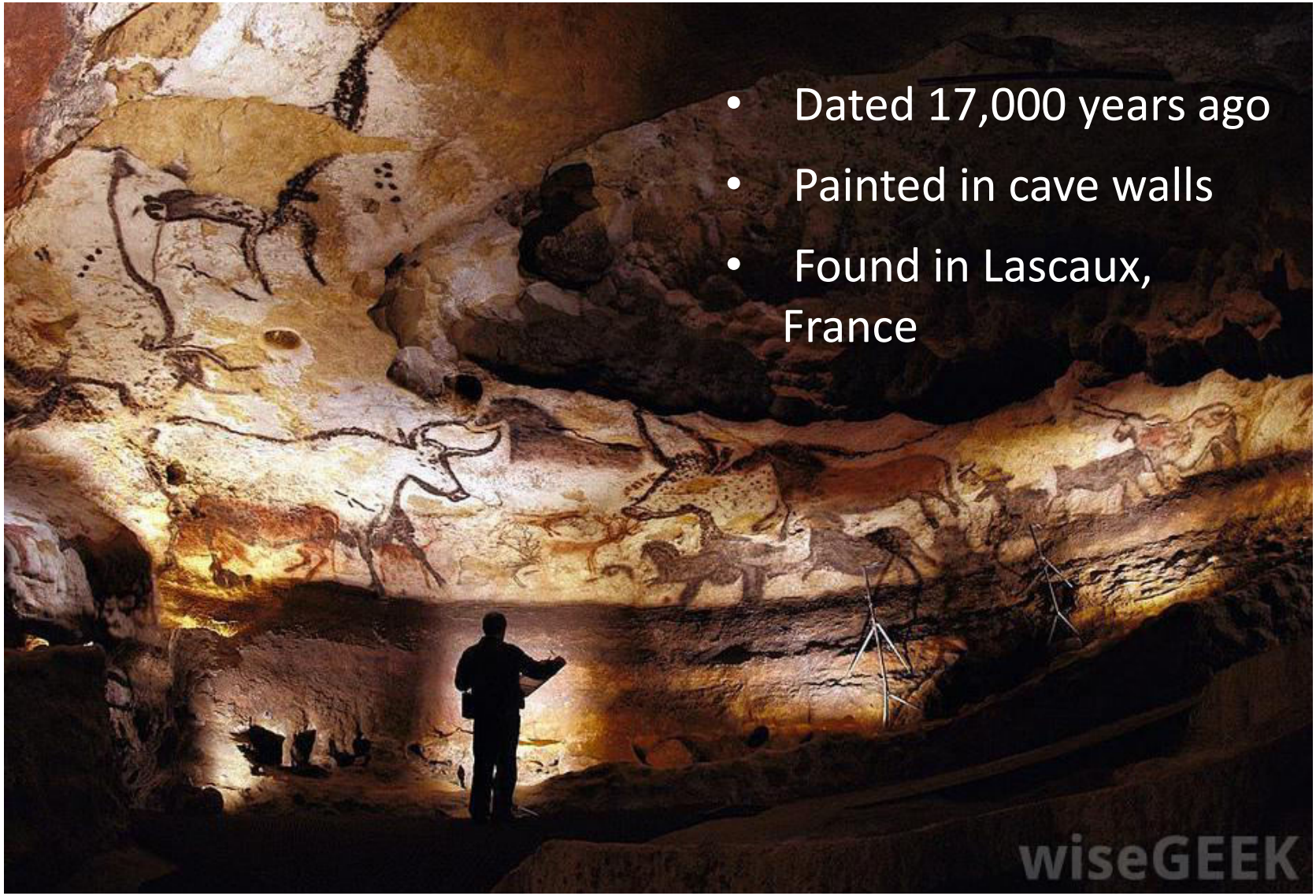
The Art and Science of Color

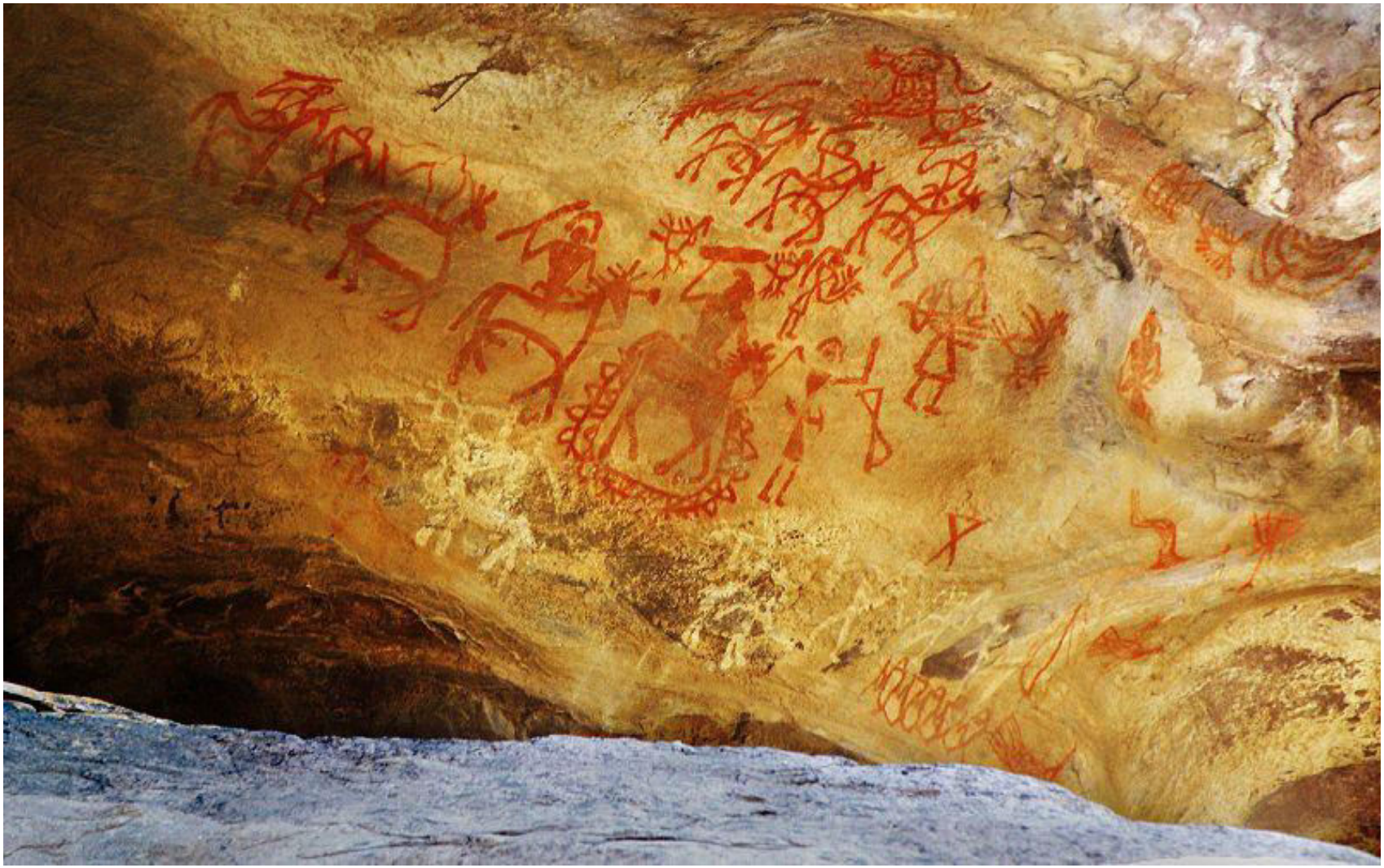
Sayam Sen Gupta

(NCL, Pune)

Brief but Colorful History of Paint



- Dated 17,000 years ago
- Painted in cave walls
- Found in Lascaux, France



Cave painting

Bhimbhetka, MP, India

Ajanta Caves

Bodhisattva Padmapani

5th Century AD

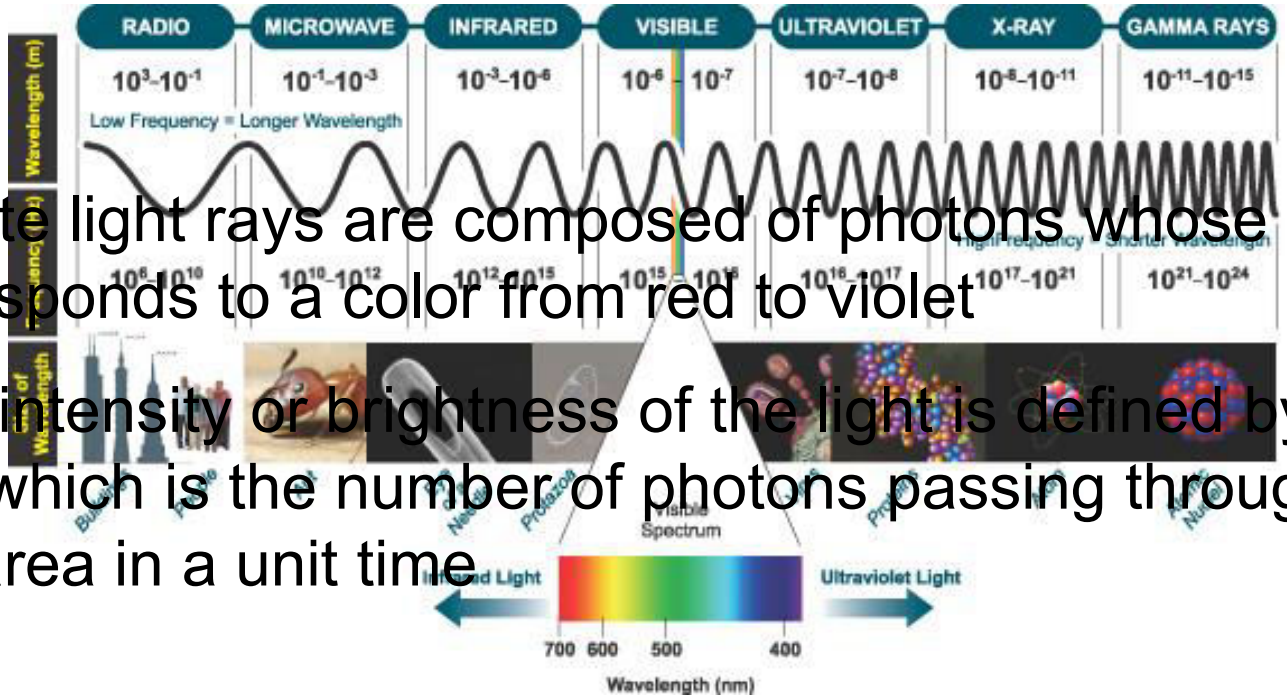
Mahajanaka Jataka; Ajanta; 6th Century AD

Colors: The Rainbow

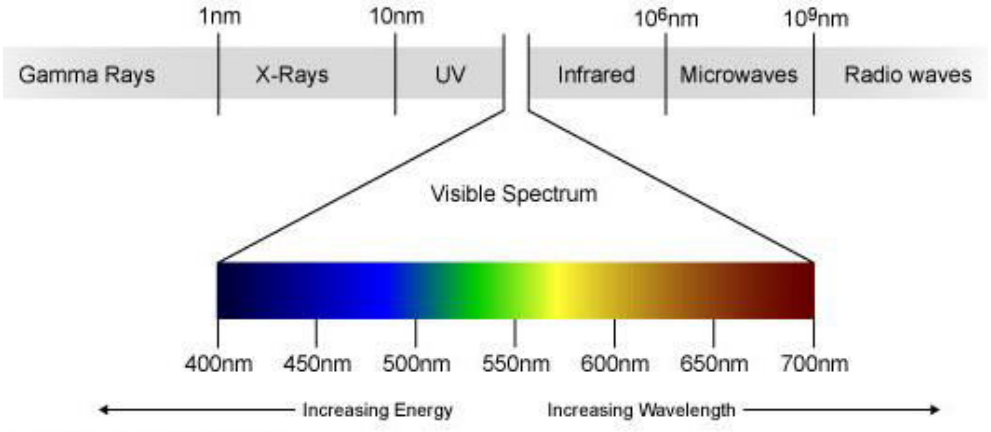
•Newton established that refraction causes the dispersion of light into its constituent hues.

