The Art and Science of Color

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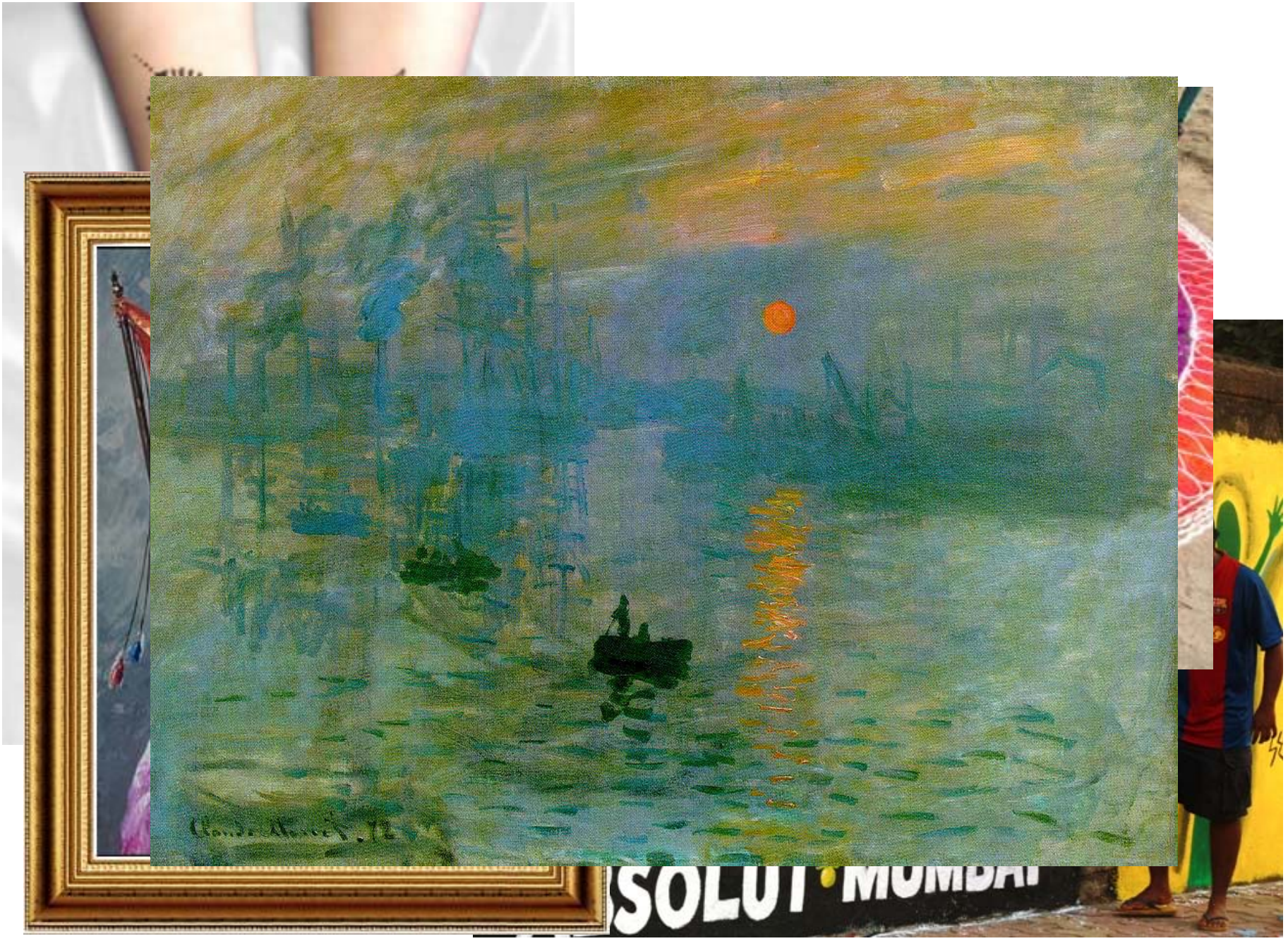
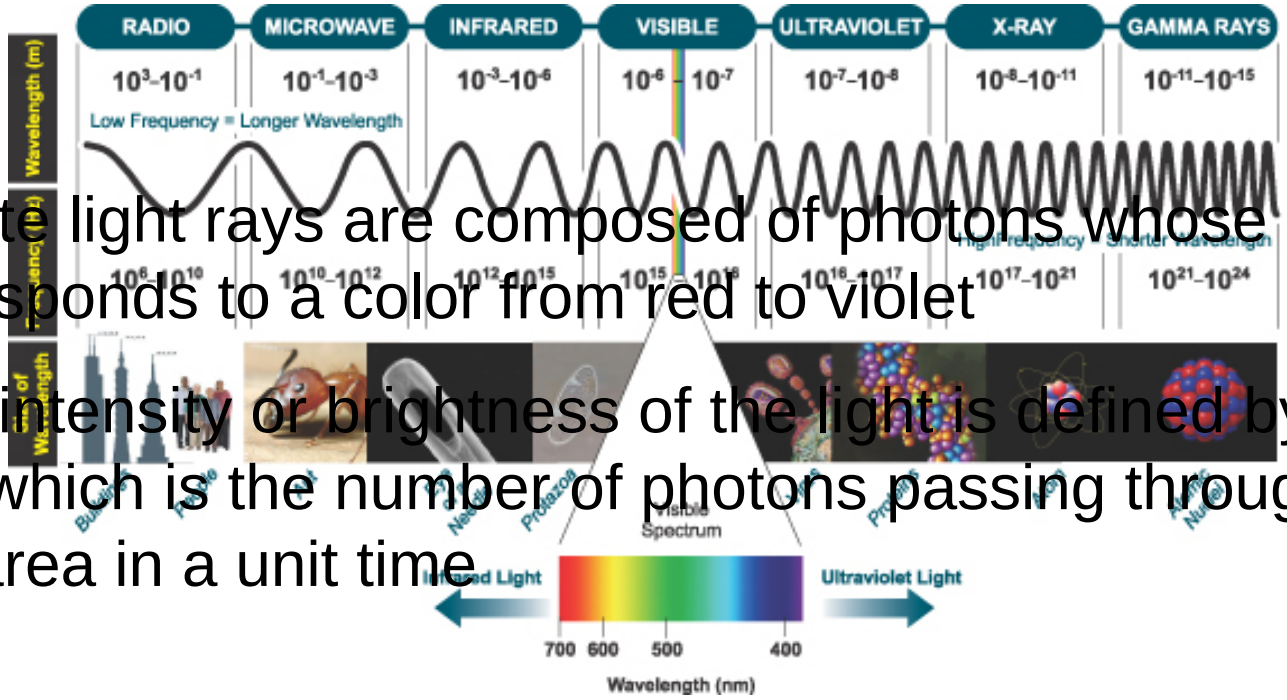


Colors: The Rainbow

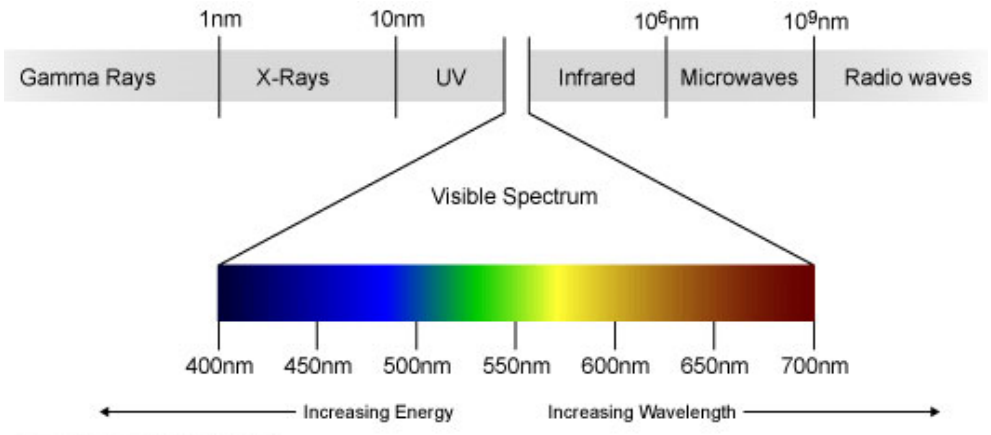
•Newton established that refraction causes the dispersion of light into its constituent hues.

