



Introducing Students to
Transdisciplinary Educational and Research Experiences

Overcoming Bias To Solve Problems

Darryl P. Butt
Dept. of Materials Science and Engineering



BOISE STATE UNIVERSITY

(C) Dr. Klaus Schmidt, Wetzlar, Germany

Example

The VIP Concept: *Science of Art*

- ✓ **Preservation and Reverse Engineering of Cultural Heritage I:**
Theme: [The Science, History, and Psychology of Color in Art](#)
Book: *Color* by V. Finley and Literature

- ✓ **Preservation and Reverse Engineering of Cultural Heritage II:**
Theme: [Archeometry—Methods of Analyzing Materials in Art and Culture](#)
Book: *Scientific Methods and Cultural Heritage* by G. Artioli and Literature

- ? **Preservation and Reverse Engineering of Cultural Heritage III:**
Theme: [Case Studies in the Forgery, Preservation, and Interpretation of Art and Materials of Cultural Heritage](#)
Book: *Caveat Emptor* by Ken Perenyl and Literature

- ? **Preservation and Reverse Engineering of Cultural Heritage IV:**
Theme: [Internship or Focused Undergraduate Research Experience](#)

“Reverse Engineering” -*Discovery*
Through Analysis of Structure,
Function, Purpose, Operation,
Provenance*, Provenience*...

*contrary to some dictionaries... Provenance ≠ Provenience

Surface Analysis

Biomimetics

Forensics

Provenience

Sustainability

Provenance

Dissection

Microscopy

Chemical Analysis

Preservation

Pathology

Materials Characterization

“Reverse Engineering”