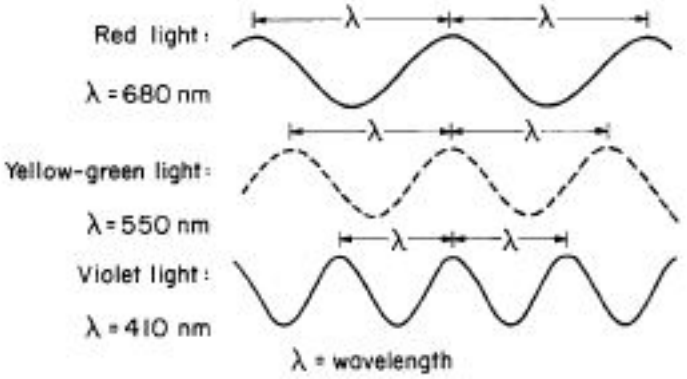
• Why is Indigo in the rainbow?

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

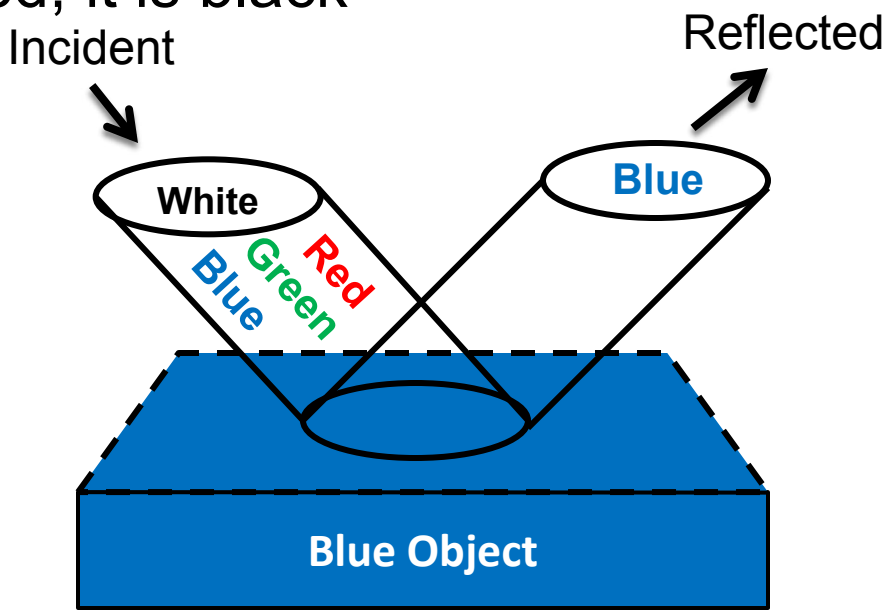




The Color of Objects

As we look at an object, the color we see exists due to white light illuminating the object, 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



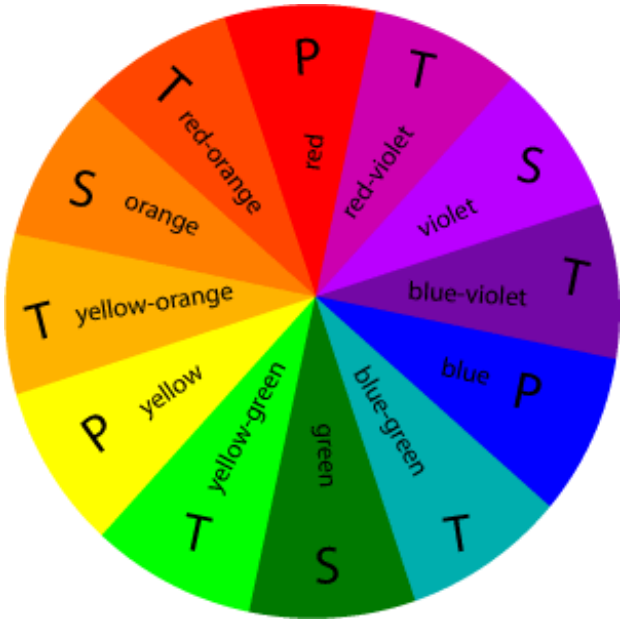
If some of the visible wavelengths are absorbed and others reflected, the object is colored

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

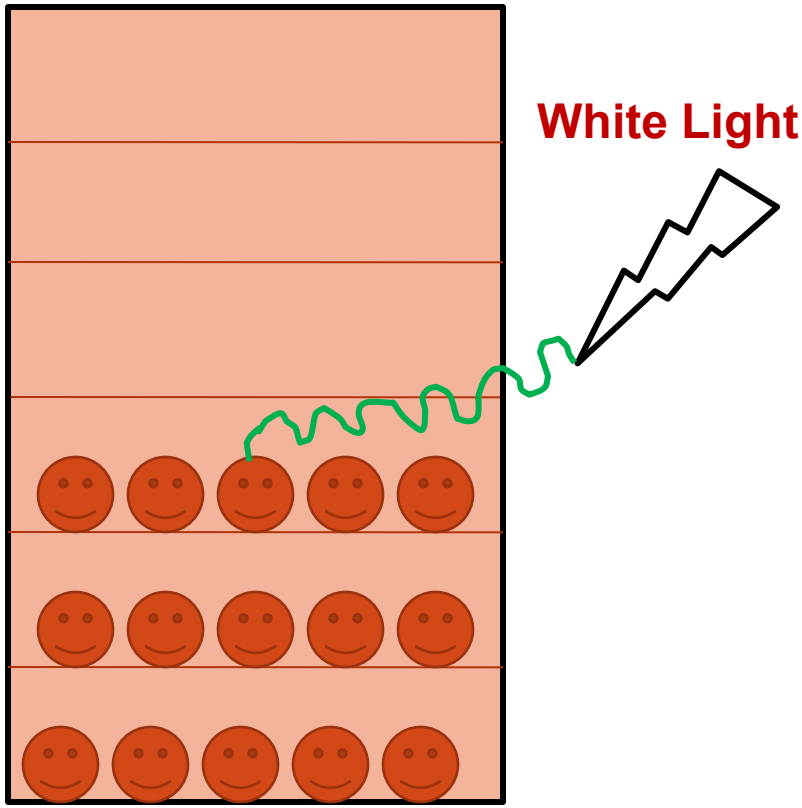
- The remaining wavelengths are reflected, and ‘complementary color’ is seen.



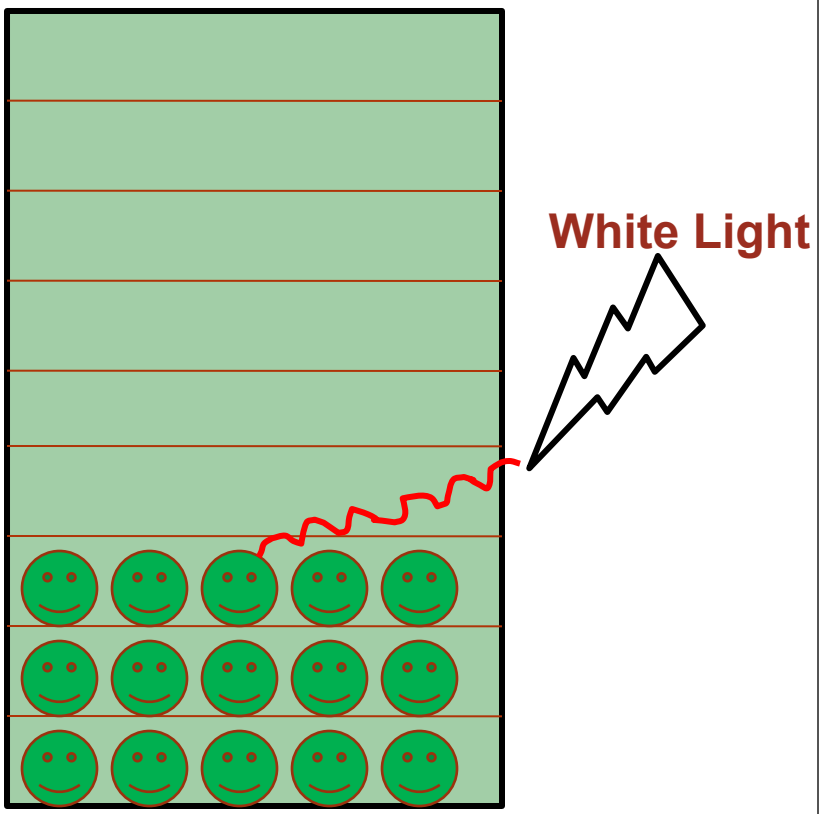
Vermilion is red since it absorbs blue green light

Different Colors!!!