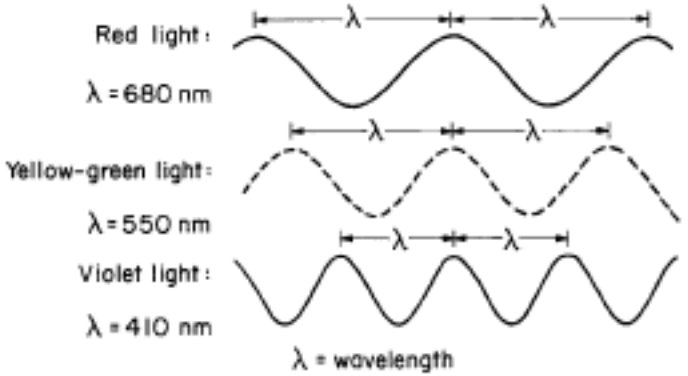
• He named seven colours, in symmetry with the seven distinct notes in the Western musical scale.

Light: Waves and Photons



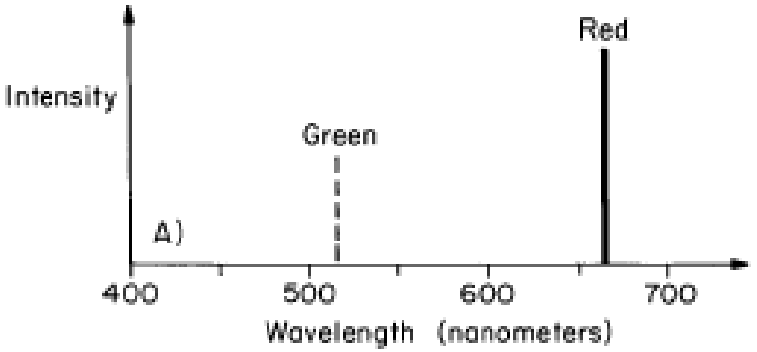
- White light rays are composed of photons whose energy corresponds to a color from red to violet
- The intensity or brightness of the light is defined by the flux, which is the number of photons passing through a unit area in a unit time



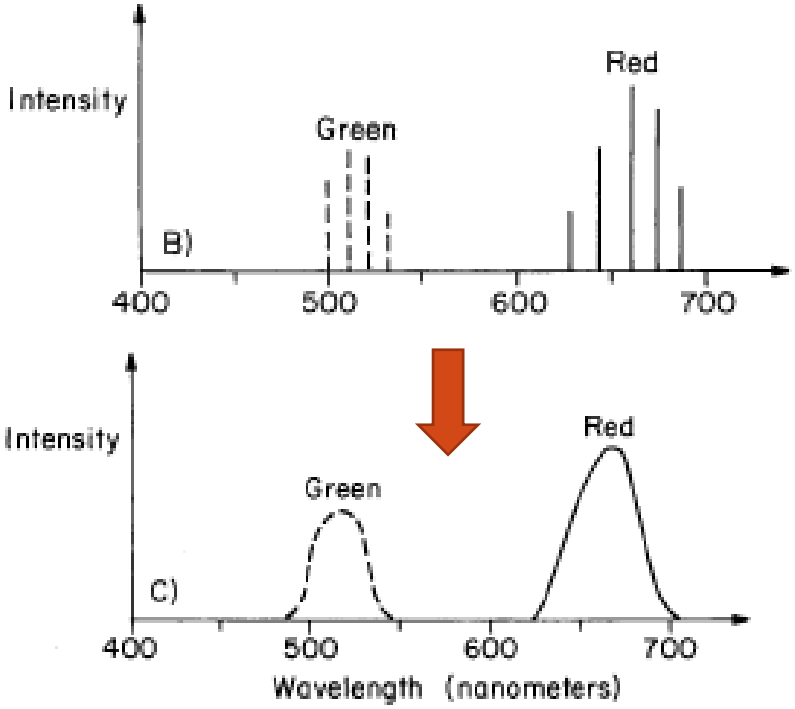


Color: Pure and Sensed

- A spectroscopically pure color has light of only one wavelength.
- Colors are seldom spectroscopically pure



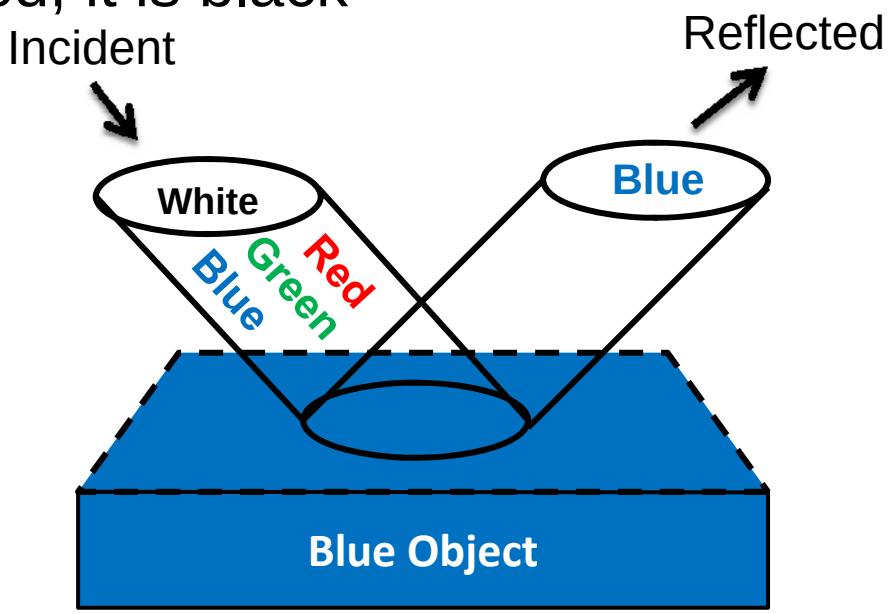
- A sensed color such as green or red will be composed of a number of photons whose wavelengths are closely spaced around that of the pure color.



The Color of Objects

As we look at a painting (object), the color we see exists due to white light illuminating the painting, interacting with the layers of pigment and varnish and reflecting back to the eye

- If all wavelengths in sunlight are reflected, the object is white
- If all are absorbed, it is black



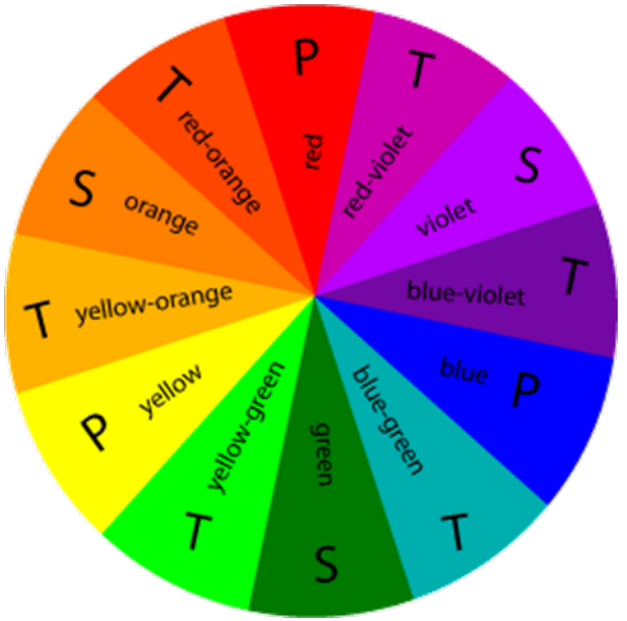
If some of the visible wavelengths are absorbed and others reflected, the object is colored

Complementary Colors

- When sunlight shines on an object, light of a particular wavelength is absorbed

- The color corresponding to that wavelength is subtracted from white light

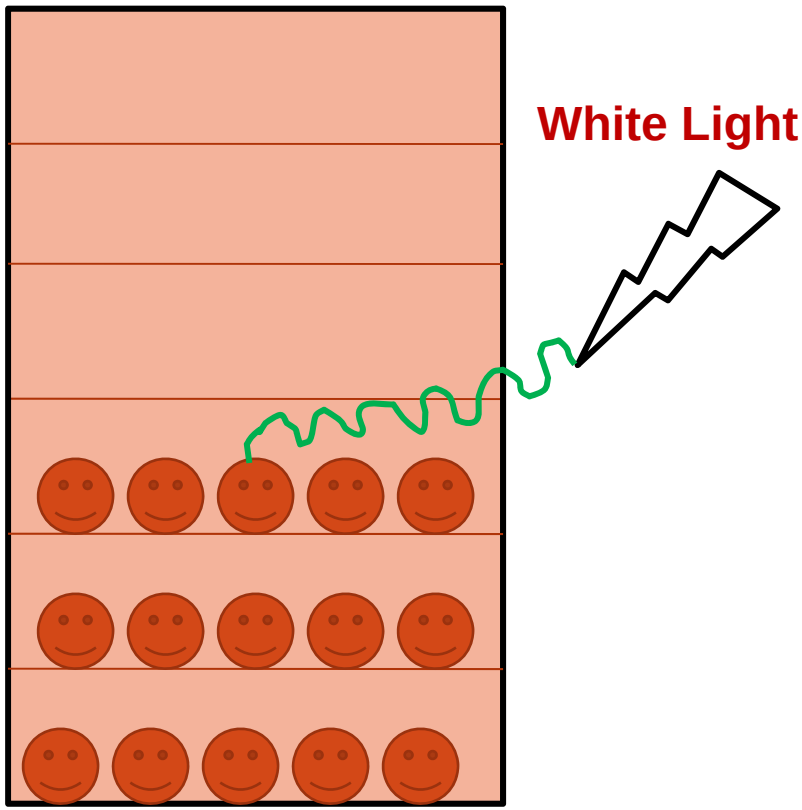
- The remaining wavelengths are reflected, and ‘complementary color’ is seen.