Forgery

Critical Infrastructure

Product Development

Restoration

Anthropology

Petrography

Archeology

Artist Purpose

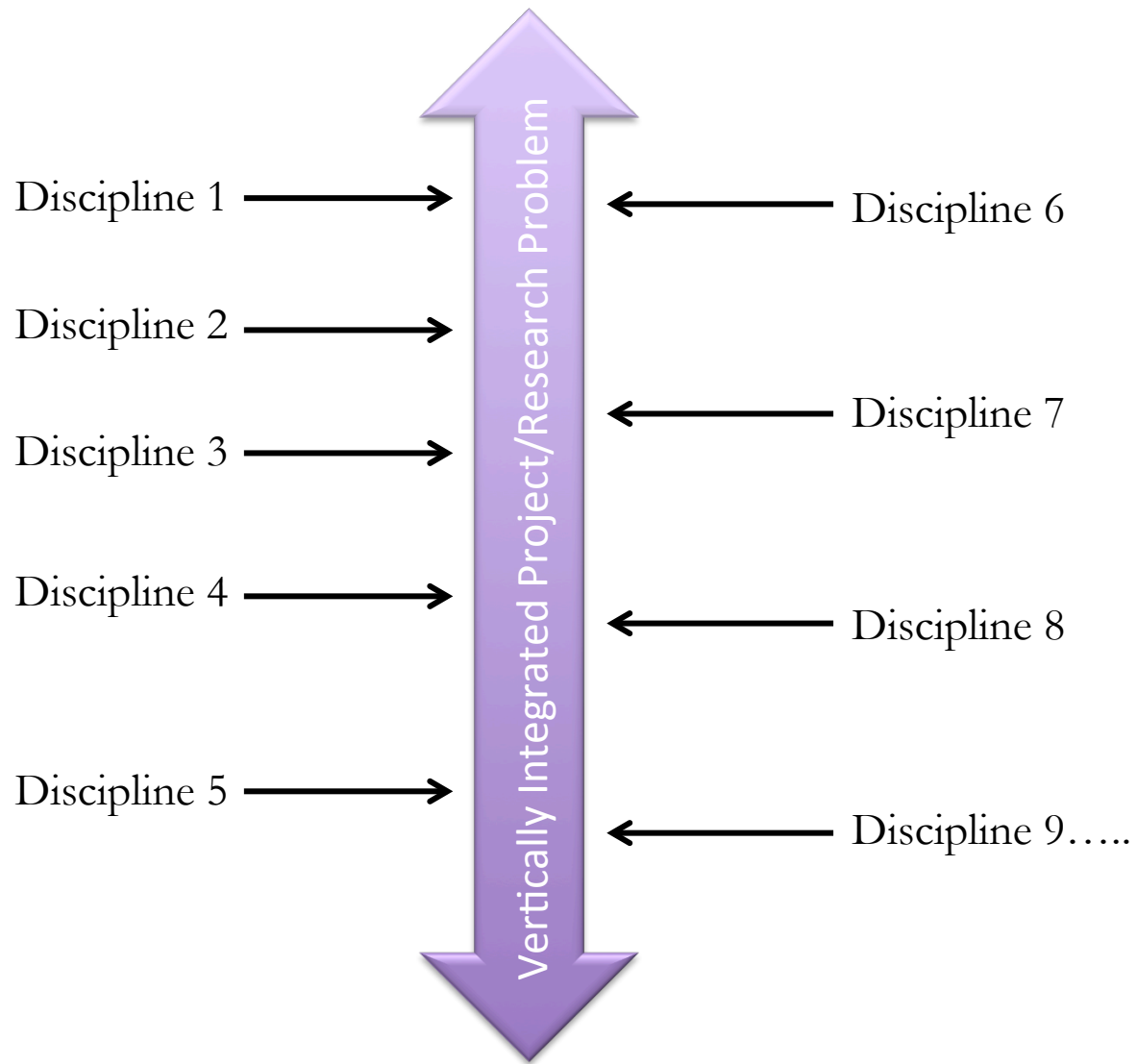
Archeometry

Geology

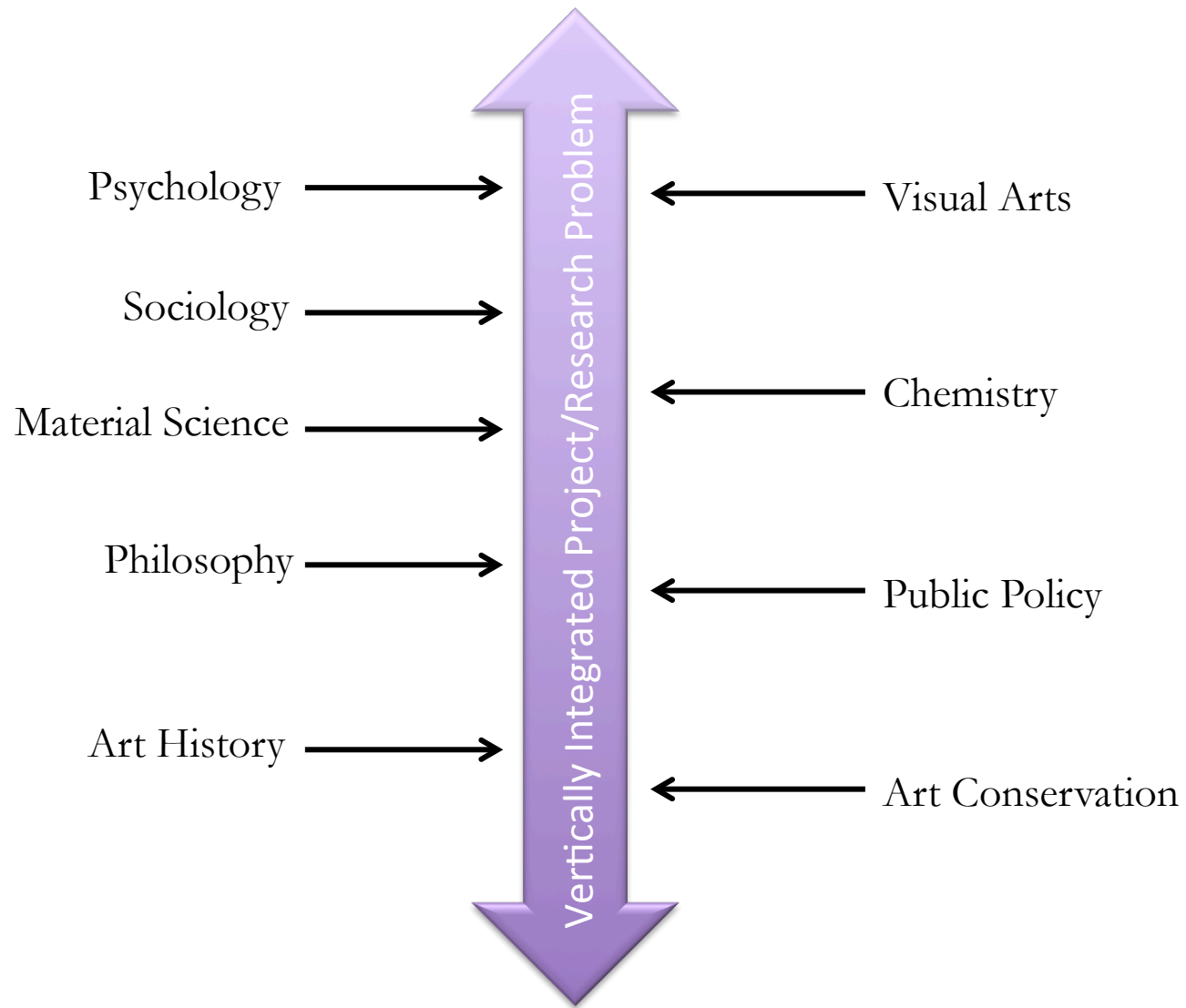
Cultural Heritage

History

The VIP (Transdisciplinary) Concept:



The VIP (Transdisciplinary) Concept:



Leonardo Da Vinci: Savant

1452-1519

Scholarship/Occupations:

Artist
Painter
Colorist
Sculpture
Metal Smith
Inventor
Alchemist
Botanist
Pathologist
Mathematician
Materials Scientist
Mechanical Scientist
Military Engineer
Military Architect
Hydrodynamic Engineer
Military Spy
Mountaineer
Set Designer
Event Planner
Writer
Musician



Red Pastel Portrait by Da Vinci, ~149X?, speculated to be a self-portrait.

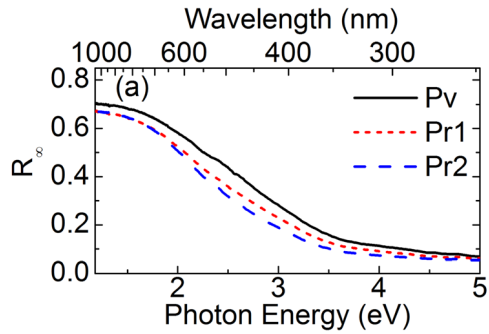
Personality/Experiences:

Son of a Slave
Son of a Notary
Perfectionist
Procrastinator
Uncompromising
Compulsive
Slow and Deliberate
No Fear of Failure
Disastrous Experimenter
No University Education
Student of Verrocchio
Employee of Lodovico
“Colorful” Dresser
Left Handed (Mancino)
Wrote Script in Reverse
Popular and Famous
Vegetarian
Devout Christian
Anti-Clergy
Humorist
Prankster
Master of Yogi-isms
Passionate, Life-Long Learner

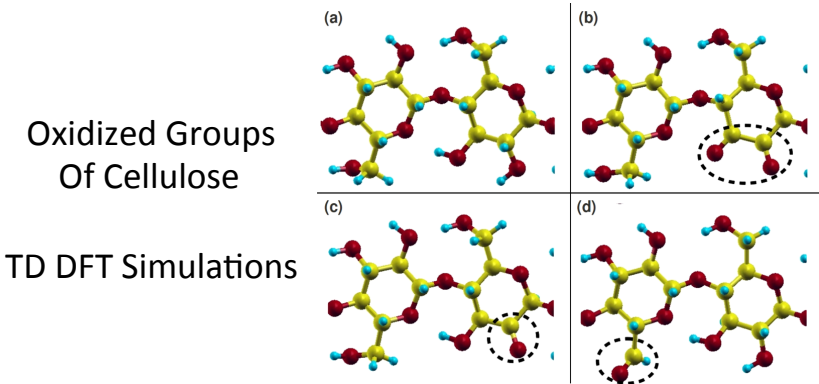
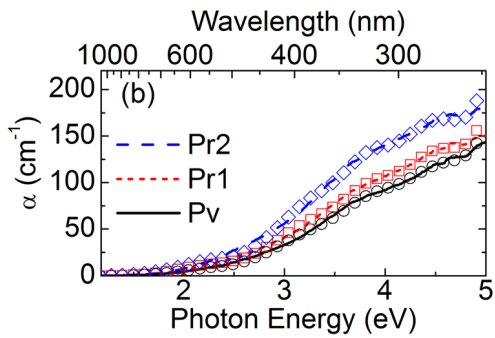
Quote: “Men of Genius Sometimes Accomplish Most When They Work the Least...”

-Da Vinci to his employer, Lodovico, ref.: G. Vasari, *et al.*, *Lives of Artists*, pp 262-263.

“Reverse Engineering” the Effects of “Entropy”



Diffuse Absolute Reflectance Spectroscopy



Post World War II Image

- Severe “foxing”
- Embrittlement
- Oxidation (yellowing) of the parchment
- Red Chalk
- The inscription, “Leonardus Vincius” has vanished

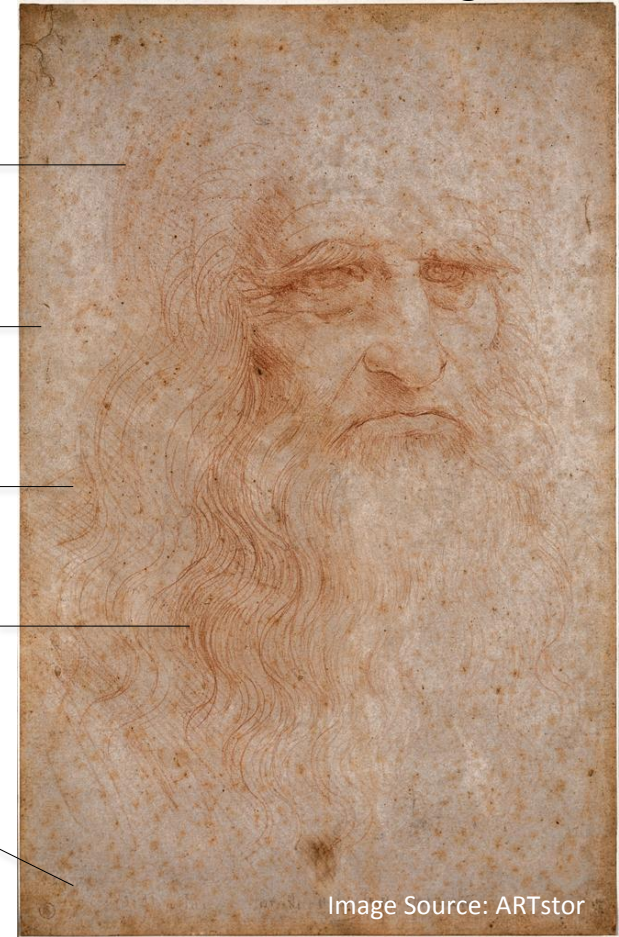


Image Source: ARTstor

Currently stored at 22°C, 55% RH, behind security cameras and light absorbing glass.

Fill in the Blank*

Proof of _____ is
Less Like a Mathematical Proof
Than it is Like a Proof in a
Court of Law

*Provenance, Provenience, a Theory, a Hypothesis, a Mechanism, a Scientific Concept...