Atoms → **Molecules** → **Electrons**

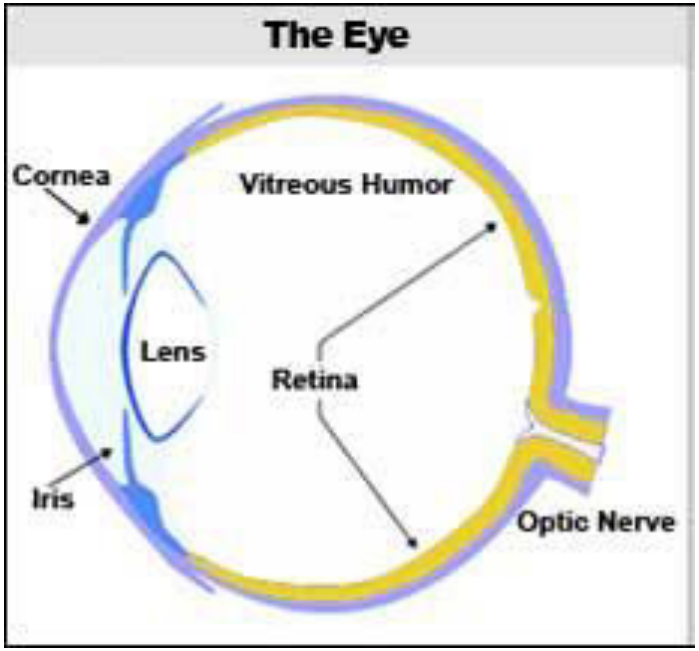


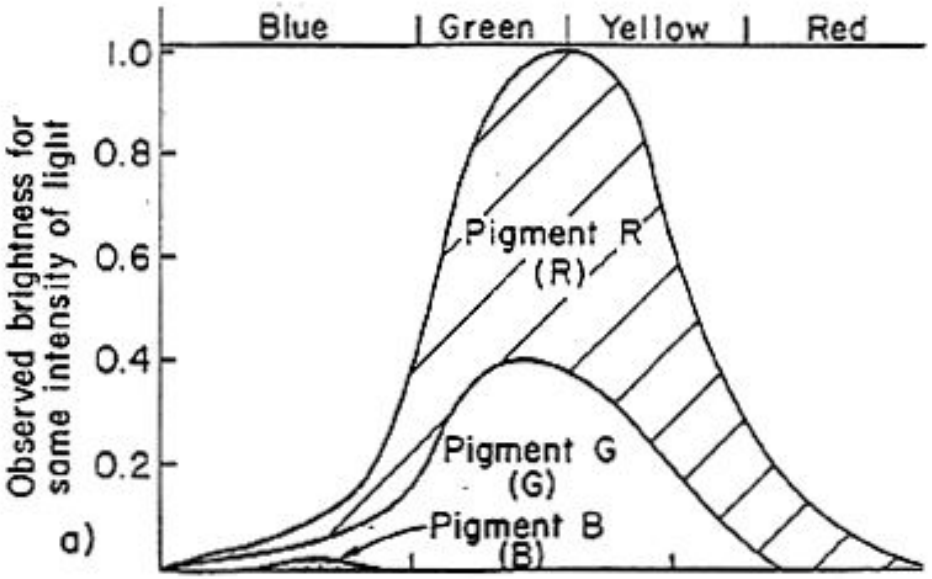
Red Object



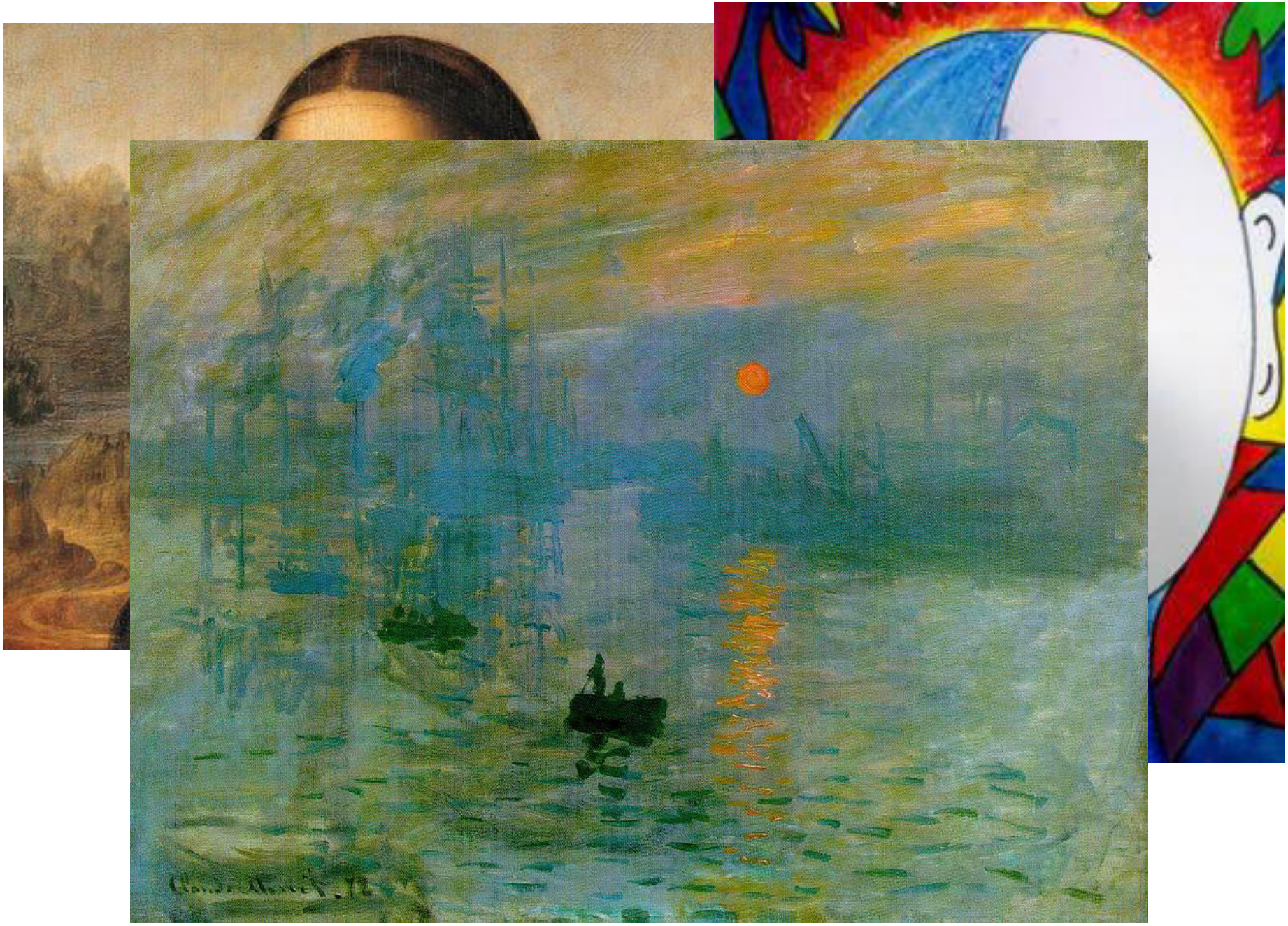
Green Object

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.



The Great Debate: 15th and 16th Century art

Disegno vs Colorito

Studies for the Libyan Sibyl
Michelangelo, 16th century

Venus and Adonis
Titan, 16th century

Pigment versus Dye

Pigments

- From latin word “pingere” meaning “to paint”
- Can be suspended into binder such as glue, oil, egg
- Typically made of minerals but examples exist where they are made from insects and bones
- Unlike dyes, they do not dissolve in binder, remain suspended

Dyes

- Colored substances typically soluble in water
- Used to color fabric: need to be “fixed”
- Need use of a mordant (latin for “biting”)
- Mordants include metals, alum as well as urine
- Can be made into readymade paints by fixing them with a mordant onto white mineral powder such as clay, crushed bone, salt

The Composition of Paint

Paint is composed of colored pigment and a binder

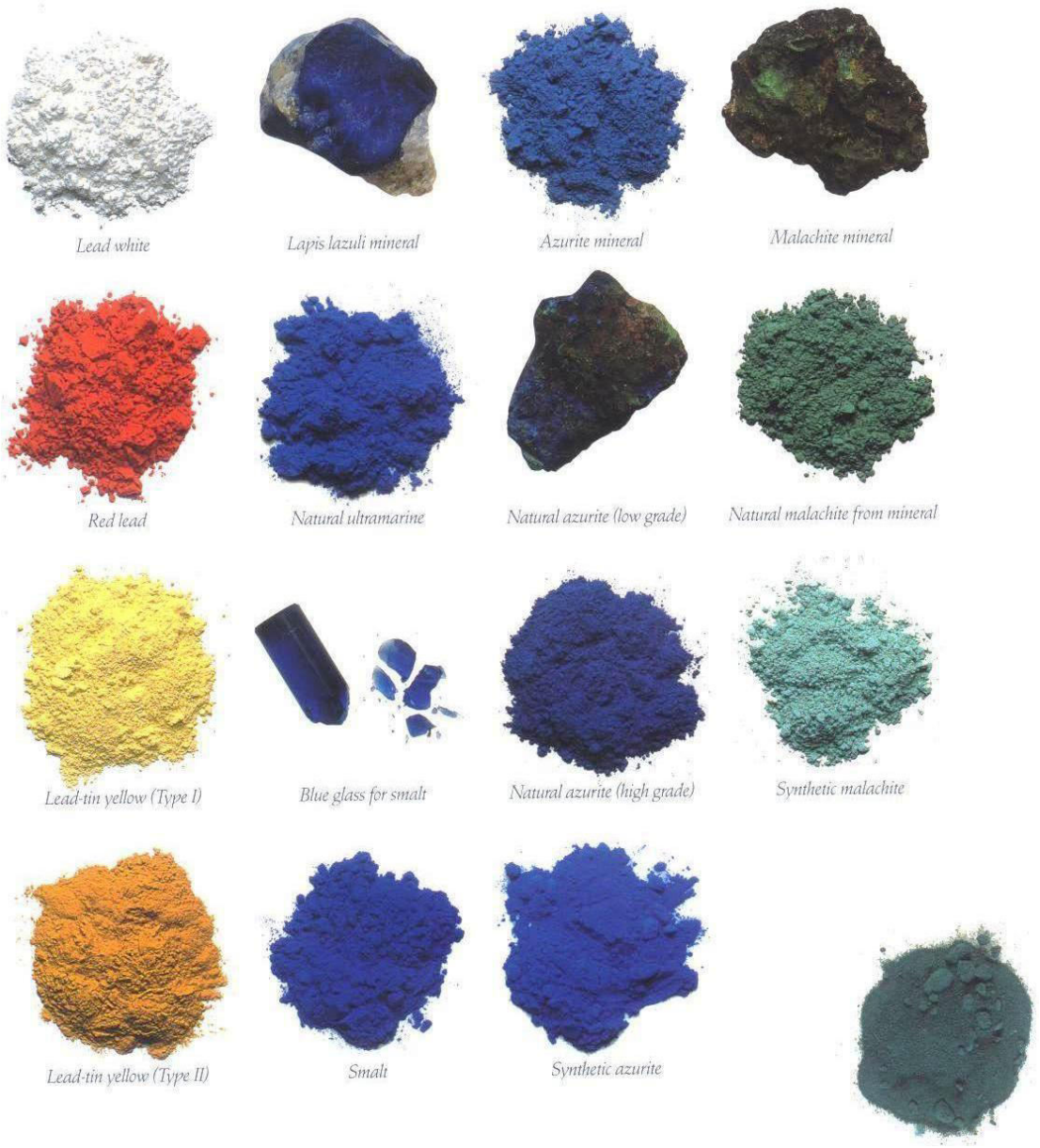
Pigment: Colored powdered substance (minerals, inorganic salts, dyes)