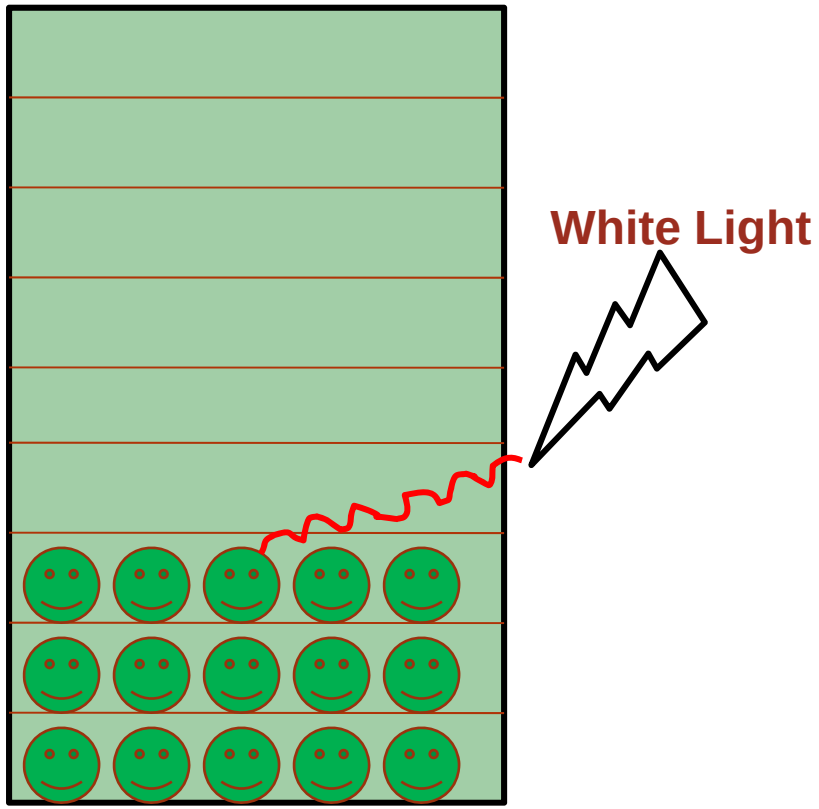
Vermilion is red since it absorbs blue green light

Different Colors!!!

Atoms → **Molecules** → **Electrons**



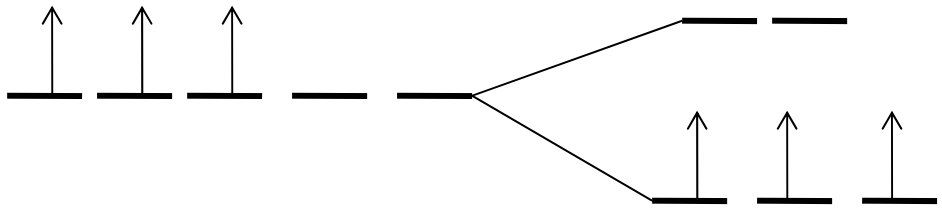
Red Object



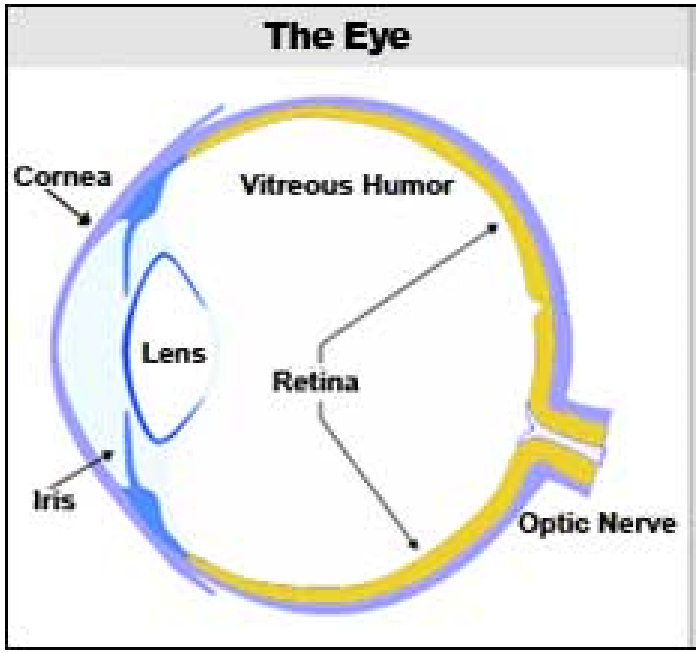
Green Object

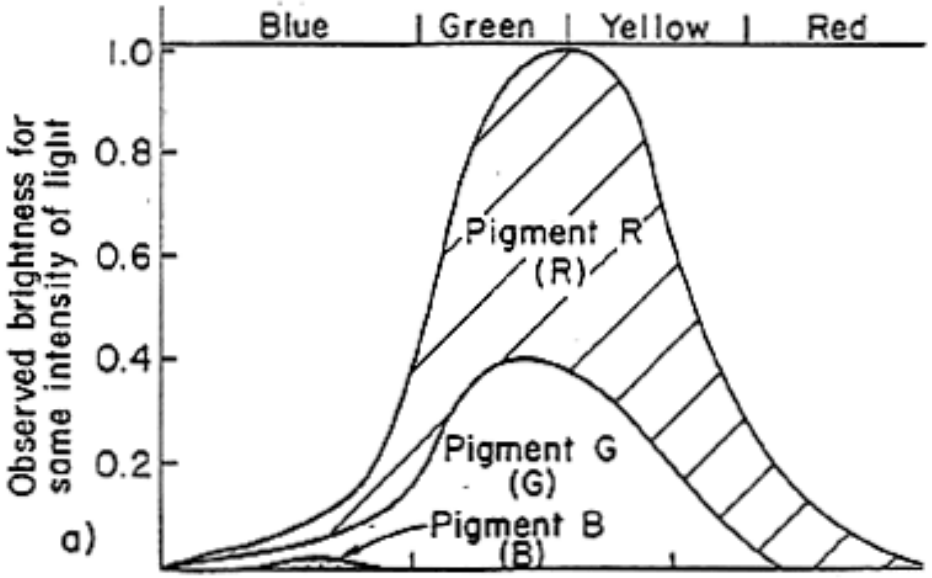
Inorganic Colors

- Most contain transition metals
- Transition metals have partially filled d-orbitals
- There are 5 d-orbitals which in a isolated ion of the metal have same energy
- However, they are not degenerate in the presence of ligand: Crystal Field Theory



