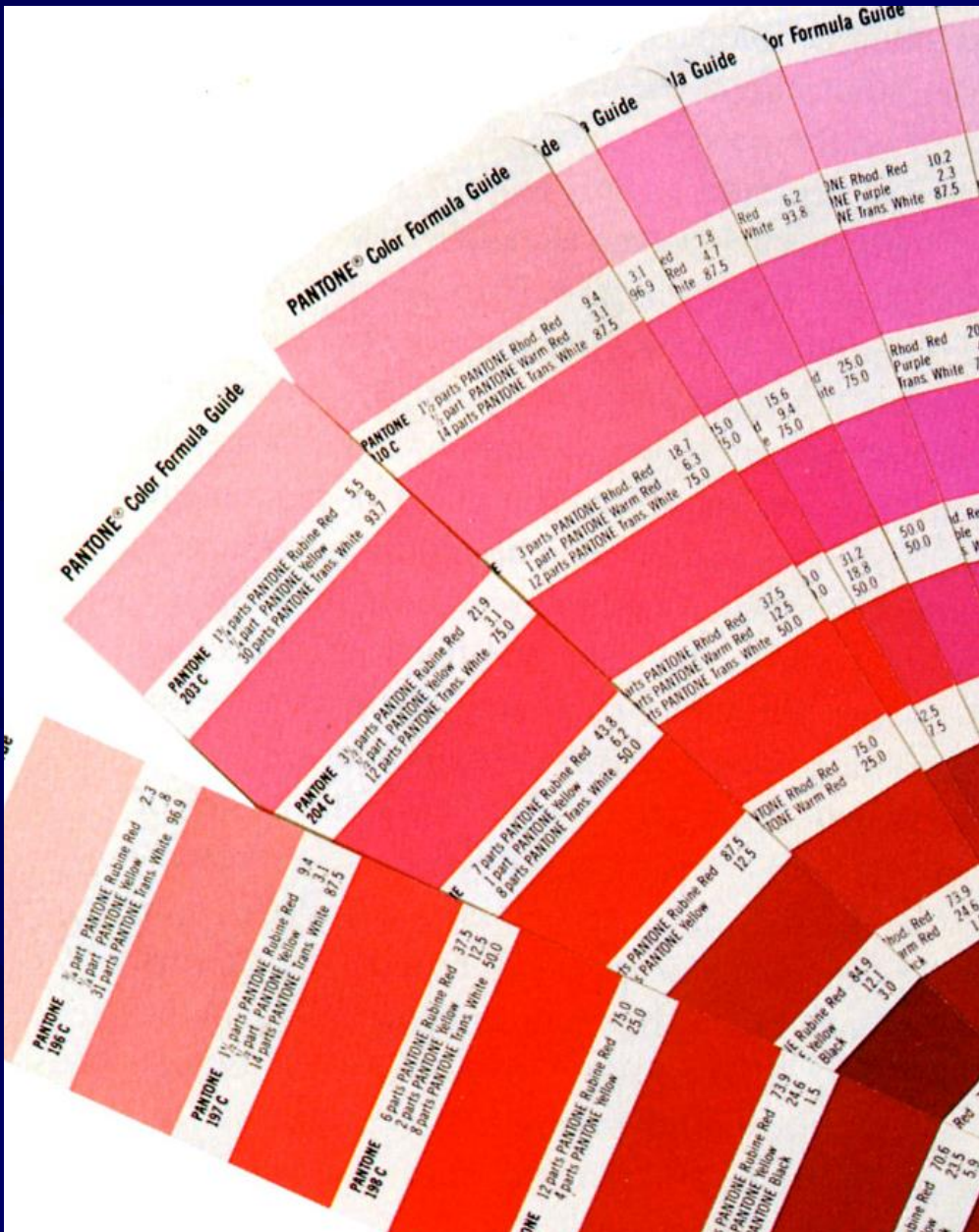
- http://www.signindustry.com/computers/articles/2002-02-15--JL-pantone.php3



Pantone Matching System (PMS)

- The Pantone Matching System (PMS) is Pantone's flagship product that targets the graphic design industry, including printing, publishing and packaging. Pantone describes PMS as the "definitive international reference for selecting, specifying, matching and controlling ink colors."

- The colors that make up the PMS system are derived from 14 base colors. Ink manufacturers license the formulation from Pantone and printers mix of the 14 ink colors to make up the entire spectrum PMS.



Pantone Matching System (PMS)

- Solid Color System
- PANTONE MATCHING SYSTEM® coated, uncoated or matte
- (examples: PANTONE 185 C, PANTONE Cool Gray 1 M)
- PANTONE FORMULA GUIDES and SOLID CHIPS contain 1,114 solid (spot) PANTONE MATCHING SYSTEM Colors for printing ink on paper.
  The majority of these colors are referred to using a three- or four-digit number followed by a C, M or U.
  A small selection are named colors, such as the 14 base colors like PANTONE Reflex Blue C or PANTONE Orange 021 M.