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

Some Pigments available until 1600

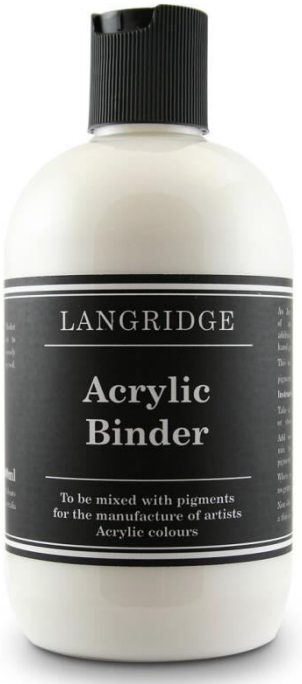


Binders: The vehicle for the color

Carbohydrate:Gum Arabic from Acacia plant

Oil and Fat: Linseed Oil

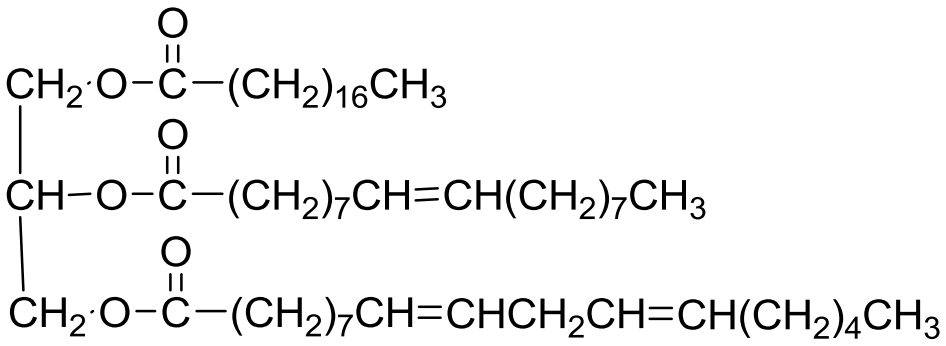
Protein: Egg yolk



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

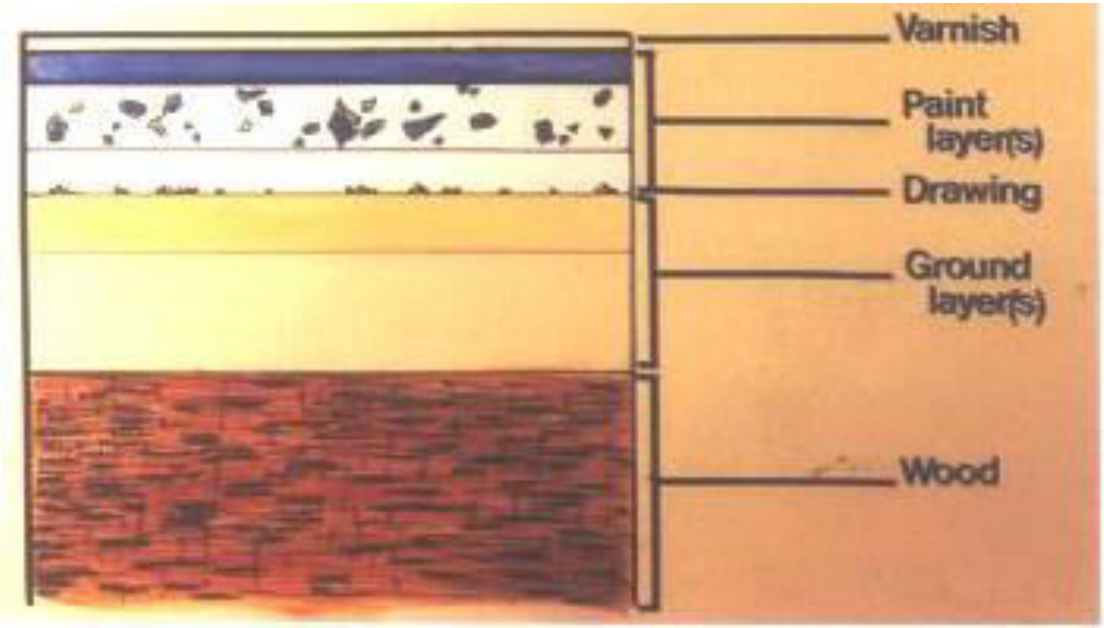
→ Oleic Acid

→ 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

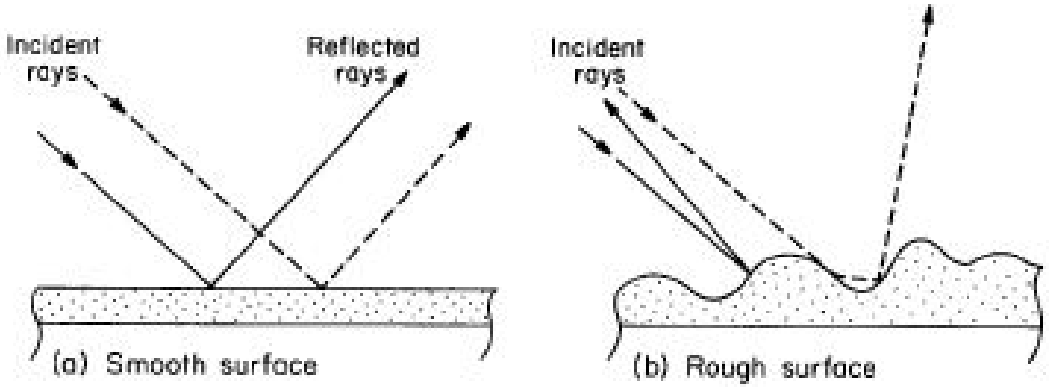
Panel Painting Construction

- 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

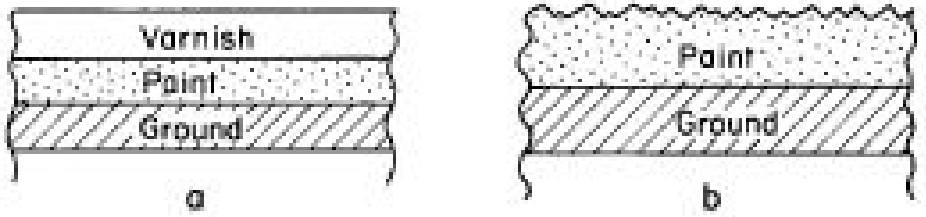


The Importance of Varnish

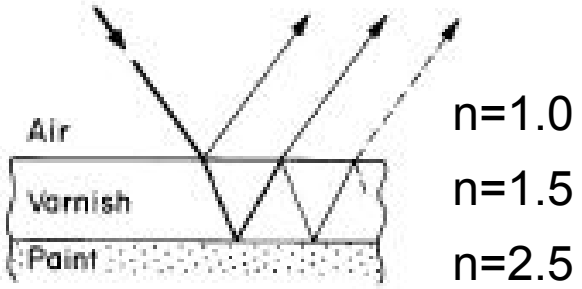
Specular and
Diffuse Reflection



Varnish provides a
shiny surface



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



Blue

Earthe's natural Blue

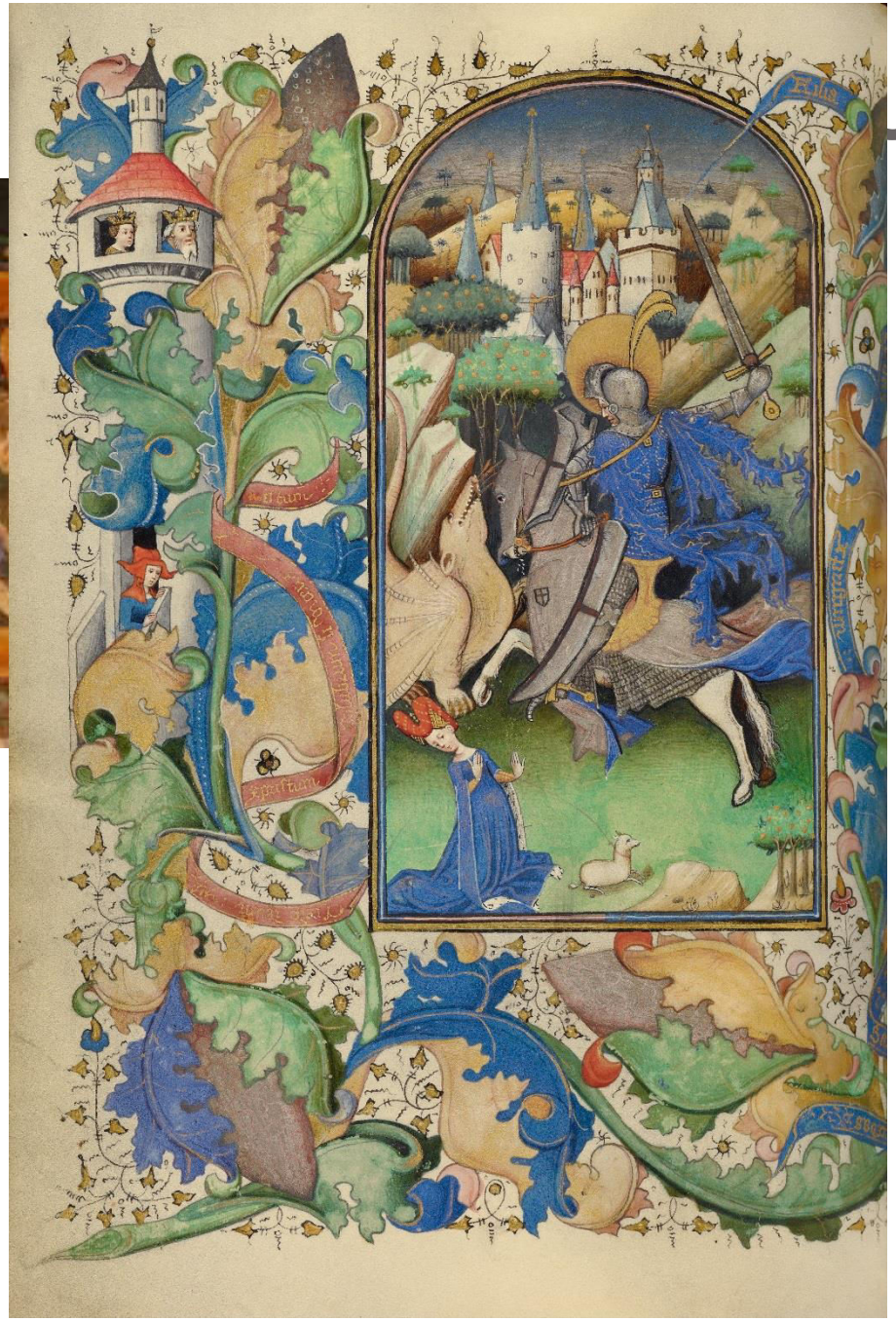
Lazurite: Bright blue; very expensive

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

Synthetic

Cobalt Blue: Only in 1802

Prussian Blue: Accidental discovery



Ultramarine

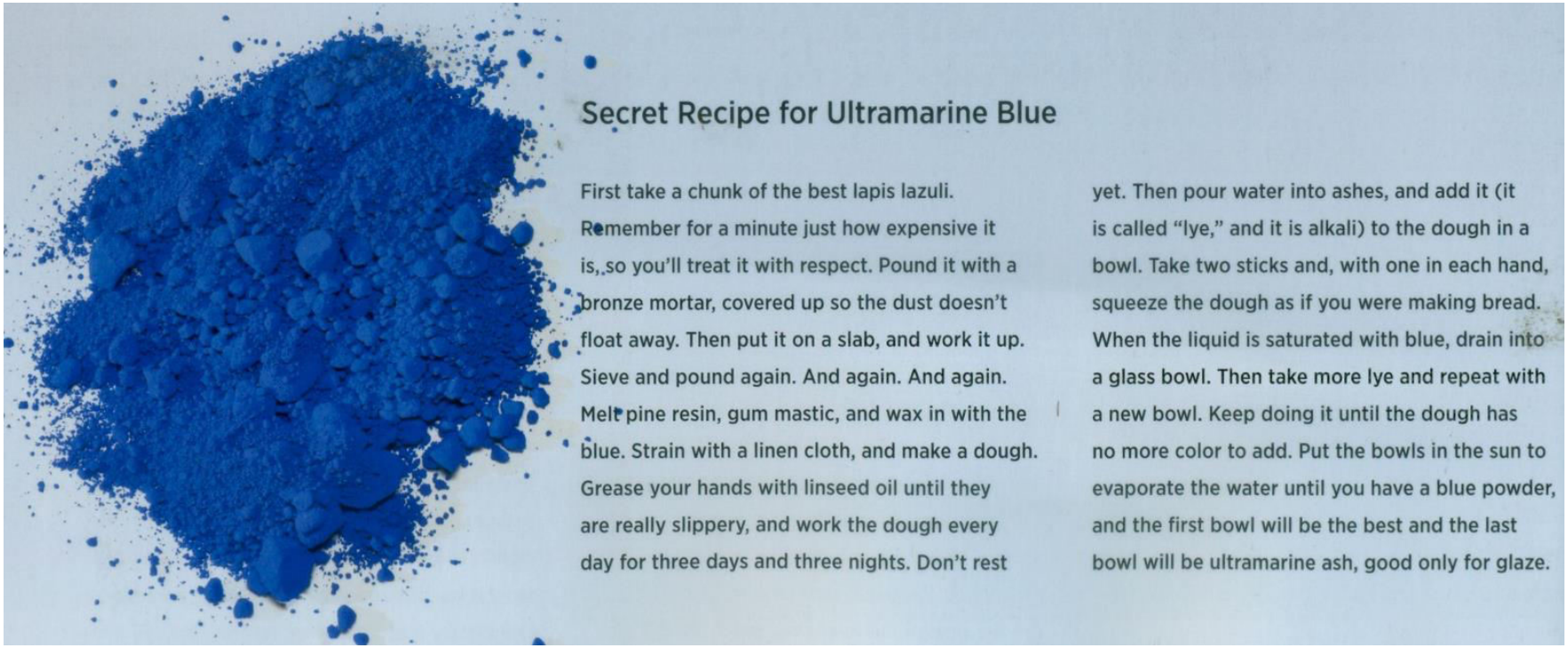
Lapiz Lazuli mined from range of mountains called Sar-i-sang in Afghanistan.
Came to Italy via Baghdad, Damascus, Cyrus, Genoa and then Venice
Came back to India from Venice

The Annunciation by Simon Bening 16th century

Lapiz Lazuli: Ultramarine

- Used by ancient Egyptians: extremely expensive- cost a fortune thousands of years ago
- People put it in jewellery and headdresses to show how wealthy they were
- They did not know how to make a paint out of it- contain pyrite, calcium, diopside etc
- First frescos observed in 6th century: Bamiyan Buddha's 9no more there) and Ajanta frescos
- Secret recipe arrived in Europe few centuries afterwards

Secret Recipe



Secret Recipe for Ultramarine Blue

First take a chunk of the best lapis lazuli. Remember for a minute just how expensive it is,,so you'll treat it with respect. Pound it with a bronze mortar, covered up so the dust doesn't float away. Then put it on a slab, and work it up. Sieve and pound again. And again. And again. Melt pine resin, gum mastic, and wax in with the blue. Strain with a linen cloth, and make a dough. Grease your hands with linseed oil until they are really slippery, and work the dough