The Eye and Color Sensation

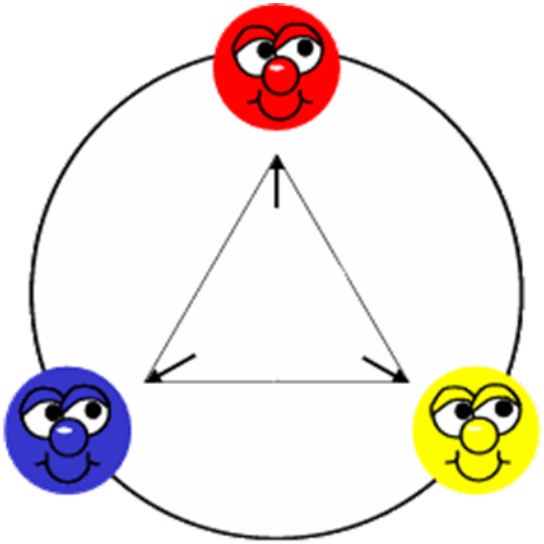




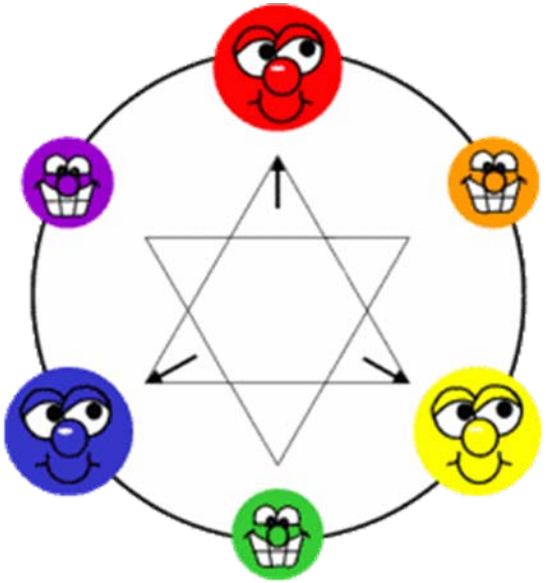
- Humans have three kinds of color receptor cells – or “cones” - in their eyes.
- Each type of cone contains a different visual pigment:"red", "green" and "blue.“
- For every color signal reaching the eye, some ratio of response within the three types of cones is triggered.

Artists Perspective: The Color Wheel

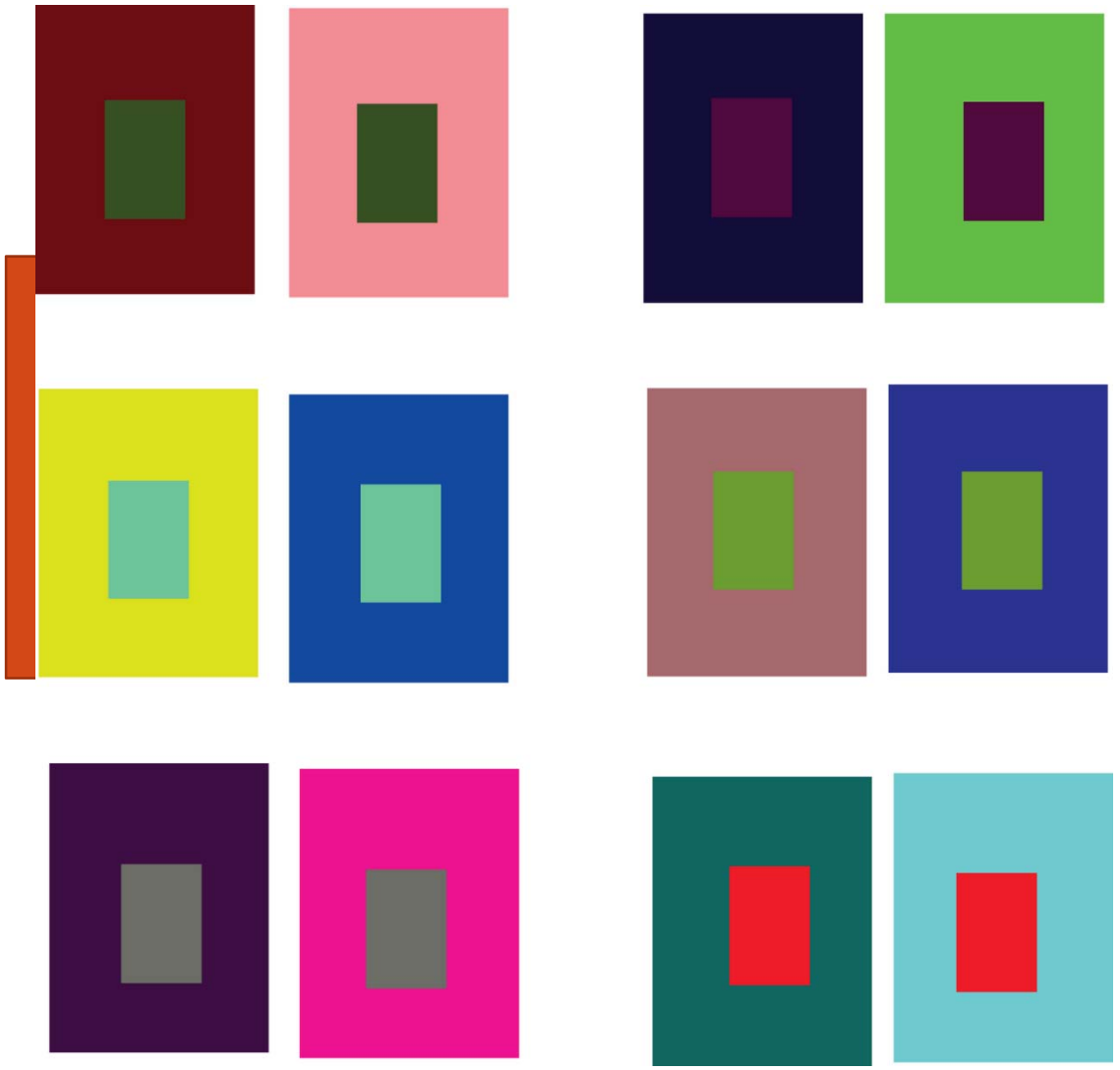
Primary Colors



Secondary Colors

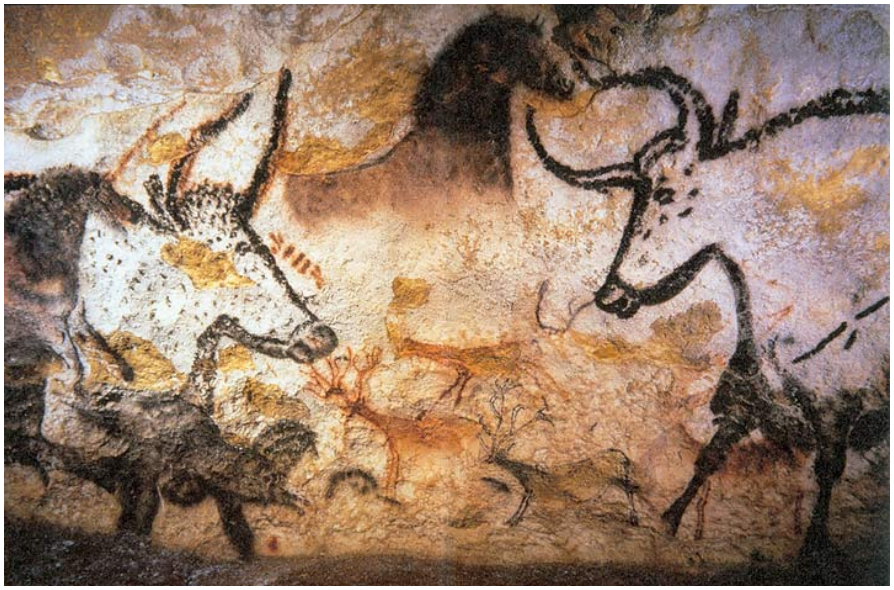


Simultaneous Contrast



Bathers at Asnières (*Une Baignade, Asnières*), Georges Seurat, 1884.