- The letter suffix refers to the paper stock on which it is printed: a "C" for coated or gloss paper, "U" for uncoated paper and an "M" for matte or dull paper.

Pantone —light boxes

- Lighting is always a factor. Experts recommend color matching under daylight, but that is not always possible.
  Pantone offers desktop color viewing lights that offer **multiple lighting environments - such as daylight, fluorescent, UV, and incandescent** - and take the guesswork out of color matching.

- The **substrate** can also make a dramatic impact on color. Options include coated, un-coated and matte papers, as well as plastic, vinyl and other materials.

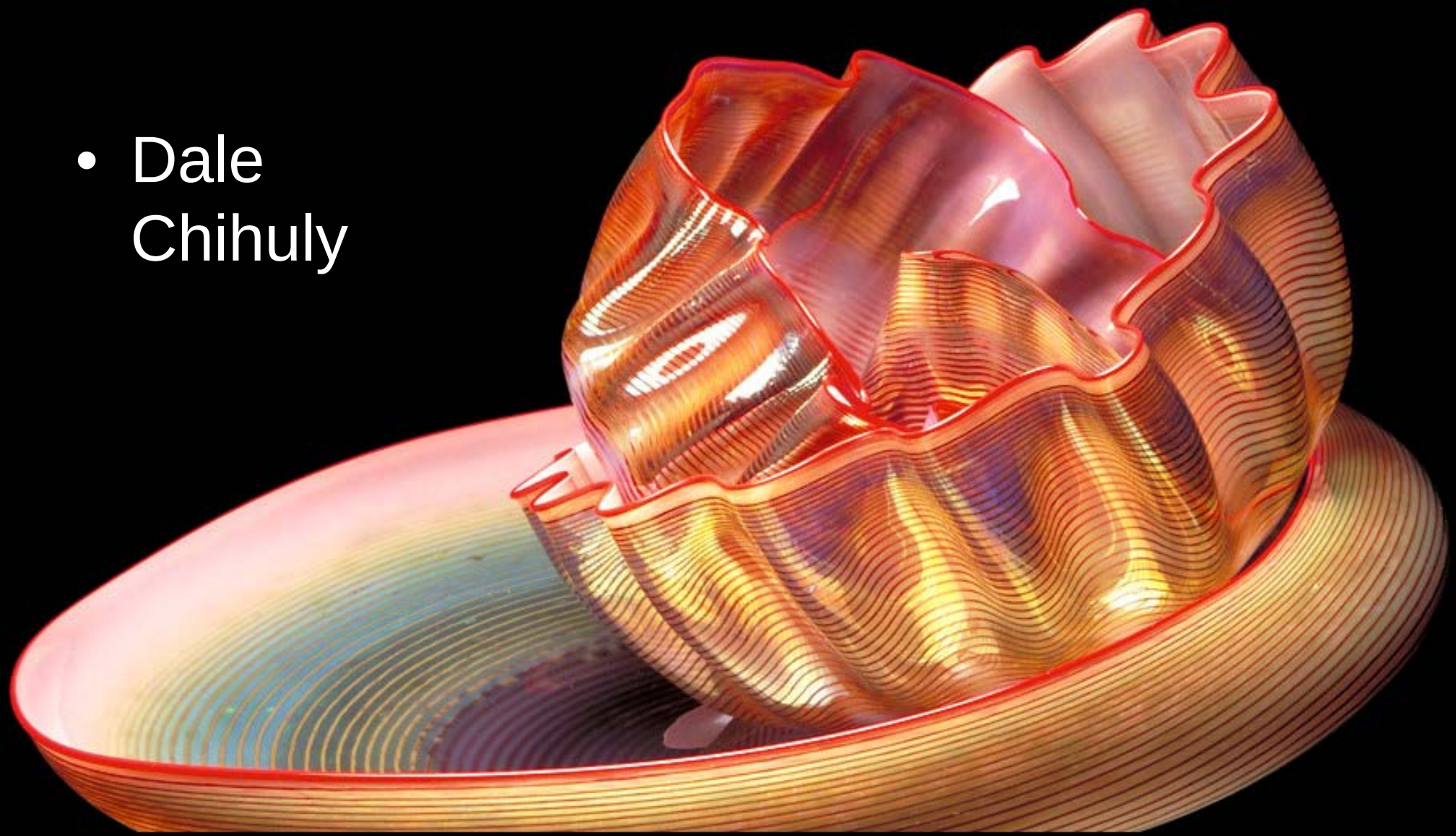
Pantone
—programmed colorimeter

- The Color Cue, a hand-held spectro-colorimeter preprogrammed with PMS system data that includes CMYK, RGB, sRGB, HTML, Lab and Hexachrome values.
-
- The device allows the user to quickly identify the closest Pantone color for any item they point to. Once a color is identified, the data is displayed through a simple scrolling feature.