every day for three days and three nights. Don't rest yet. Then pour water into ashes, and add it (it is called "lye," and it is alkali) to the dough in a bowl. Take two sticks and, with one in each hand, squeeze the dough as if you were making bread. When the liquid is saturated with blue, drain into a glass bowl. Then take more lye and repeat with a new bowl. Keep doing it until the dough has no more color to add. Put the bowls in the sun to evaporate the water until you have a blue powder, and the first bowl will be the best and the last bowl will be ultramarine ash, good only for glaze.

In 1824, French society offered a prize to synthesize ultramarine. Won by Jean-Baptiste Guimet from France and Christian Gmelin from Germany- called French Ultramarine

Cobalt Blue

- Me cs for ag

Lavacourt under snow: Monet

Eventually in 1802, it was discovered how to make into a blue pigment- by roasting Co salts with alumina in a furnace

Cobalt Blue: At the scene of the crime

The women taken in adultery

Amsterdam art dealer Han van Meegeren

- In 1943, sold to Nazi field marshall Hermann Goering as a fake for the great 17th century painter Johannes Vermeer
- After WWII, was charged, arrested and put in trial for collaborating with enemy
- Was saved as the blue turned out to be cobalt blue instead of ultramarine

Ultramarine vs Cobalt Blue

The Marquise de Seignelay and Two of her Sons: Pierre Mignard

Prussian Blue

- Johann Jac 703 had promised to make rec
- Needed drie
- Potash was om blood): turned blue immed
- Potash reac rrocyanide
- This reacts e”

Blue-print

Ferric ammonim citrate + Light + Potassium Ferrocyanide: **Blue**

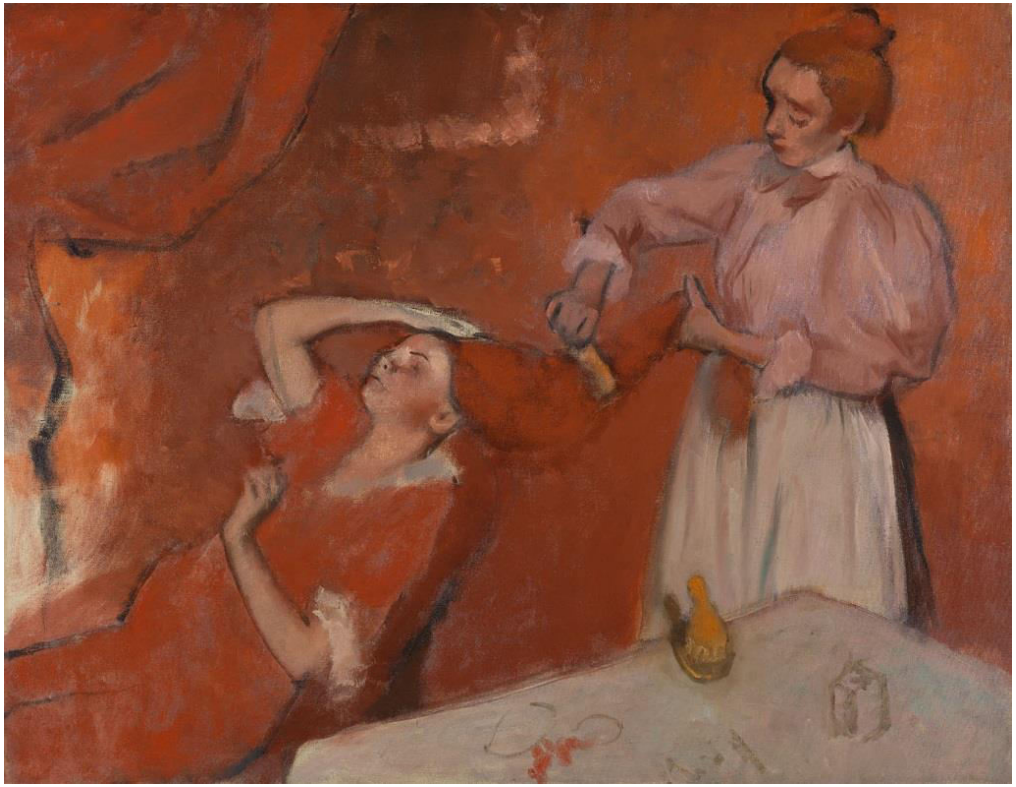
1842: English Astronomer Sir John Herschel

Red

Hematite: Iron Oxide

Cinnabar: Contains mercury; toxic

Combing the hair by Degas



Four reds used: Vermilion, Red lead, Indian red, Red lake

Cochineal

Cochineal is a bug, grows in particular cactus: Mexico

Portrait of a Young Man in Red by Raphael, 1505

Earth's Natural Palette

Yellow and Orange

- Yellow ochre
- 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

- Green earth is a mixture of hydrosilicate of Fe, Mg, Al, K,
- Malachite is a copper compound (copper carbonate hydroxide mineral) and is possibly the oldest known green pigment used.