The Color Purple

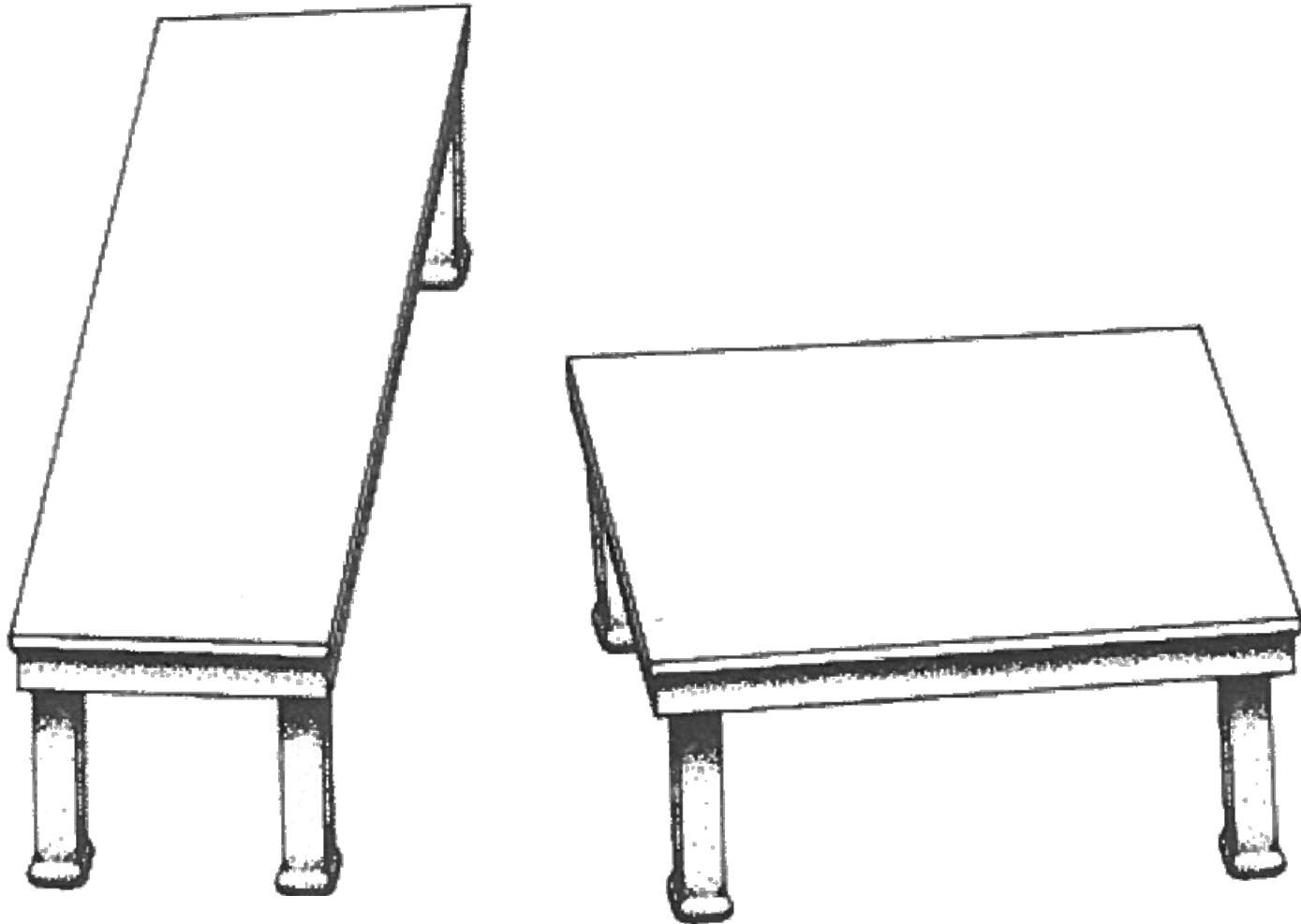


400 nm

700 nm



Which is longer? Which is wider?



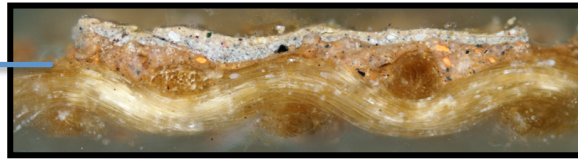
“The greatest deception men suffer is from their own opinions.” — *The Notebooks of Leonardo Da Vinci.*

Construction of a Painting



Oil on Linen, in the style of the Hudson River School, D. P. Butt, 2012.

Painting Cross Section



Belgian Linen, Oil Primed
#66 Median Weave
on Kiln Dried,
Laminated Baltic
Birch (1/8x12x16")

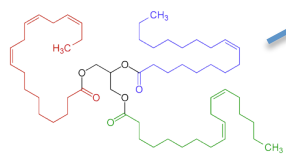
Materials and Limited Palette

Solvent: Gamsol, a mixture of aromatic hydrocarbons

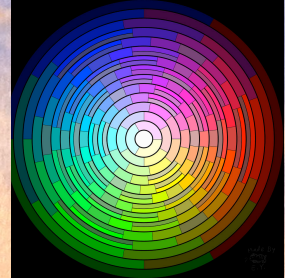
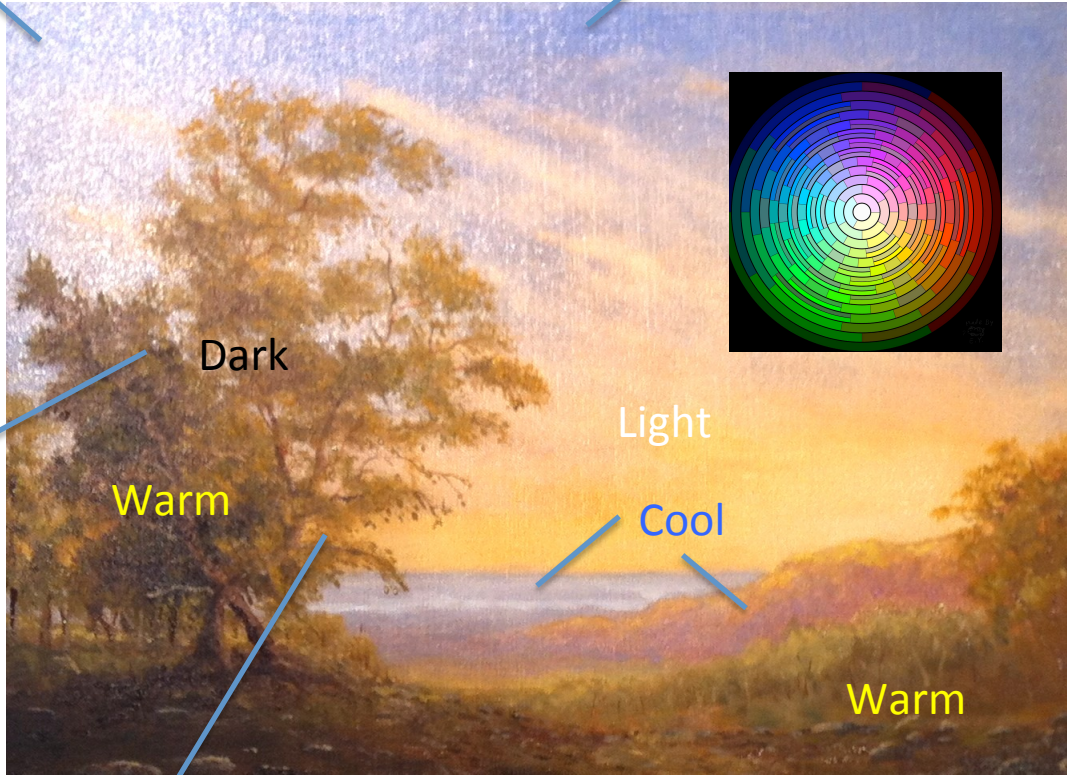
Primary Binder:
Viscosity = 5 cPoise

Mixture of

Vegetable Oil
(Triester derived from linoleic and oleic acids)



Siccatives (lipophilic carboxylic and naphthenic acids)



Pigments:
0.5-5 μm mineral derived powders or organics

Opaque White: Titanium Dioxide (Rutile) or TiO_2 ($n = 2.72$)

Cool and Warm Blues:
Complex Silicate of Sodium and Aluminum with Sulfur or $\text{Na}_8\text{Al}_6\text{Si}_6\text{O}_{24}\text{S}_{4-x}$

Iron Oxide Mix of FeO and Fe_2O_3

Cool and Warm Reds:
1,2-Dihydroxyantraquinone or $\text{C}_{14}\text{H}_8\text{O}_4$

