We will begin momentarily at 2pm ET

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“Why am I muted?”
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"The Material World of Color: Chemical Characterization of Pigments in Art"

Barbara Berrie, Head of Scientific Research, National Gallery of Art, Washington D.C.

Eric Breitung, Senior Research Scientist, Metropolitan Museum of Art

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This ACS Webinar is being co-produced with National Chemistry Week
We’ll start with a few thoughts about what is color.

Instrumental methods used to identify and characterize colorants and some examples.

Unexpected discoveries about artists’ innovation and experimentation with colorants.
What is color?

Color is the visual perceptual property corresponding in humans to the categories called red, green, blue, and others. **Color derives from the spectrum of light** (distribution of light power versus wavelength) **interacting in the eye with the spectral sensitivities of the light receptors.** Color categories and physical specification of color are also associated with objects, materials, lights sources, etc., based on their physical properties such as light absorption, reflection, or emission spectra. By defining a color space, colors can be identified numerically be their coordinates.

wikipedia

http://www.oneonta.edu/faculty/baumanpr/geosat2/RS-Introduction/RS-introduction.html
What is the red pigment known as “Dragon Blood” made from?

- Insect
- Vegetable
- Mineral
- Dragon
- Synthetic organic
**Answer:** vegetable

The pigment is made from the resin from trees, most often *Croton, Daemonorps* or *Draecaena* trees.

Subtractive Primaries

- mixing paint

Additive Primaries

- mixing light

Some Sources of Color

**Physical**
- scattering
- Interference
- diffraction
- dispersion
- refraction

**Chemical**
- ligand (crystal) field transitions
- charge transfer
  - ligand to metal
  - metal to ligand
  - intervalence
  - band gap transitions
  - lattice defects

Electronic Transitions in Organic Molecules

http://www.chemguide.co.uk/analysis/uvvisible/theory.html#top
Many fun facts about red pigments at https://storify.com/ngadc/seeingredchat

Some of the Analytical Methods Used to Identify Colorants in Works of Art

Sample Required
• chromatographic methods
• mass spectrometry
• optical microscopy (PLM)
• scanning electron microscopy with energy dispersive (or WDS) analysis
• infrared/Raman spectroscopy
• X-ray powder diffraction

No Sample Required
• X-ray fluorescence analysis
• Raman spectroscopy
• multispectral imaging
  – VIS-NIR-SWIR
  – XRF mapping

For more information on any of the techniques go to:
http://cameo.mfa.org/wiki/About_CAMEO

Art Object Analyzer US Patent 4178513, Dec 11, 1979

Handheld XRF 2014
X Ray Fluorescence (and Energy Dispersive) X Ray Analysis

Energy levels of atomic orbitals

e$^{-}$ or X ray

Characteristic X ray

Seurat, Seascape, 1890
Texture is Given to the Surface using Calcareous Sand

Frédéric Bazille, The Ramparts at Aigues-Mortes, 1867

Vibrational Spectroscopy

Fourier transform infrared spectroscopy
Near-infrared imaging
Raman spectroscopy

Micro-Raman spectrum reveals artist’s use of *bismuth metal*


Jean Bourdichon,
*Katherine Hours*, 1480-1485
NIR Reflectance Spectroscopy


Fiber Optic Reflectance Spectroscopy

Scanning electron microscopy/energy dispersive X ray analysis
Orazio Gentileschi
The Lute Player, 1608


Vincent van Gogh
Self-Portrait, 1889
August, 1889
St. Rémy
F 626
Detail of the area of paint which was protected from light by the edge of the frame. The original violet color remains visible.

it is dark purple-blue...”
Letter 604 /800

Audience Survey Question

This is a scan of a color film transparency of the painting. Why does the background appear purple instead of blue in this image?

- The picture was taken in 1910
- The picture was photoshop-ed
- He used magic paint
- The IR response of color film
- None of the above
Why is the picture of van Gogh’s Self Portrait purple?

Do you remember that I told you that we perceive color based on our reception of wavelengths of light in the so-called visible region of the electromagnetic spectrum? In comparison, the sensitivity of the chemical in color film that registers reds goes lower in energy than our eyes do. So, if there something that reflects in the close infrared spectrum the dye responds to it and creates a chemical we see as red.

Cobalt blue, CoAl₂O₄, the major pigment van Gogh used in the paint in the background of this painting does in fact reflect this near infrared radiation, sometimes called the photographic region; the dye in the film undergoes a chemical reaction and makes the red color. In combination with the chemical that makes blue, we see purple!
Date: Saint-Rémy-de-Provence, Thursday, 5 and Friday, 6 September 1889

letter 800 dated early September
1889://www.vangoghletters.org/vg/letters/let800/letter.html

- 10 mètres toile
- Grands tubes 6 tubes blanc de zinc
- "" 2 "" vert d’emeraude
- 2 "" cobalt
- Petits tubes
  - 2 Carmin
  - 1 vermilion
- 1 Grand tube laque ordinaire
- 6 pinceaux Putois [fitch], 25 poil noir

---

1. 5% eosine A ppt by lead acetate
2. 5% eosine A on blanc fixe
3. 5% eosine A on clay
4. 5% eosine A on barytes and kiesselguhr
5. 10% eosine barium lake of brilliant orange R on blanc fixe
6. 10% eosine barium lake of brilliant orange R ppt on a clay and alumina lake, simultaneous with the production of blanc-fixe
eosin

zinc white, chrome yellow, organic reds, emerald green, chalk, red lead?

ultramarine, chrome yellow, emerald green, zinc white

lead white, barium sulfate, yellow iron oxide, chalk

lead white, chalk, barium sulfate
BSE image of a scraping of the pink paint on the palette

phloxine?

lead salt of eosin?

erythrosine

Microspectrophotometry
Carmine  carminic acid

Madder  alizarin

Geranium lake  erythrosine

Xanthene  Rose Bengal  phloxine
**Additional Resources**

- [http://www.nga.gov/content/ngaweb/conservation/publications/publication-list.html](http://www.nga.gov/content/ngaweb/conservation/publications/publication-list.html)


Surprising Results

• Glasses and frits of various colors including an orange-yellow which was designed for enamelling glass and painting ceramics

• Metal flakes, including elemental bismuth, were used for dark colors.

• Van Gogh used the brilliant eosin (with erythrosine and phloxine) from the time was available as an artist’s pigment.

Conclusion

Artists love to experiment with new materials to get interesting and innovative color effects
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