The virgin and child with St John Ghirlandaio

Green

- Medieval painters used green earth pigments for flesh undertones.
- To paint the pinks of flesh directly onto the white gesso would acheive a "sunburn" effect in the flesh of the figures.
- To neutralize the pink, painters painted a layer of green earth under the pink.
- The red pigments' layer has often faded away leaving a greenish color

The importance of Pure Colors: Blue and Yellow also makes Green

The marriage of virgin

Making Gesso

Gelatin

Making Binder for Egg Tempera

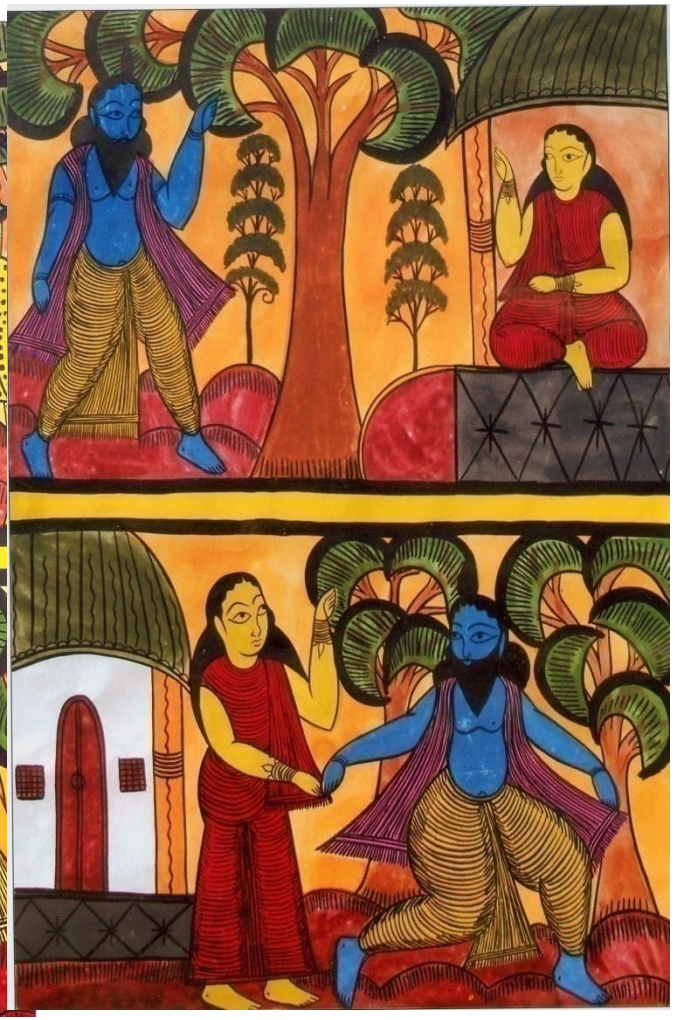
The egg yolk will now be mixed with equal amount of water to make the binder

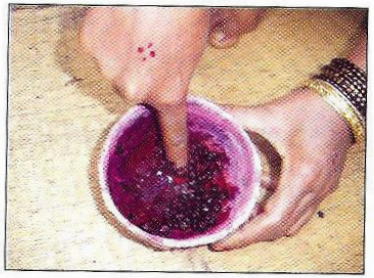
St Jerome and John the Baptist

Apollo and Daphne

Patchitra: Folk Art In Bengal

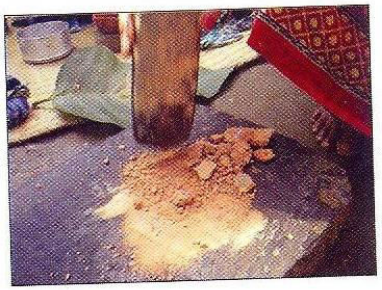
(dates back 2000 years)



Bael seed	Gokarna	Saag flower	Bael leaves
			
			
			
			
Binder	Blue Color	Purple Color	Green Color









Haldi

Henna

Clay

Kalamkari: On Cloth

(Andhra Pradesh)

Panchatantra Story

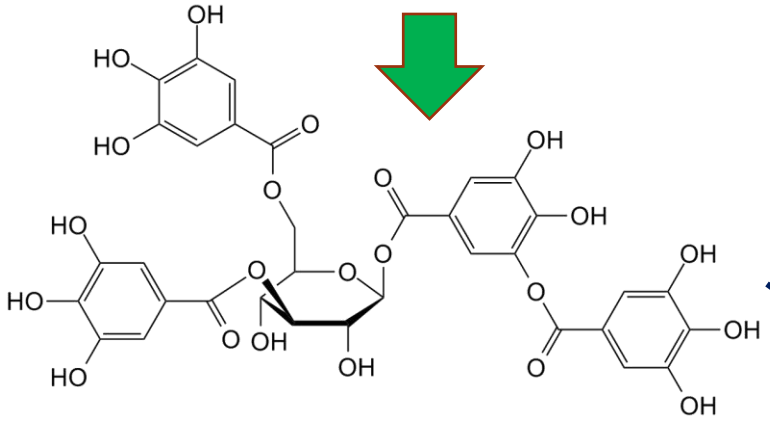

IS IN THE

Kassem: The Black Ink

Myrobalan Nut

Myrobalan Powder

\+ Buffalo Milk
(high fat content)



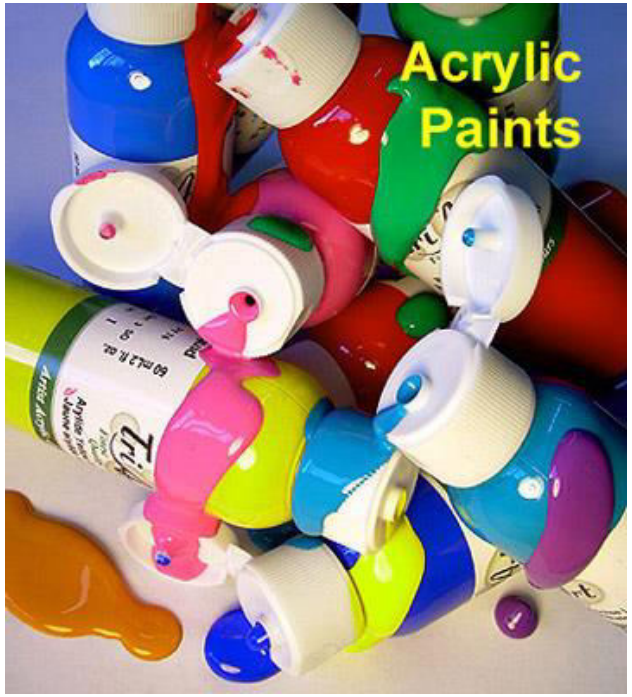
BLACK

Iron filings +

(old jaggery)

Iron acetate
(brown)

Acrylic paints and other medium



Poster Paint

Transparent Water Color

Art Conservation

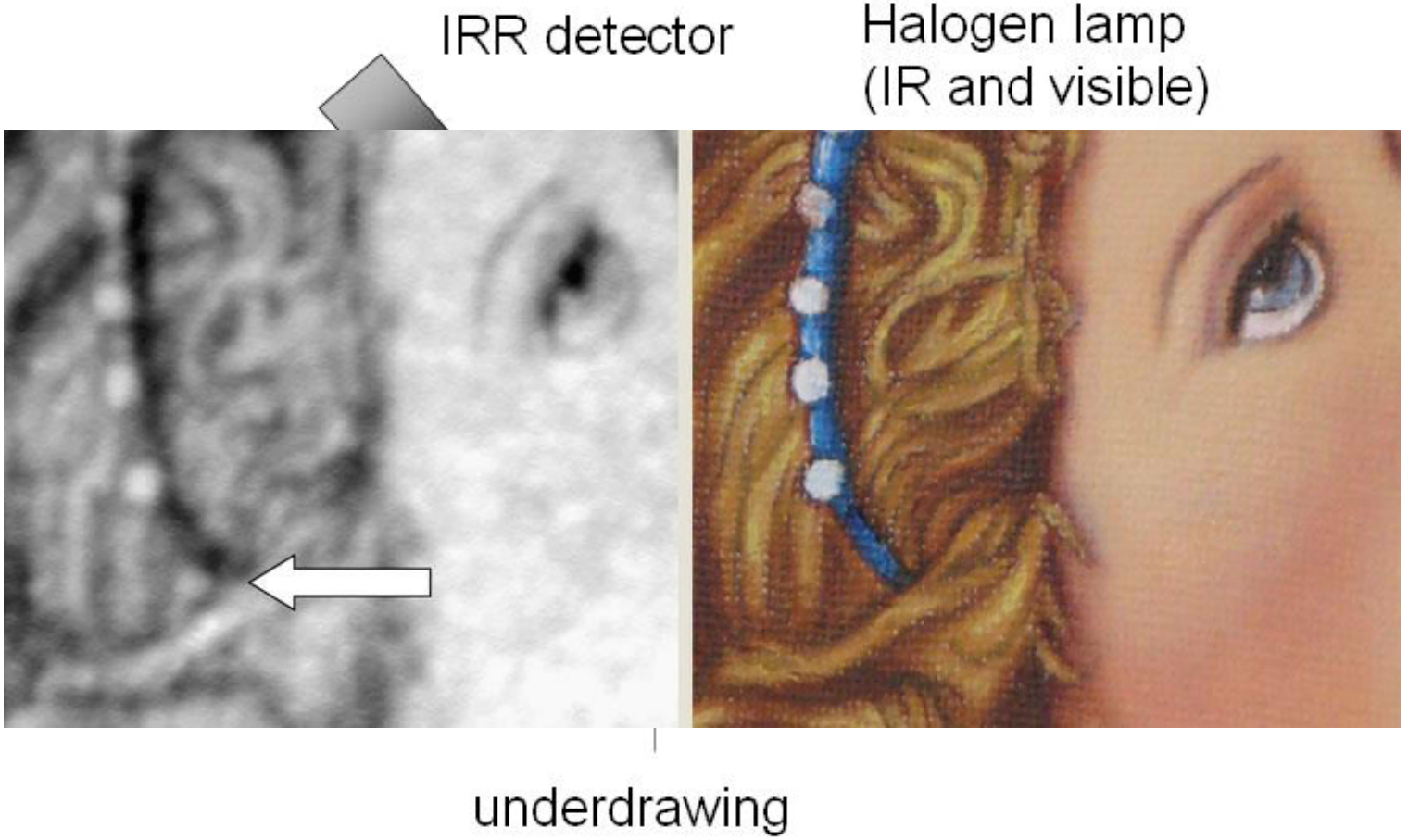
- Great works of art are susceptible to effects of aging: atmospheric oxygen, temperature and humidity changes, air pollution and exposure to light

- 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

Infrared Reflectrography

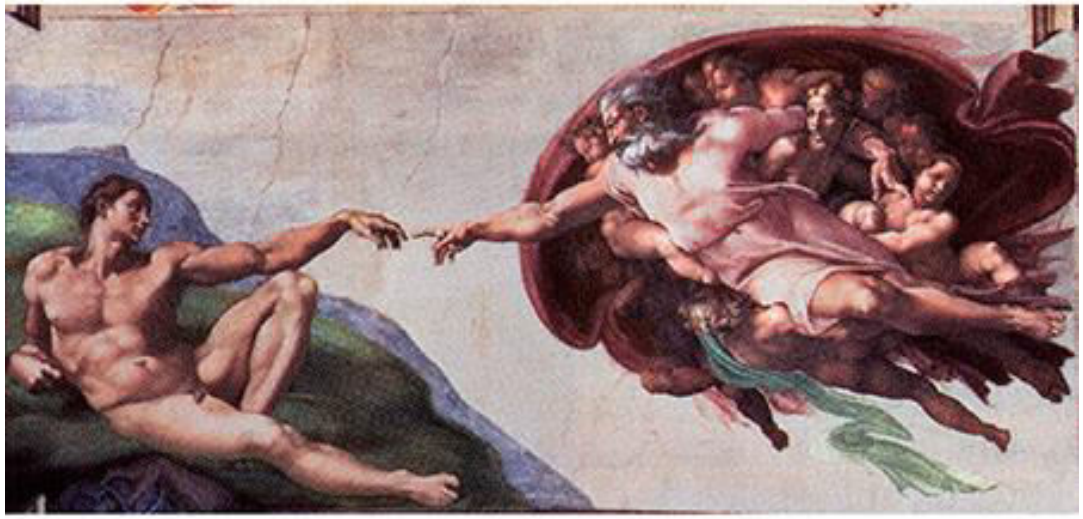


• Being able to "see" underneath the first layer of pigment provides the art historian or conservationist with critical information about the original intent of the artist.
•It can also validate whether or not the work is an original piece of art or identify details with historical context.