Iron Oxides including FeO and $\text{Fe}_2\text{O}_3\text{-H}_2\text{O}$

Cool and Warm Yellows:
Mix of Zinc Oxide, Cadmium Zinc Sulfide, and Iron Oxide or ZnO , CdZnS , and $\text{Fe}_2\text{O}_3\text{-H}_2\text{O}$

Hydrated Iron(III) Oxide or $\text{Fe}_2\text{O}_3\text{-H}_2\text{O}$

Azomethine or $\text{C}_{16}\text{H}_{19}\text{N}_5\text{O}_6$

~12 Layers of Glaze

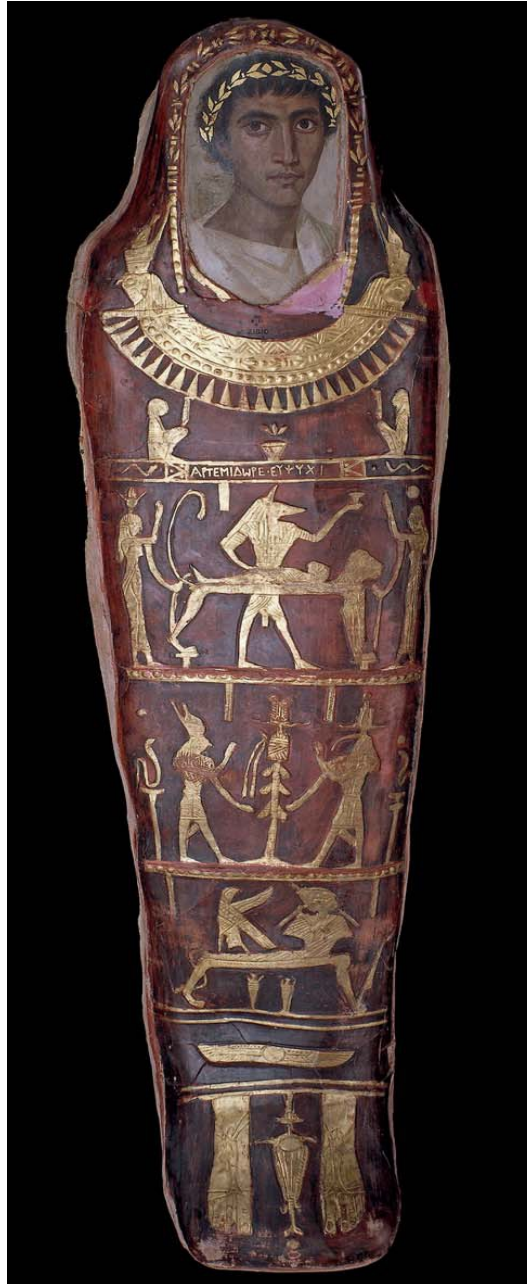
Oil on Linen, in the style of the Hudson River School, D. P. Butt, 2012.

“The surface of any opaque body is affected by the color of surrounding objects... colors are most intense when surrounded by their contrasts...” — from the notebooks of Leonardo Da Vinci.

Reverse Engineer This



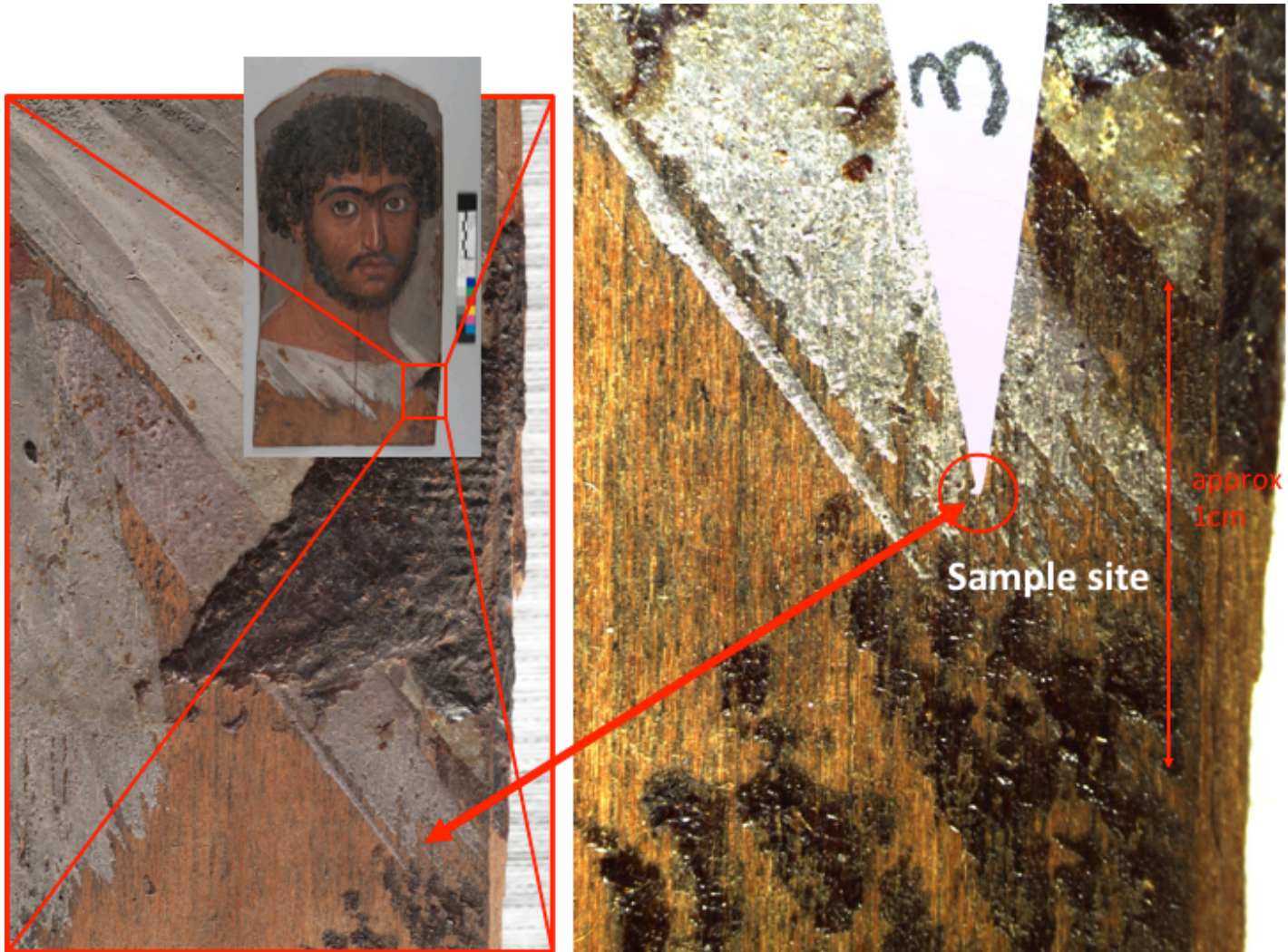
("Fayum") Mummy Portraits and the Color Purple