Brief but Colorful History of Paint



Bison

- Dated 35,000 years ago
- Painted in cave walls
- Found in Lascaux, France

Cave painting

Bhimbhetka, MP, India

Dated 30,000 years ago

Ajanta Caves

Bodhisattva Padmapani

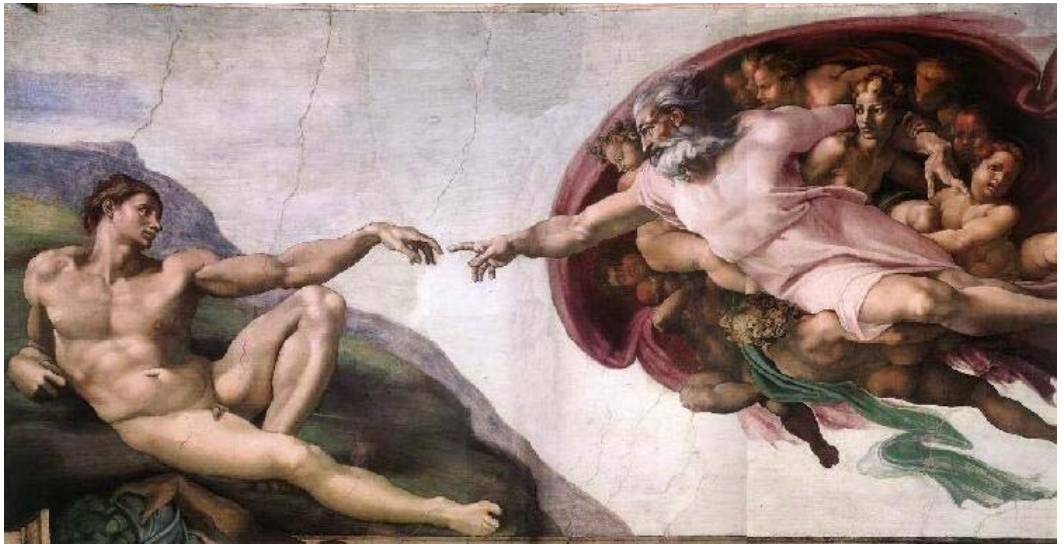
5th Century AD

Mahajanaka Jataka; Ajanta; 6th Century AD

The Frescos

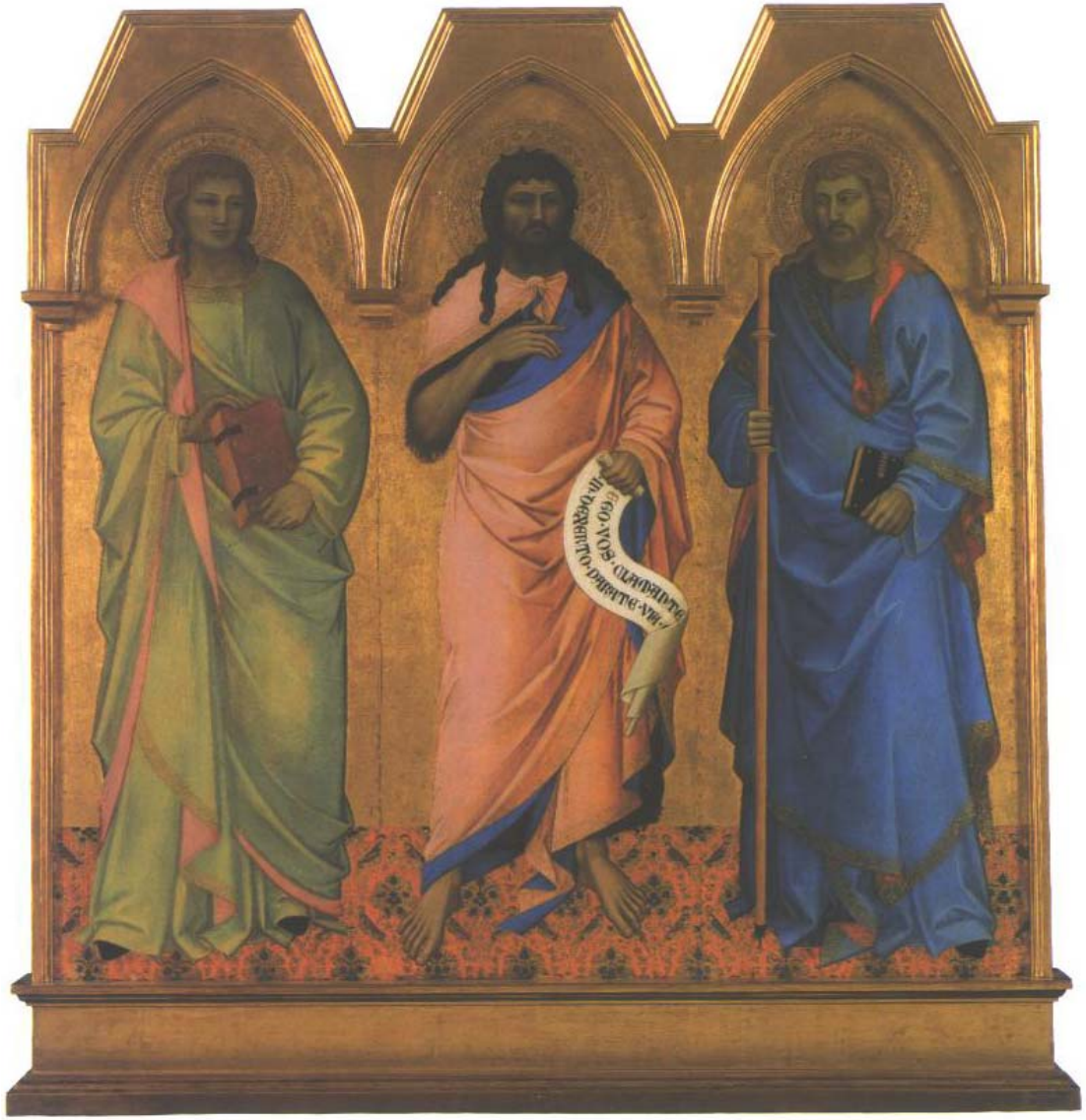
Ceiling of Sistine Chapel, Vatican City

Michelangelo: Created the most influential works in Fresco in the western art history



Creation of Adam

Saint John the Baptist with Saint John the Evangelist and Saint James



- Artist: NARDO di Cione
- Medium: Egg tempera
- Support: Poplar
- Date: About 1365

National Gallery, London

The Composition of Paint

Paint is composed of colored pigment and a binder

Pigment: Colored powdered substance (minerals, inorganic salts, dyes)

Binder: Material that evenly disperses the pigment, adheres to surface when paint applied and then dries

Additives: Such as Glycerine for brushability, antioxidants to prevent paint spoliage

Paints are homogeneous mixtures, are uniform throughout

Earth's Natural Palette

Red

Hematite: Iron Oxide

Cinnabar: Contains mercury; toxic

Blue

Lazurite: Bright blue; very expensive

Azurite: Blue with green tinge; basic copper carbonate much cheaper; used by Michelangelo

Earth's Natural Palette

Yellow and Orange

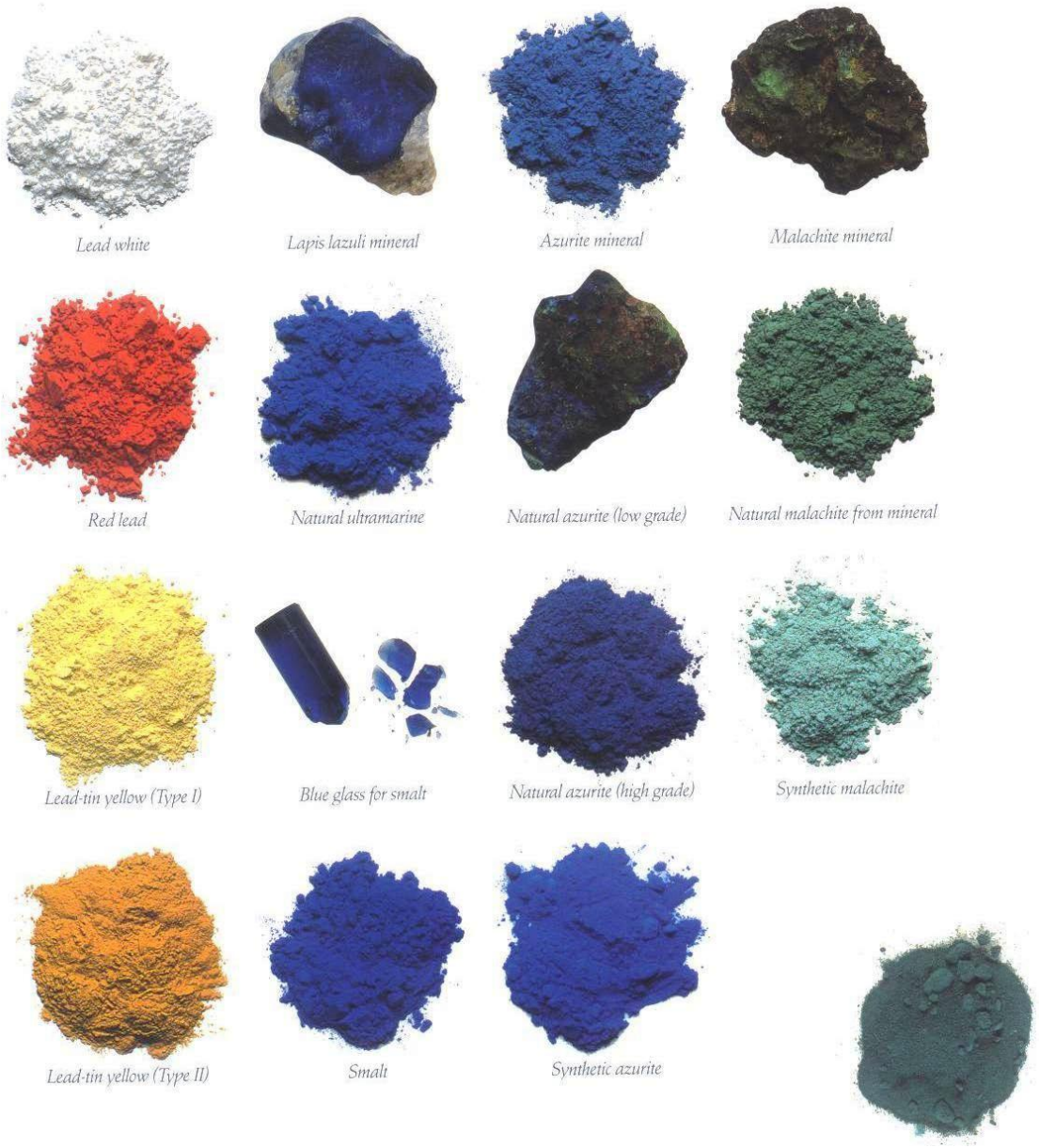
Orpiment and Realgar: used as late till 19th century when it was discovered to have arsenic.