Restoration of Sistine Chappel

Pre-restoration

Post restoration



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

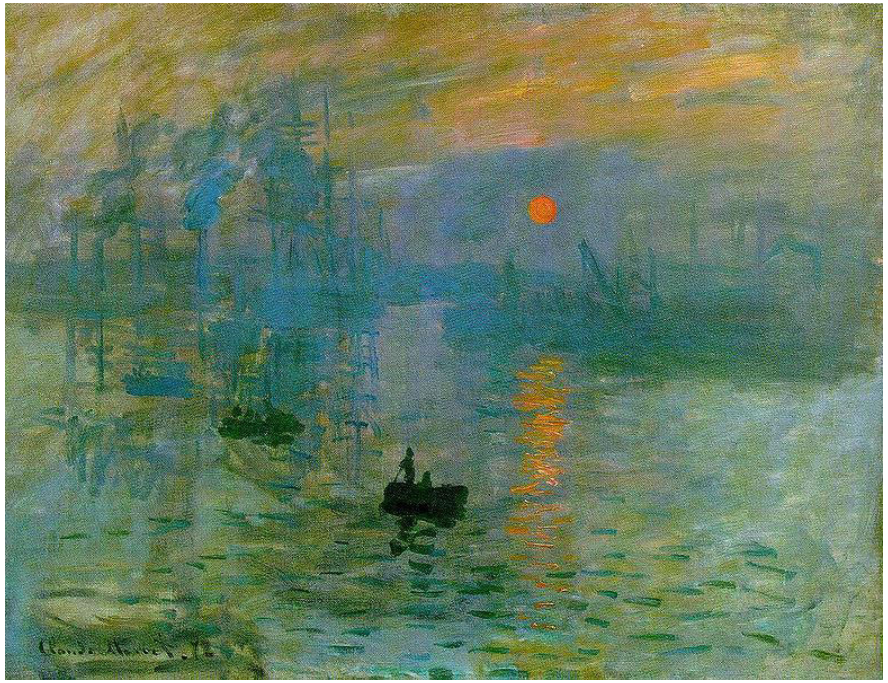
Henry Prince of Wales on Horseback: Robert Peake the Elder (1610-12)

After Restoration

Thank you

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

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

The pigment

Yellow lead chromate

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

White zinc hydroxide

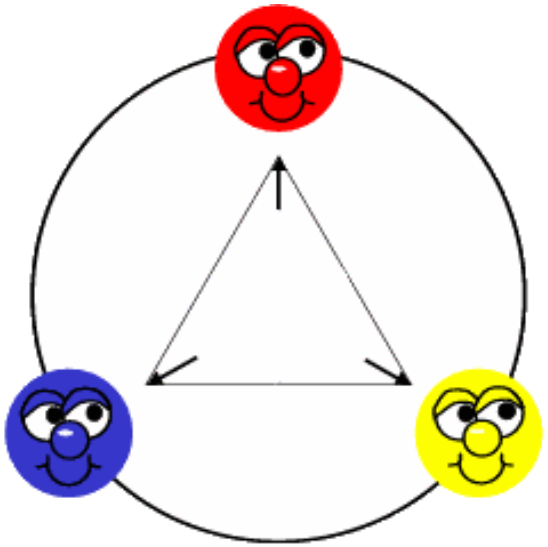
$$Zn(NO_3)_2 + NaOH \longrightarrow Zn(OH)_2 + 2NaNO_3$$

Blue Copper Carbonate

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

Artists Perspective: The Color Wheel

Primary Colors



Secondary Colors

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

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

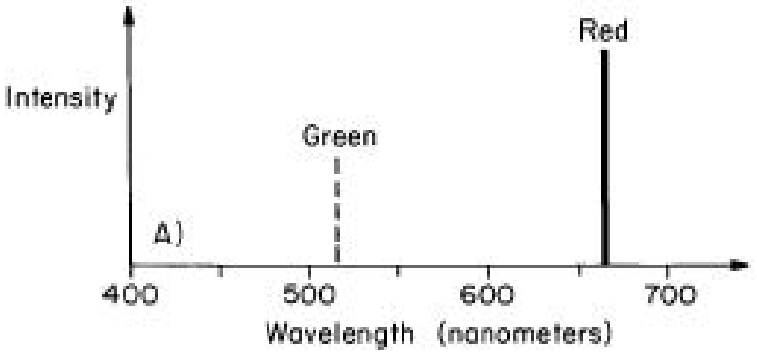
Blue Copper Carbonate

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

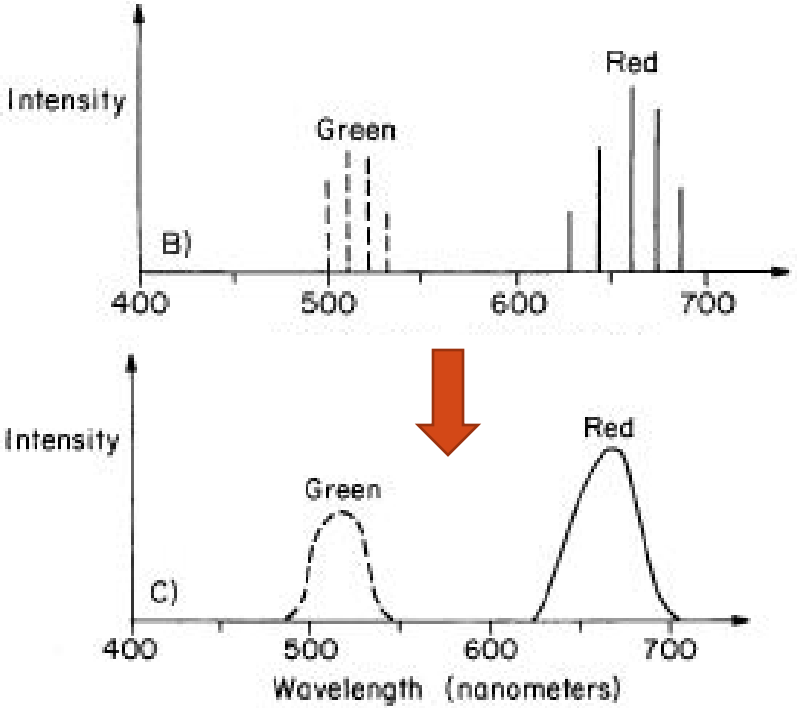
Color: Pure and Sensed

•A spectroscopically pure color has light of only one wavelength.

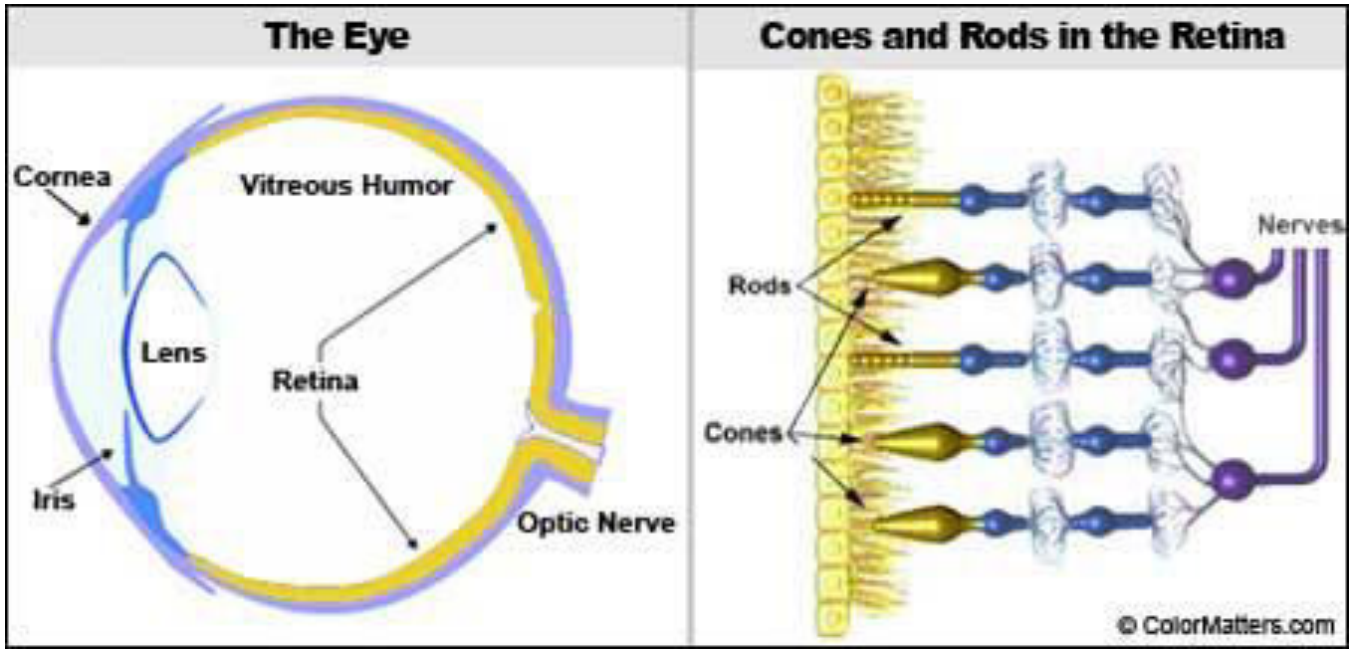
•Colors are seldom spectroscopically pure



• 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.