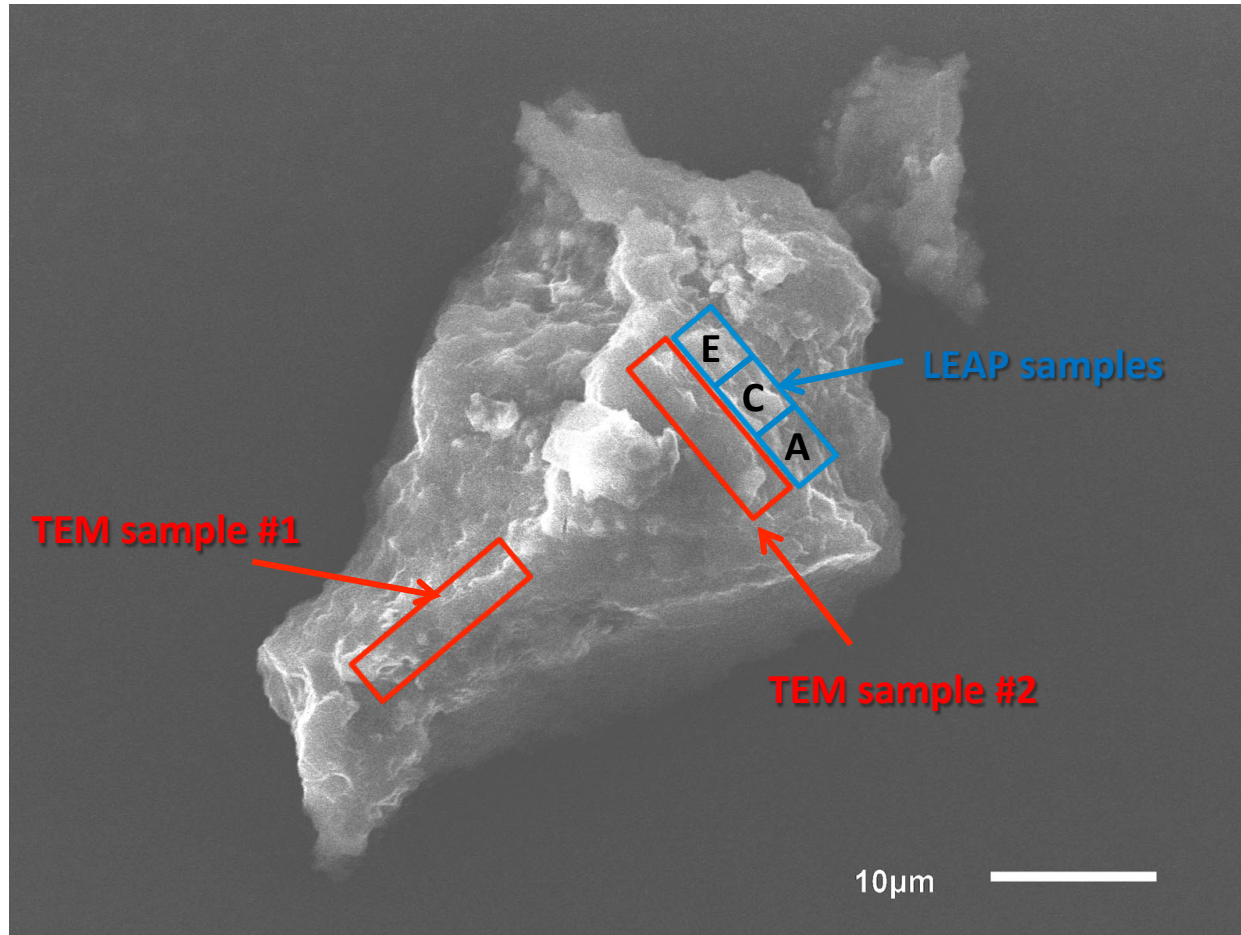
Fusion of Egyptian religious rites,
Roman artistic style, and Greek
cultural traditions*

*Ref. C. Cartwright and A. Middleton, *Br. Mus. Tech. Res. Bull.*, 2, 59 (2008).