Van Gogh's mental illness and Monet's blindness were probably caused by it

Green

Malachite is a copper compound and is possibly the oldest known green pigment used.

Some Pigments available until 1600



The pigment

Yellow lead chromate

$$Pb(NO_3)_2 + Na_2CrO_4 \longrightarrow PbCrO_4 + 2NaNO_3$$

White zinc hydroxide

$$Zn(NO_3)_2 + NaOH \longrightarrow Zn(OH)_2 + 2NaNO_3$$

Blue Copper Carbonate

$$Cu(NO_3)_2 + Na_2CO_3 \longrightarrow CuCO_3 + 2NaNO_3$$

Binders: The vehicle for the color

Carbohydrate:Gum Arabic from Acacia plant

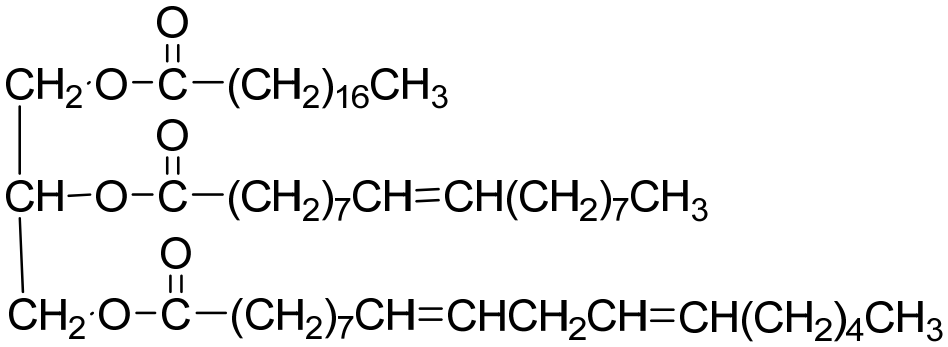
Oil and Fat: Linseed Oil

Protein: Egg yolk

Synthetic

The Importance of “Drying Oil”

• In Oil Paint, the vehicle used to spread color pigments is a “drying oil”: Linseed oil typically used
• Oil such as coconut oil or olive oil is not typically used.



→ Stearic Acid

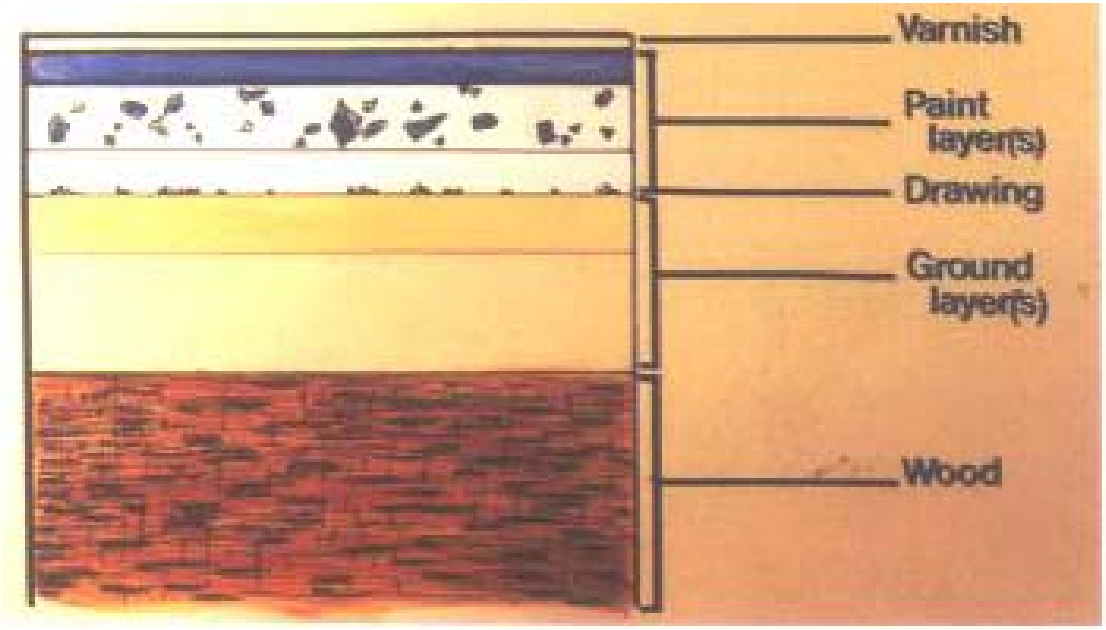
→ Oleic Acid

→ Linoleic Acid

• When spread in thin layers, the unsaturated oil reacts with oxygen in the air and polymerizes to form a solid surface that is resistant to chemical attack
• This helps to fix and protect the pigment
• Coconut and olive oil are monosaturated or saturated triglycerdes: takes a long time to polymerize

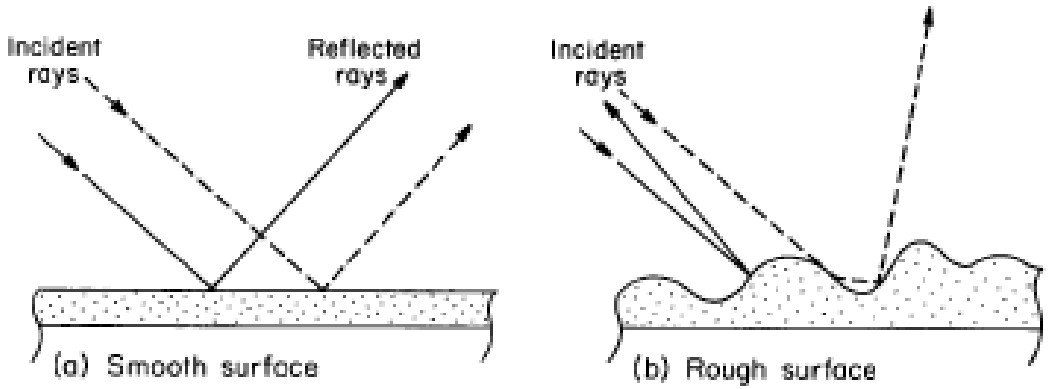
Panel Painting Construction

- The Support: What the painting is painted on (wood, canvas)
- The Ground: Preparatory layer put on the support before paint is applied- typically several layers of gesso
- The Paint: Composed of pigment and liquid binder