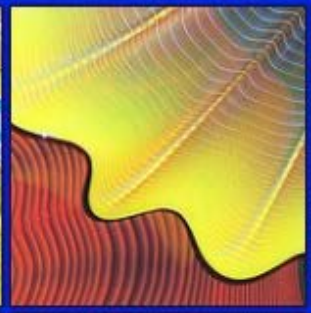
Next time...

- Glass
- Ceramic Glazes
- Natural Colors
- …& genetic color

- Dale Chihuly



















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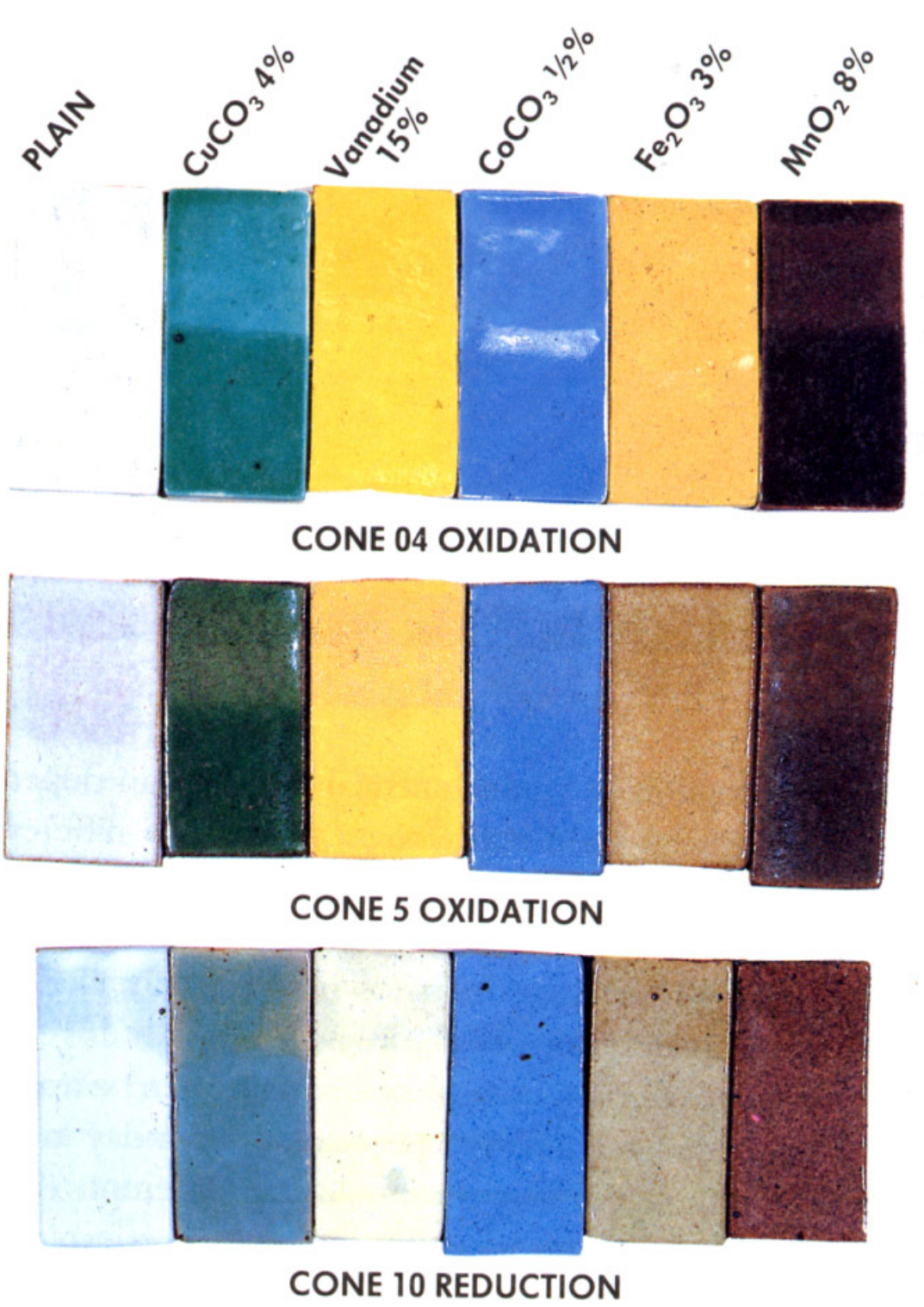
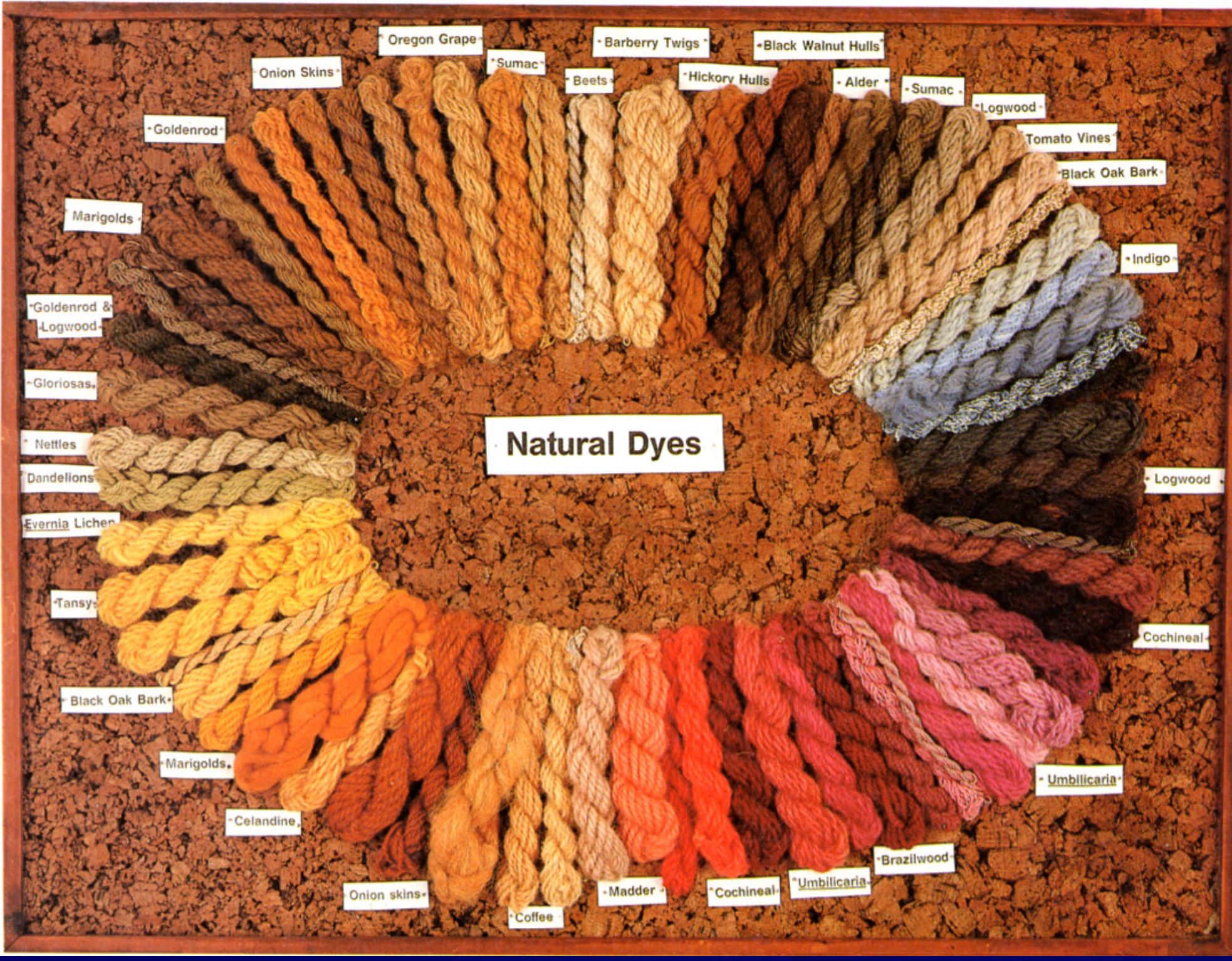
- Test tiles must be fired and the resulting colors observed.
- Firing conditions alter the color and finish of a glaze…
- …particularly the firing temperature; the same glaze will produce a different color and finish if fired to a different temperature.




Natural Dyes
Oregon Grape
Barberry Twigs
Black Walnut Hulls
Onion Skins
Sumac
Beets
Hickory Hulls
Alder
Sumac
Logwood
Goldenrod
Tomato Vines
Black Oak Bark
Marigolds
Indigo
Goldenrod & Logwood
Gloriosas
Nettles
Logwood
Dandelions
Evernia Lichen
Tansy
Cochineal
Black Oak Bark
Marigolds
Umbilicaria
Celandine
Brazilwood
Onion skins
Madder
Cochineal
Umbilicaria
Coffee