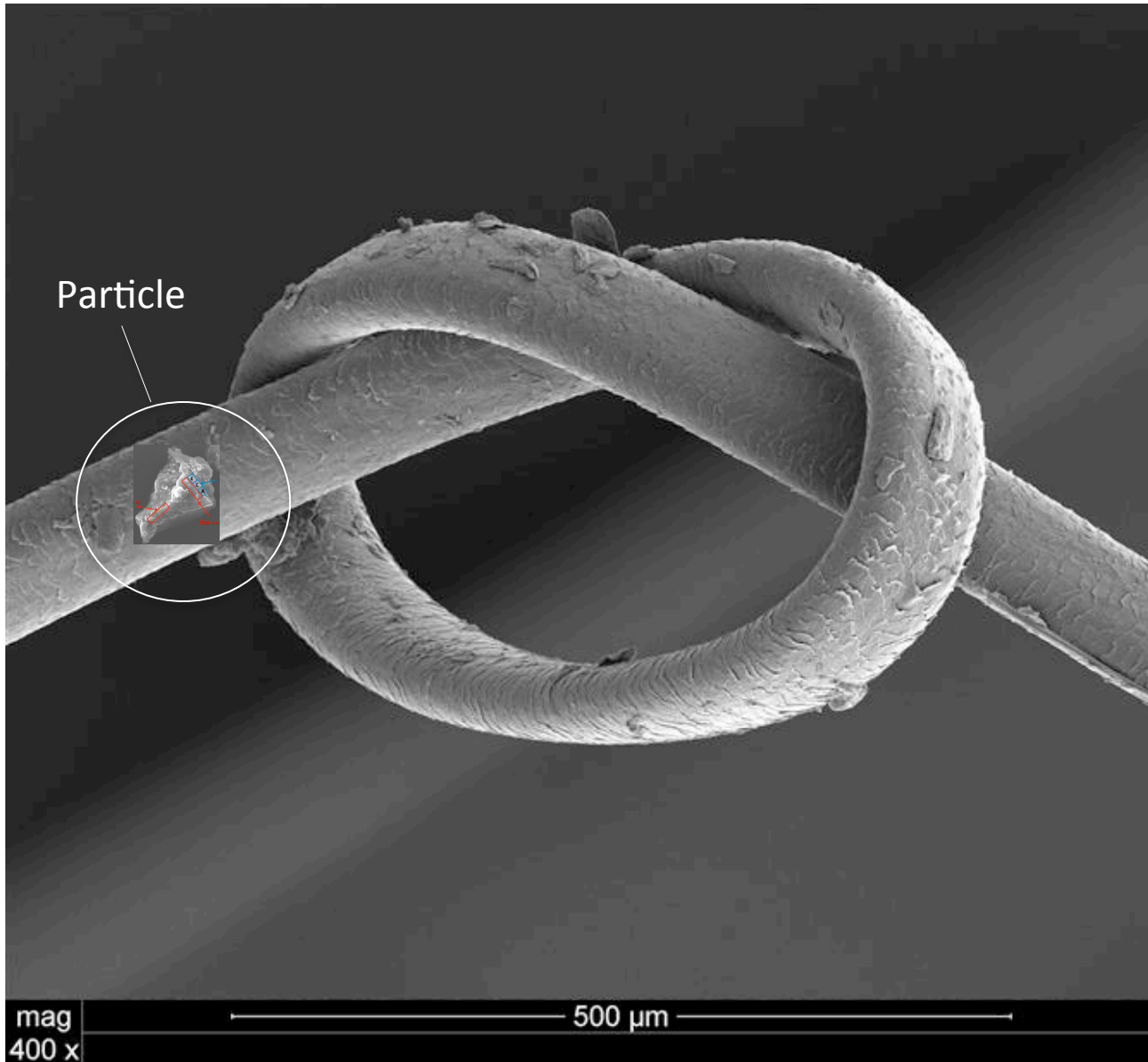
Mummy Sampling for the APPEAR Project



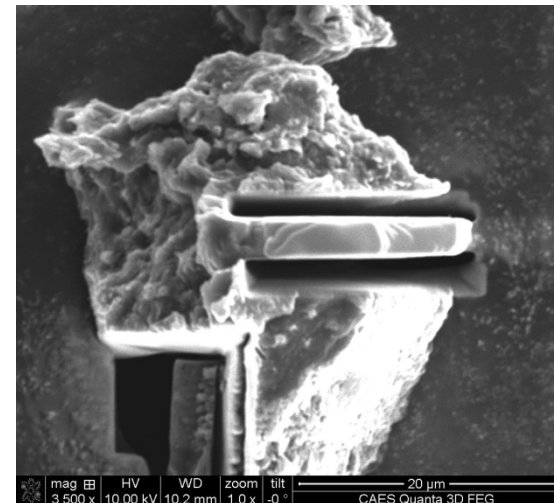
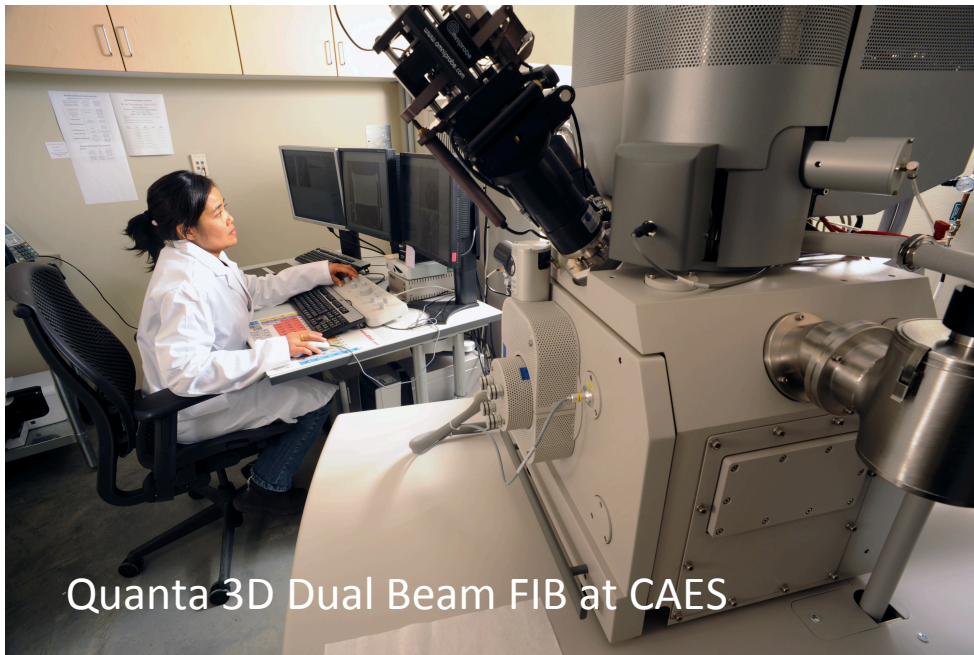
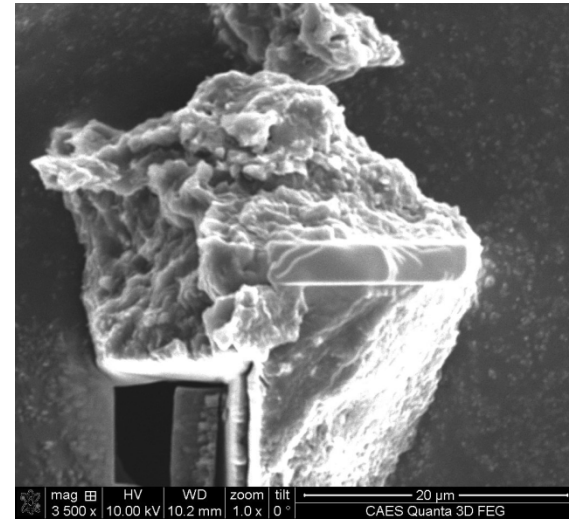
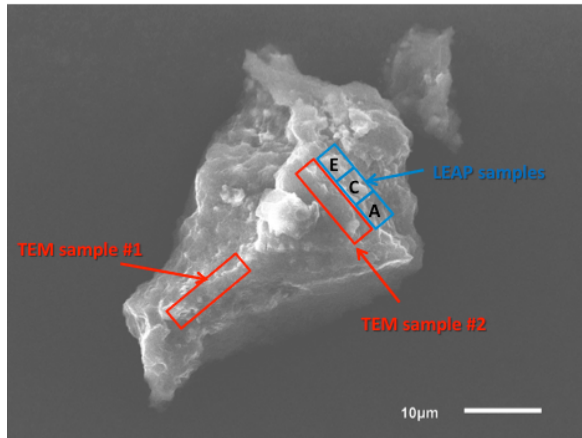
Pigment particle

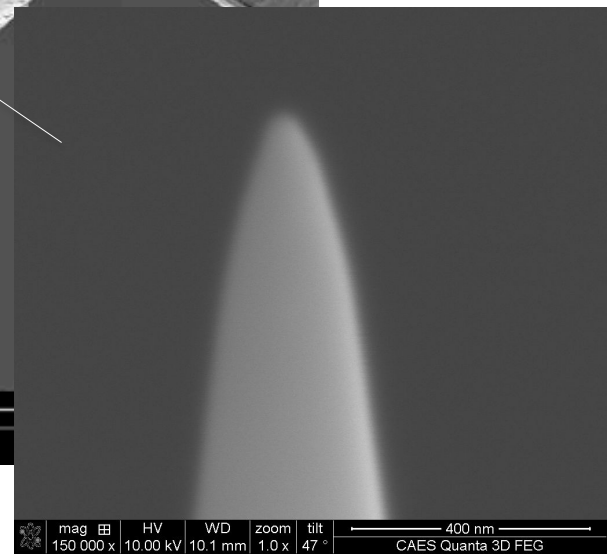
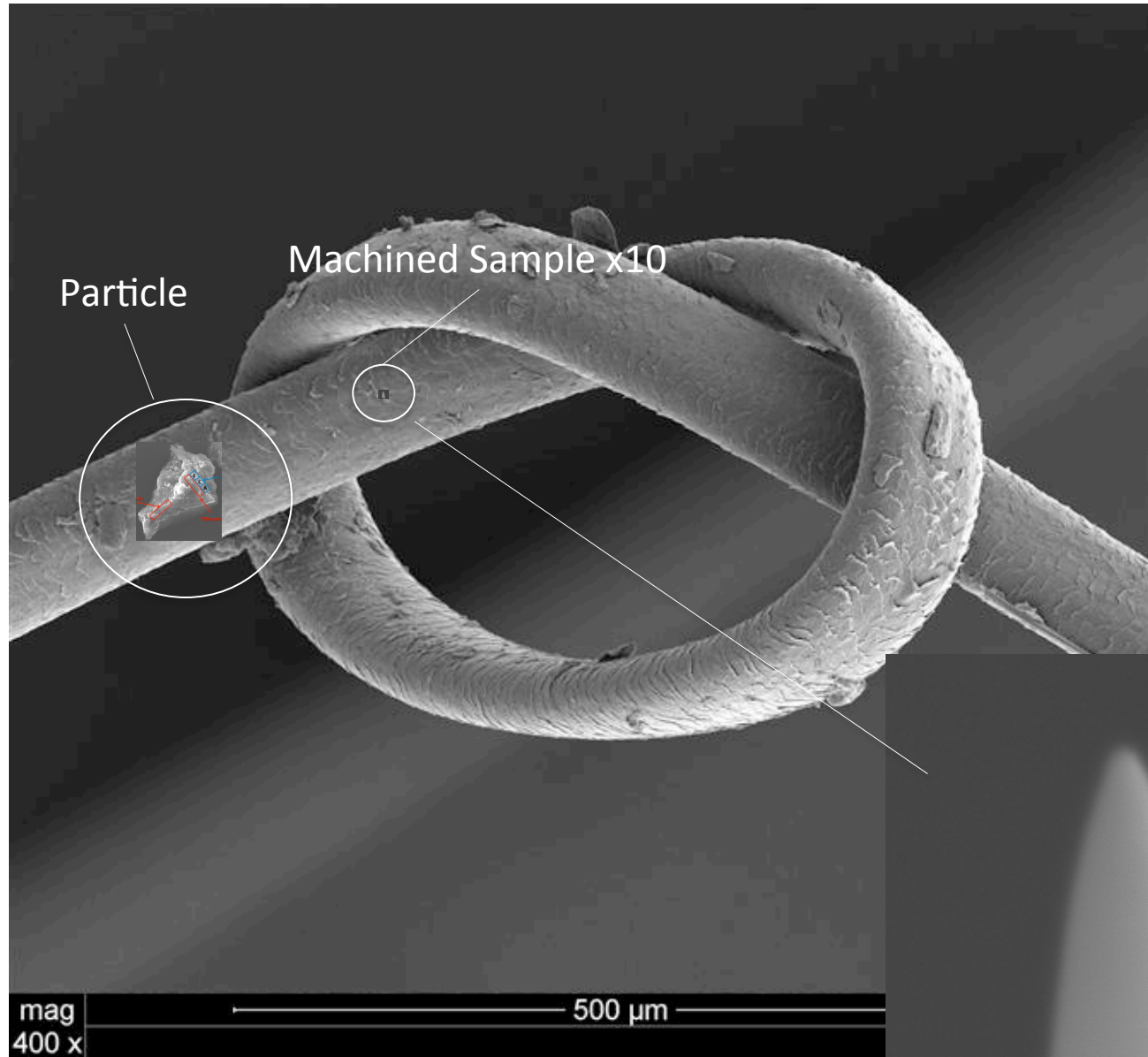


Pigment particle under SEM. Locations of TEM samples are in red and those of LEAP samples are in blue.