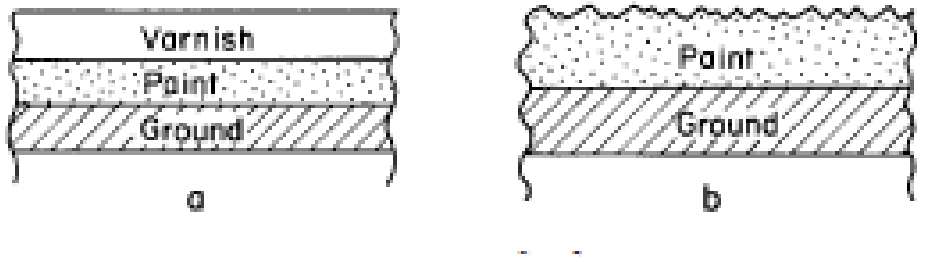


The Importance of Varnish

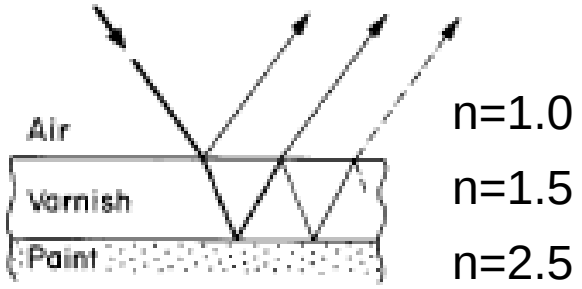
Specular and
Diffuse Reflection



Varnish provides a
shiny surface



Difference in RI between
varnish and paint small:
deeper and richer color



Making Gesso

Gelatin

Making Binder for Egg Tempera

The egg yolk will now be mixed with equal amount of water to make the binder

Patchitra: Folk Art In Bengal

(dates back 2000 years)

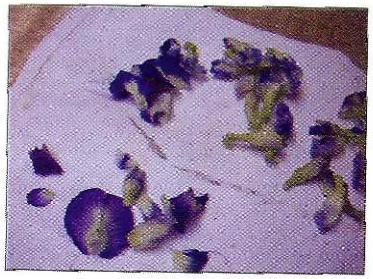
Patchitra: Dukhushyam Chitrakar

Bael seed

Gokarna

Saag flower

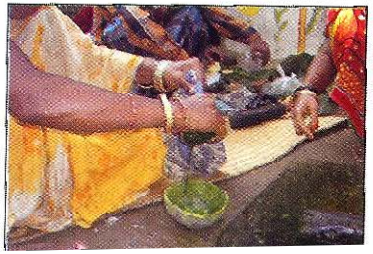
Bael leaves



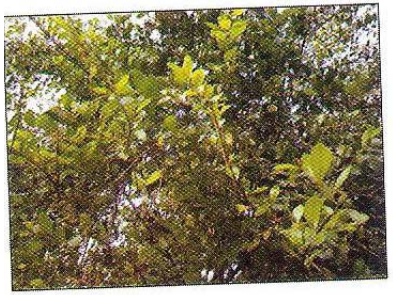
Binder

Blue Color

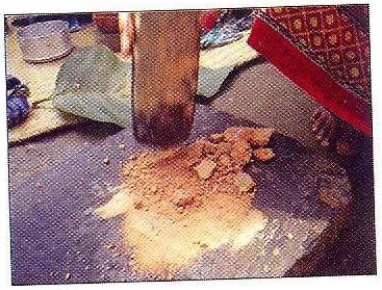
Purple Color



Green Color









Haldi **Henna** **Clay**

Kalamkari: On Cloth

(Andhra Pradesh)

Panchatantra Story

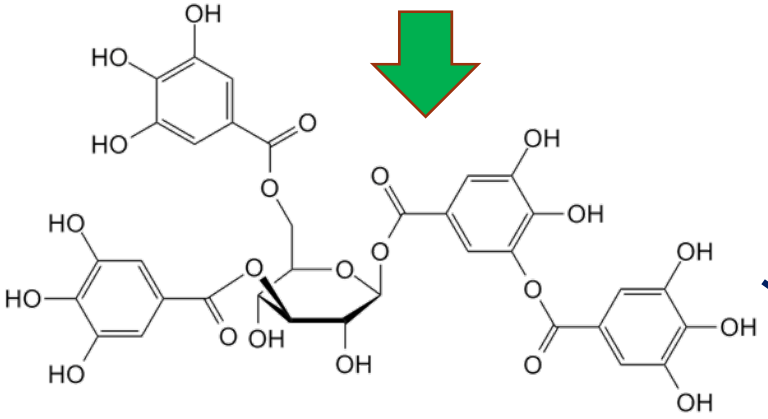

BEAUTY IS IN THE

Kassem: The Black Ink

Myrobalan Nut

Myrobalan Powder

\+ Buffalo Milk
(high fat content)



BLACK

Iron filings +

(old jaggery)

Iron acetate
(brown)

Art Conservation

- Great works of art are susceptible to effects of aging: atmospheric oxygen, temperature and humidity changes, air pollution and exposure to light

- Conservation involved cleaning the work, analyzing the work for damage, restoring the damaged areas and preserving the original

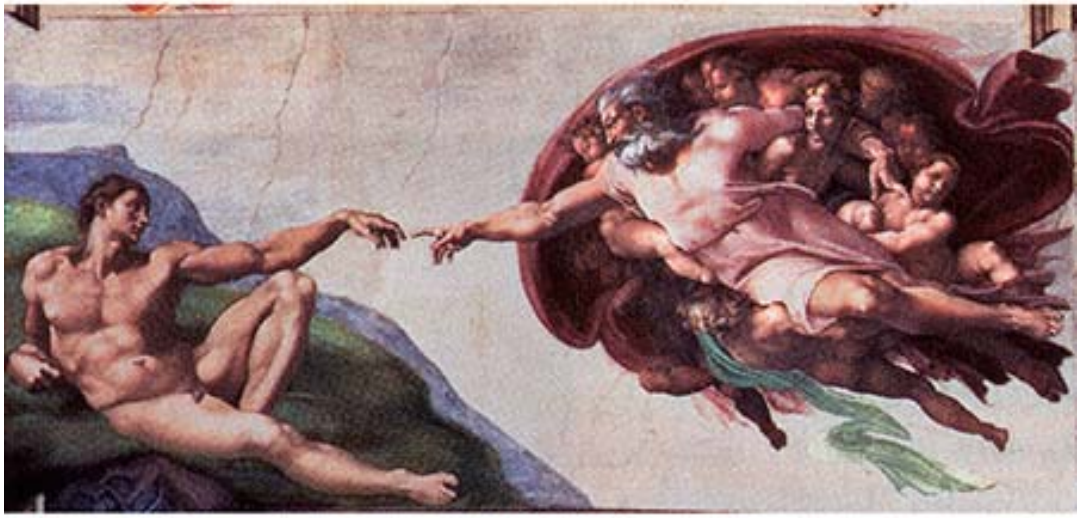
- Modern Analytical techniques are very routinely used: Infrared Reflectography, Laser Raman Spectroscopy, Autoradiography, Microscopic analysis etc