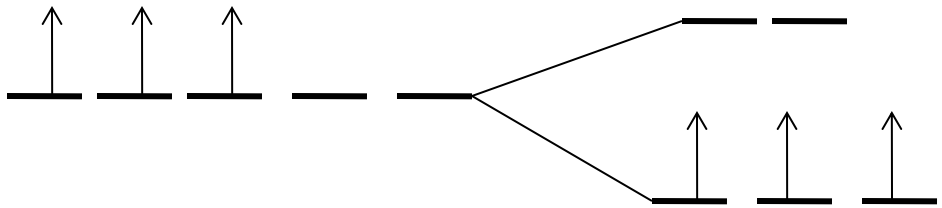
Vision



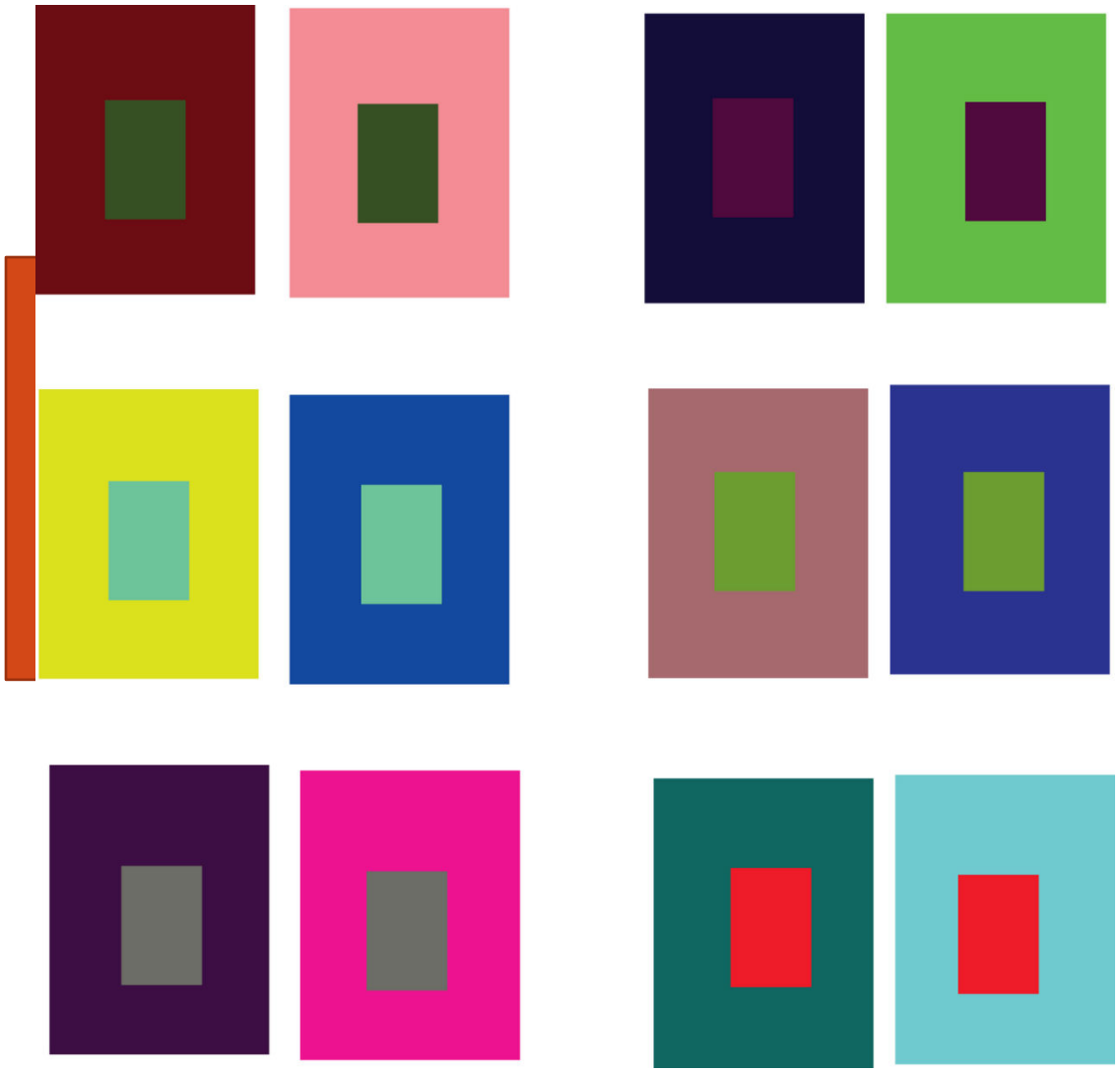
- Humans have three kinds of color receptor cells – or “cones” - in their eyes.
- Each type of cone contains a different visual pigment:"red", "green" and "blue."
- Therefore, we are “trichromats” (tri = 3, chroma = color).

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



Simultaneous Contrast

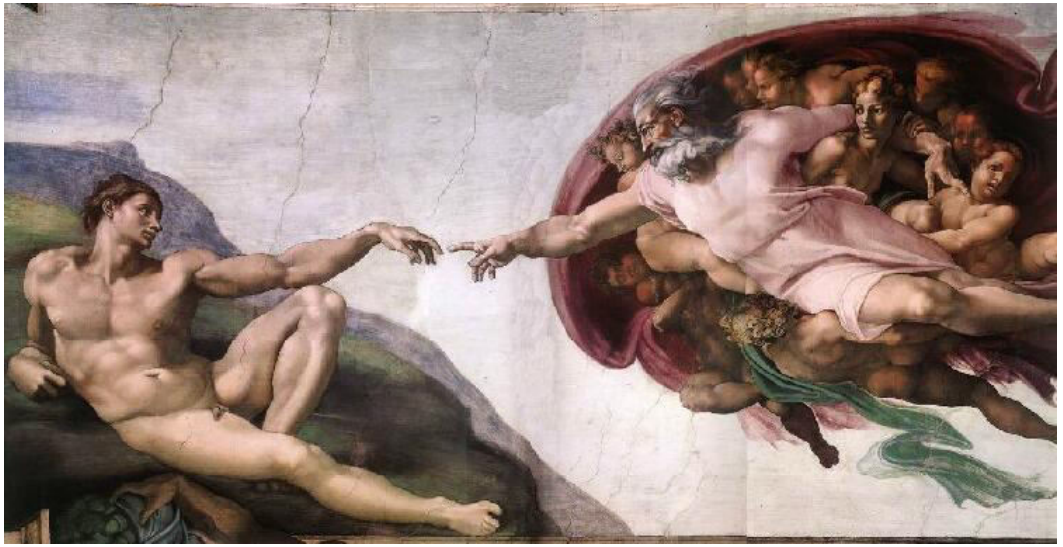


Bathers at Asnières (*Une Baignade, Asnières*), Georges Seurat, 1884.

The Frescos

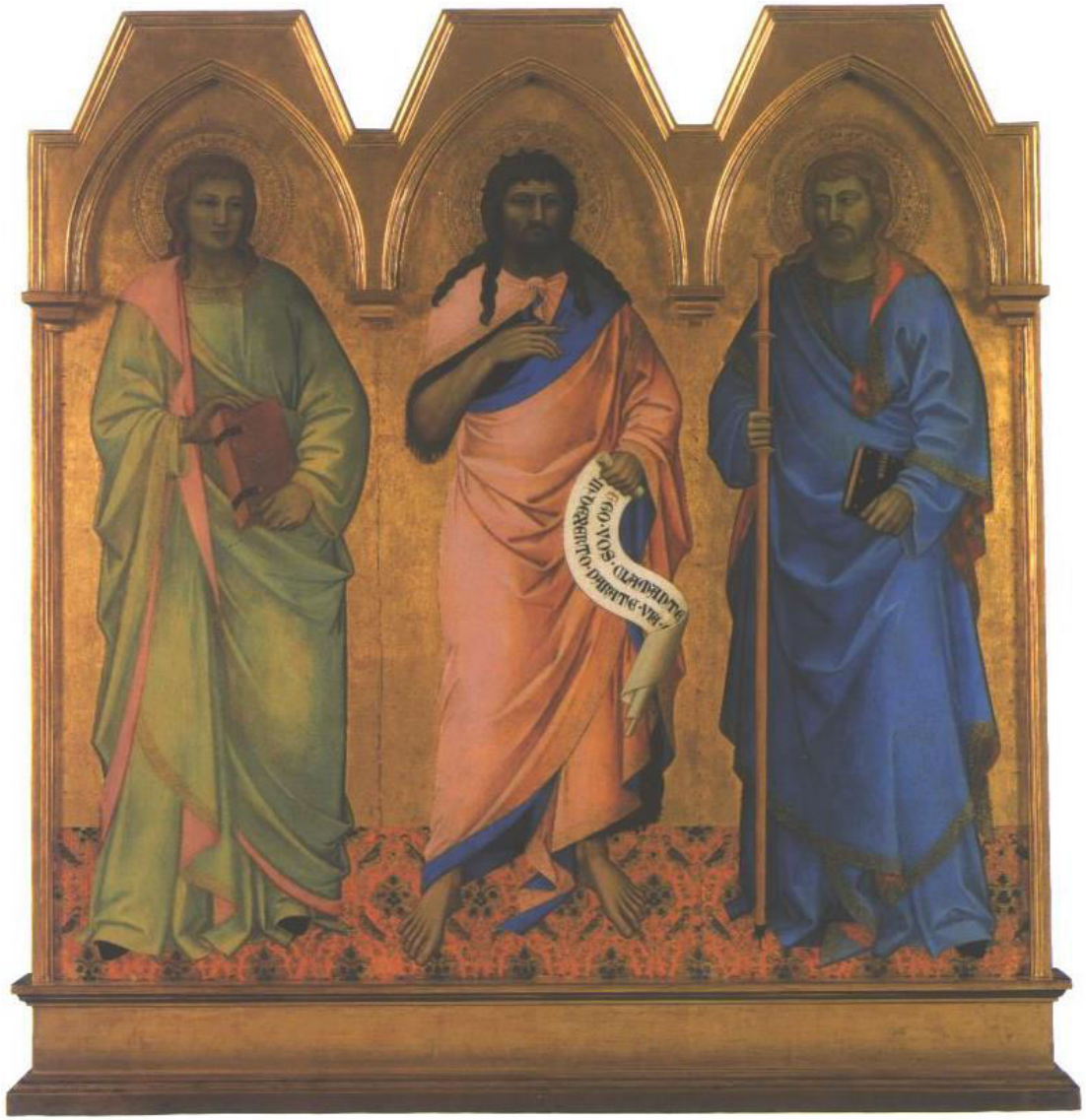
Ceiling of Sistine Chapel, Vatican City

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