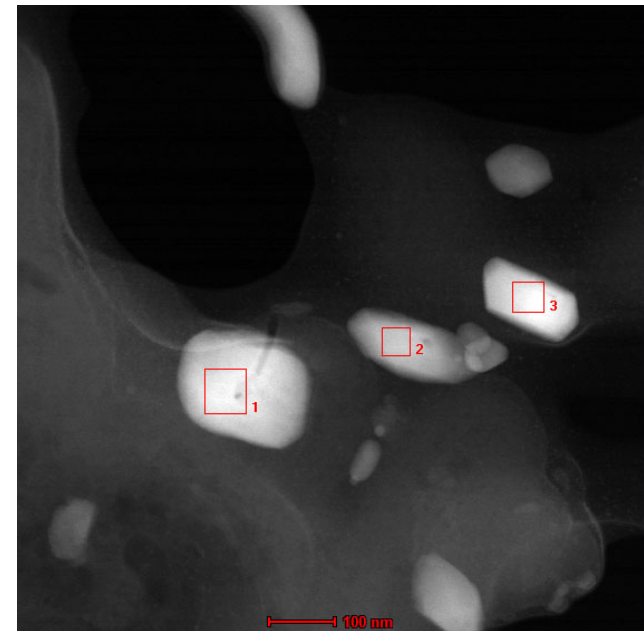
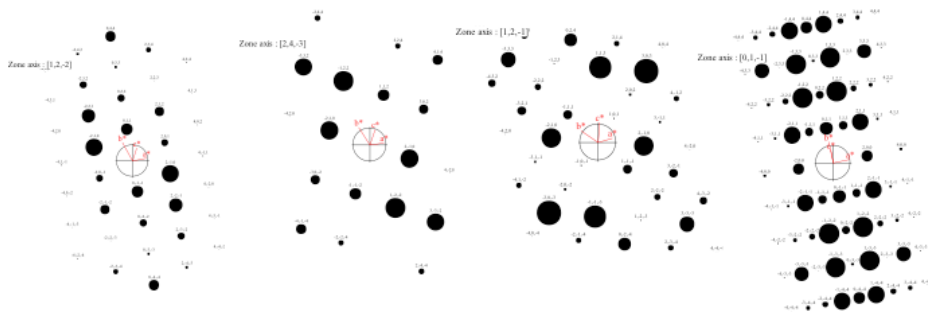
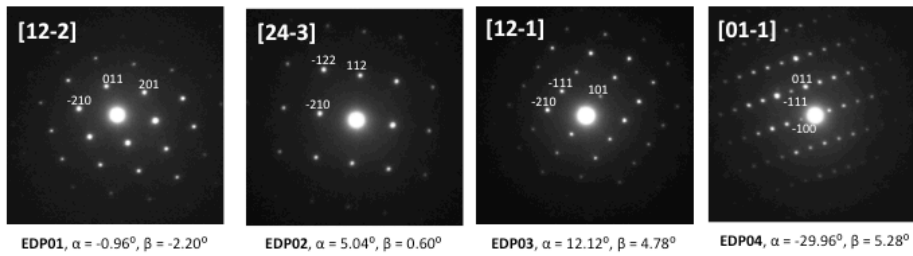
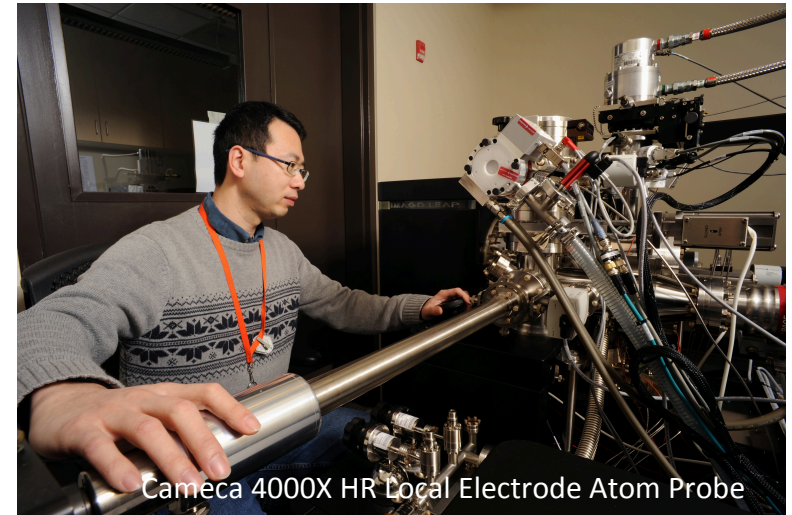
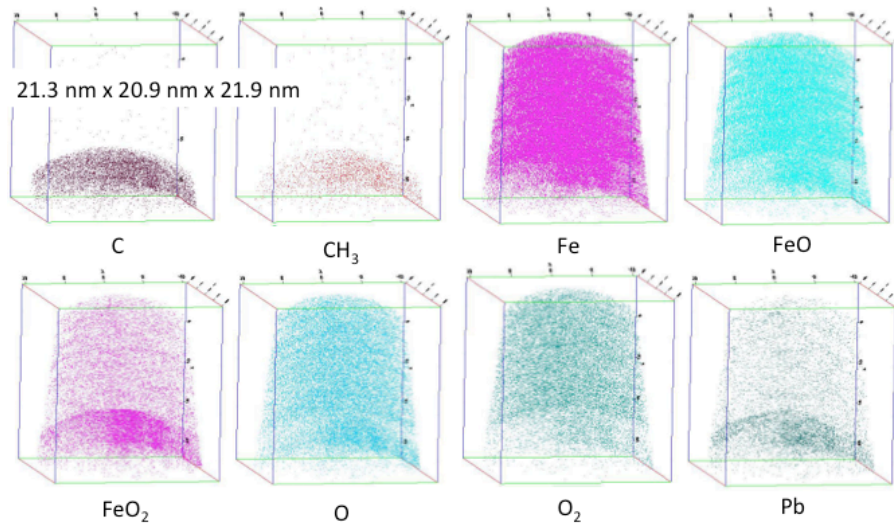


Partially Machined Pigment Particle





mag	HV	WD	zoom	tilt	400 nm
150 000 x	10.00 kV	10.1 mm	1.0 x	47 °	CAES Quanta 3D FEG