Artists, Material Scientists, Spectroscopists work together

Restoration of Sistine Chappel

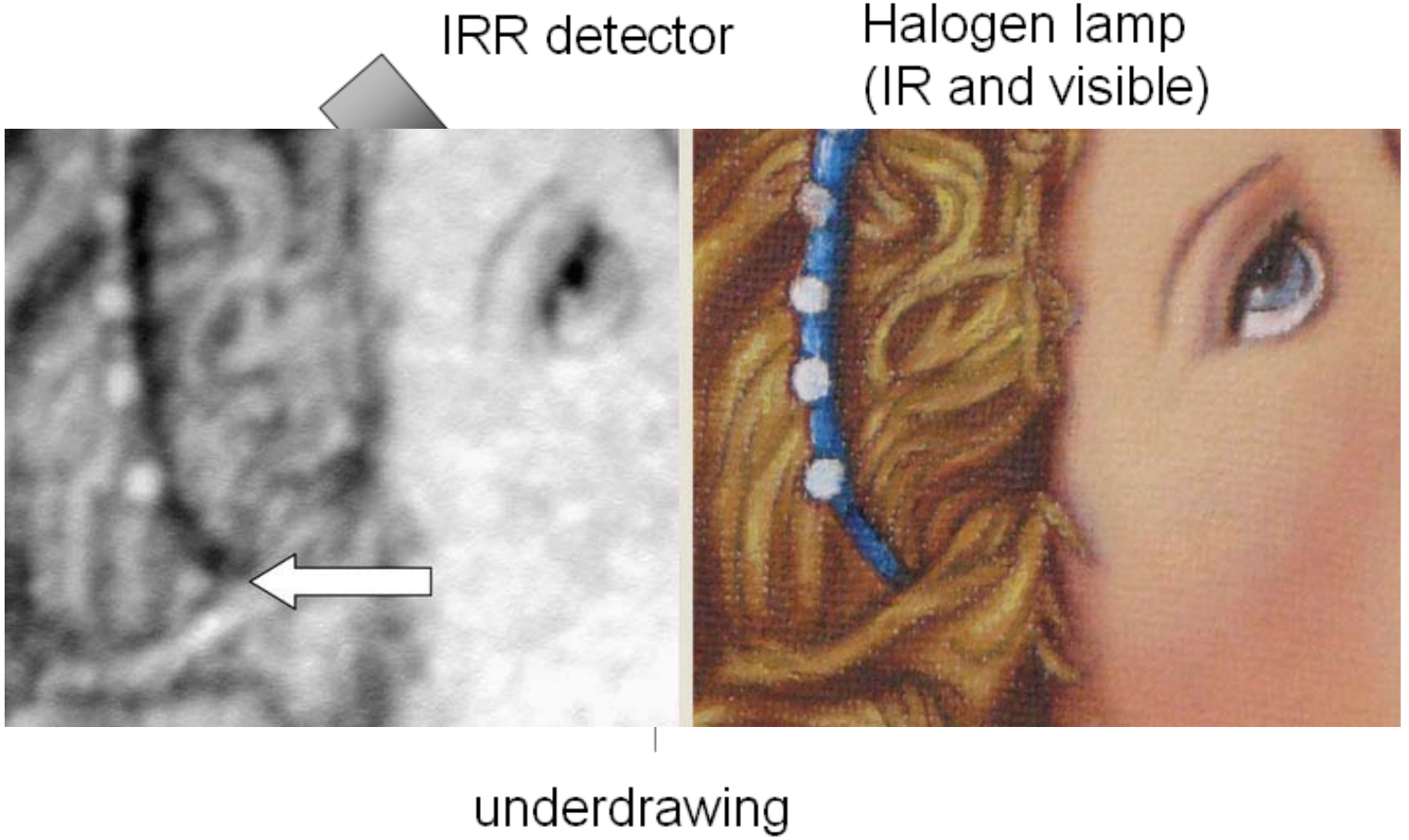
Pre-restoration

Post restoration



Treated with solution containing:
Ammonium Bicarbonate
Sodium Bicarbonate
Desogen (Surfactant and antibacterial agent)
Carboxymethylcellulose (thixotropic agent)

Infrared Reflectrography



• Being able to "see" underneath the first layer of pigment provides the art historian or conservationist with critical information about the original intent of the artist.
•It can also validate whether or not the work is an original piece of art or identify details with historical context.

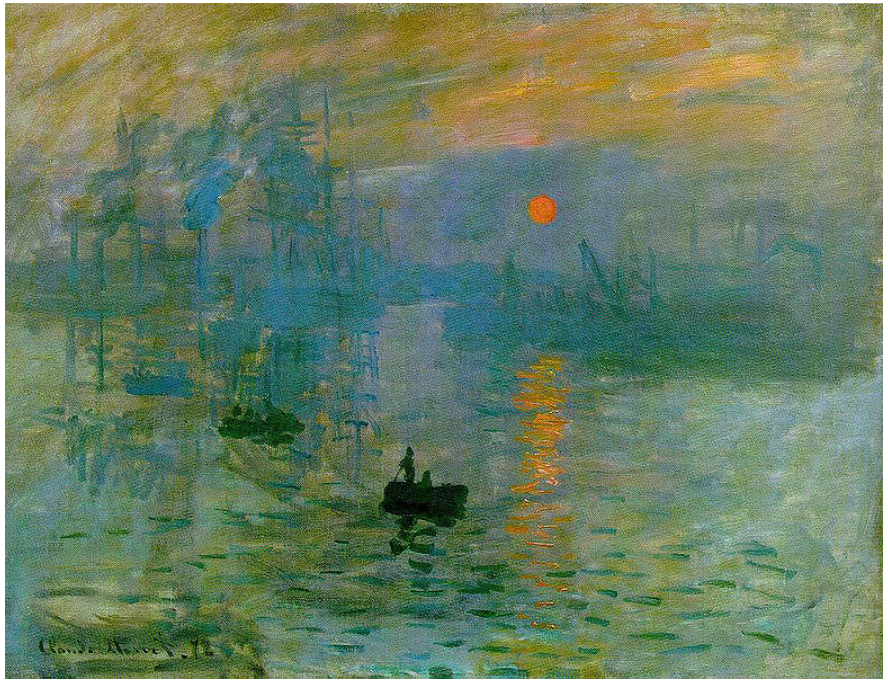
Henry Prince of Wales on Horseback: Robert Peake the Elder (1610-12)

After Restoration

Warli Painting

Oil Paintings

Oil Paints, pigment combined with oil discovered in early 15th century. Oil such as terpentine oil and linseed oil is the binder.



Sunrise- An impression by Monet

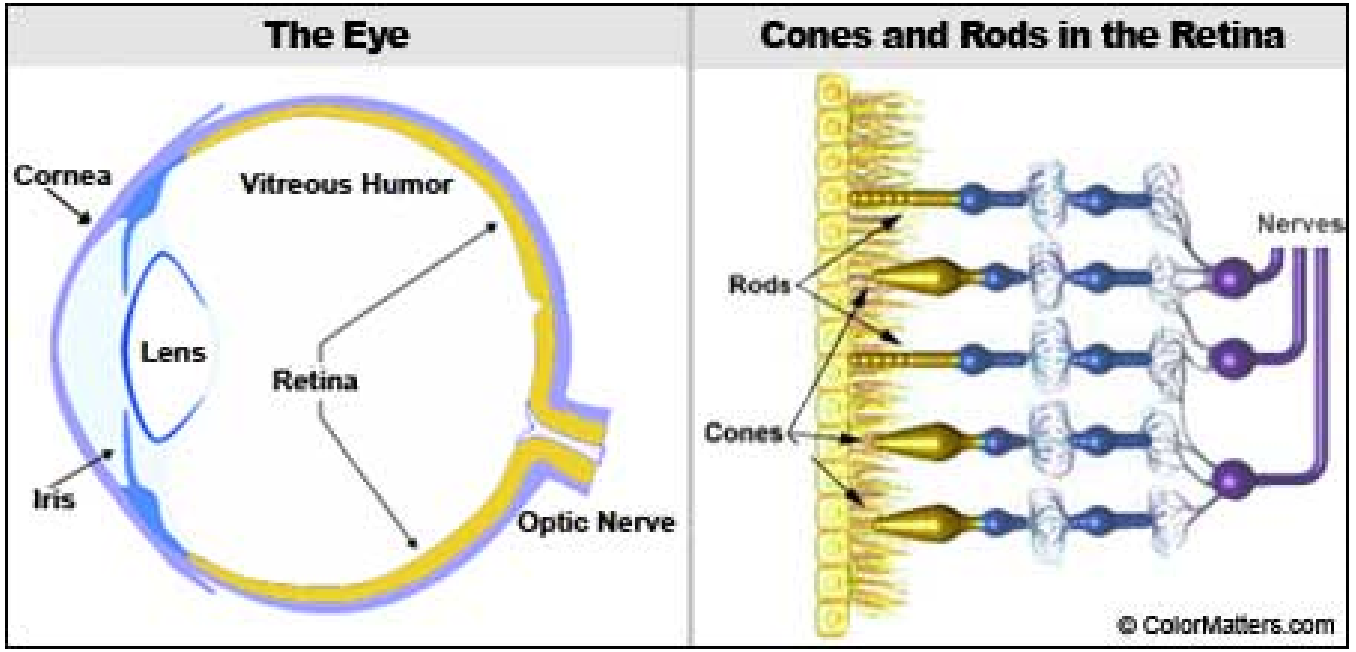
Starry Nights by Van Gogh

Acrylic paints and other medium

Poster Paint

Transparent Water Color

Vision



- Humans have three kinds of color receptor cells – or “cones” - in their eyes.
- Each type of cone contains a different visual pigment:"red", "green" and "blue."
- Therefore, we are “trichromats” (tri = 3, chroma = color).

Painting of Fresco's and Secco's: Egg Tempera

- They were done mostly using egg tempera paint
- It contains a colored pigment and the yolk of an egg mixed with water
- The egg temperas were absorbed into freshly spread wet plaster and remained vibrant as long as the paint survived
- The paint became part of the plaster

Inorganic Salts as Pigments

Colored Pigments can be formed by precipitation of aqueous ions in solution

Yellow lead chromate

$$Pb(NO_3)_2 + Na_2CrO_4 \longrightarrow PbCrO_4 + 2NaNO_3$$

White zinc hydroxide

$$Zn(NO_3)_2 + NaOH \longrightarrow Zn(OH)_2 + 2NaNO_3$$

Blue Copper Carbonate

$$Cu(NO_3)_2 + Na_2CO_3 \longrightarrow CuCO_3 + 2NaNO_3$$