VIP Topic and Motivation

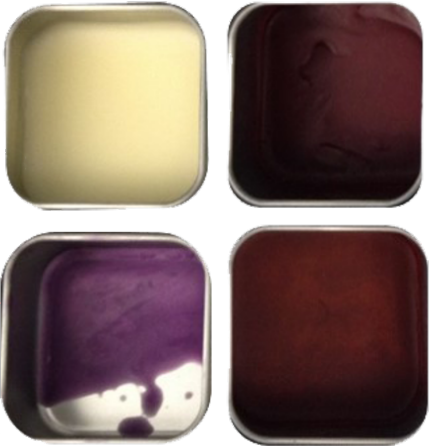


Cultural Studies + Materials Science Analyses

Greco-Roman Egypt + Nanoscale pigment analyses

Fayum mummy portraits + Materials for the color purple

Methods



Types of Organic Pigments

Madder Root



Cochineal Insect



Kermes Insect



Lichen



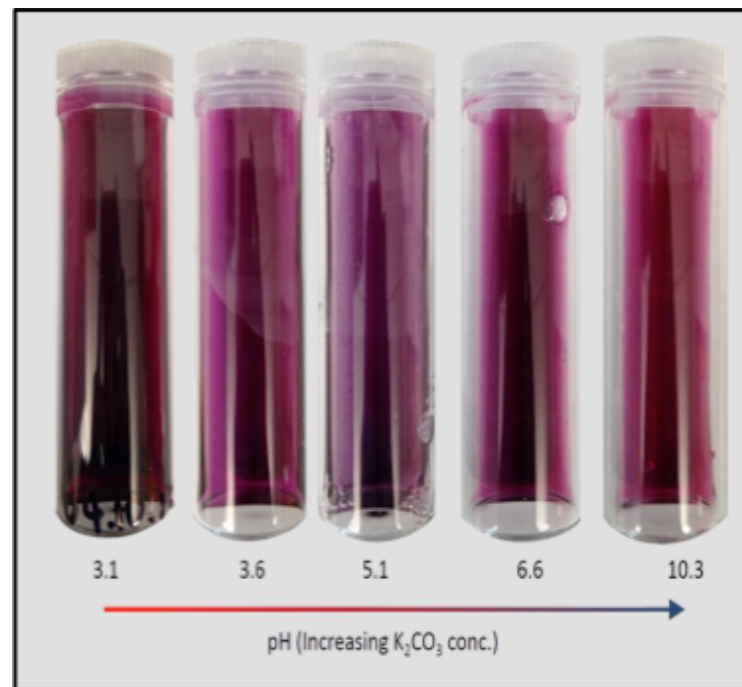
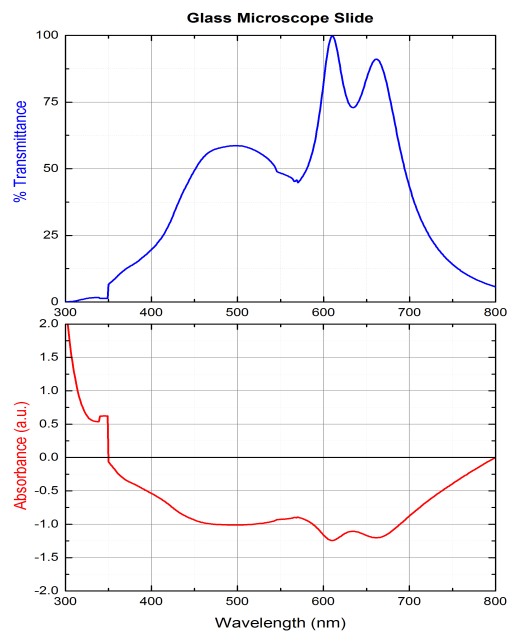
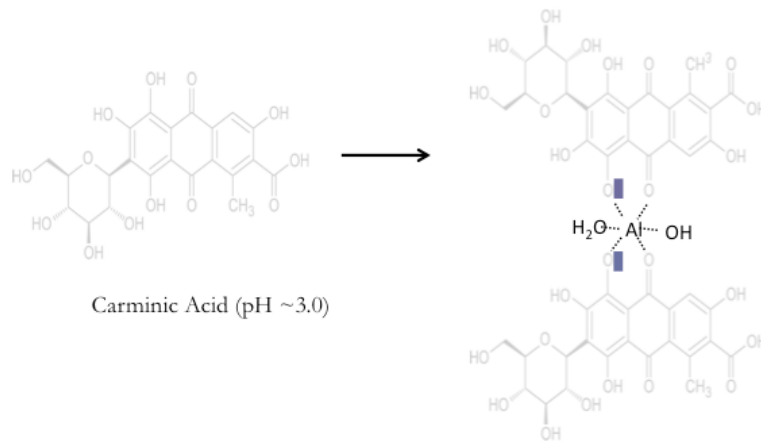
Indigo



Color Shifting Techniques



- Metal Salts



Resurrecting THE POOR MAN'S PURPLE

SYNTHESIS AND CHARACTERIZATION



Figure 1: Raw (a) madder root and (b) cochineal. The raw materials were prepared by (c) grinding the matter into a powder and (d) steeping within a water bath for multiple days to release the pigment. While in solution, mordants, metal salts, and alkali salts were added to induce a color change. The solvent was then evaporated off and (e) the resulting product was crushed into a fine powder. (f) The powder was then set into a wax binder, which would be used for both a replicated painting of the Bearded Man and for optical analysis.

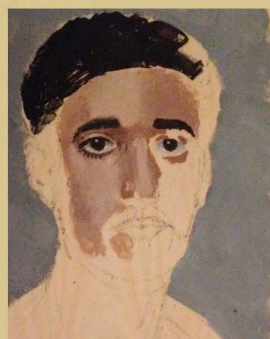


Figure 2: Picture illustrating the effect of mixing metal salts (i.e., chrome (Cr), lead (Pb), and iron (Fe)) with a cochineal and Alum solution. Adding 100 μL of 2.4 M chrome solution to the cochineal mixture produces a reddish-orange hue, 100 μL of 0.6 M iron solution results in a deep purple/black hue, and 300 μL of 145 μM lead solution yields a negligible color shift.



Figure 3: Samples demonstrating color shifts of a cochineal and Alum solution with the addition of 1.4 M K_2CO_3 . The cochineal and Alum solution has a 3.1 pH level prior to the addition of an alkali salt, due to the carminic acid. Titrating with a 0.14 M K_2CO_3 (i.e., potassium carbonate) solution results in a color shift towards a blueish purple hue for neutral pH levels and returns to a more reddish purple hue with the high pH levels.

HISTORY

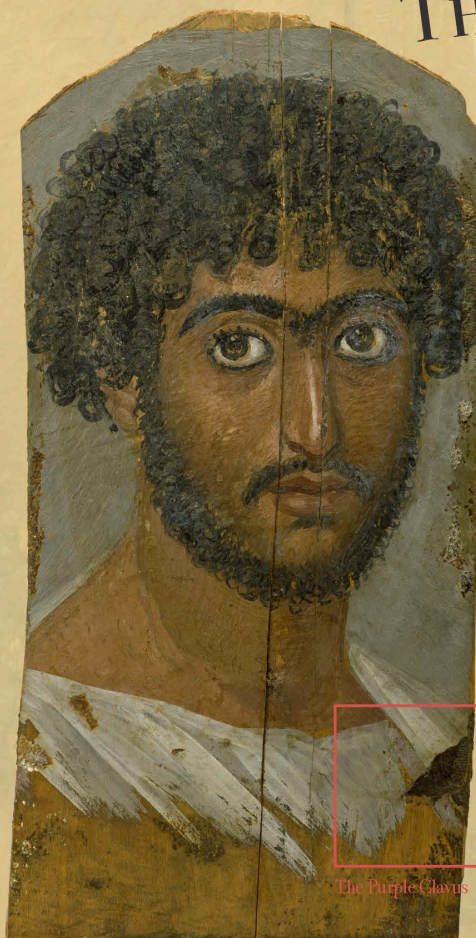
The Mummy portraits of the Fayum are encaustic paintings, where dry pigments are mixed into a molten wax binder before being applied to a hardwood panel [4] [2]. During the Roman rule of Egypt (60 BC - 393 AD), the expensive purple pigment derived from the murex mollusc, Tyrian Purple, was reserved for the elite [5]. The Bearded Man (32.6) dons a purple clavius determined to be colored by a material not that of the murex. Nanoscale analysis of the pigment revealed it to contain an organic phase rich in chrome, iron, phosphorus and sulfur, suggesting the presence of a metal salt shifting the color of a red organic pigment, likely from Madder or Kermes, to purple [1] [3].

ABSTRACT

It is the goal of this project to reverse engineer the unknown pigment from the Fayum portrait and replicate the process used by the Roman-Egyptians of taking raw organic materials and metal salts to shift a red pigment to purple. Analytical comparisons of the original pigment to our synthesized specimens will allow the identification of the original materials and techniques likely used which shall then be applied to our own recreated encaustic portrait.

METHODOLOGY

We are a transdisciplinary research team consisting of both undergraduate and graduate students from the Arts, Sciences, and Social Science disciplines, who seek to discover the motivation behind Fayum Mummy portraits and the ingredients used to make a poor man's purple pigment by recreating it with known available raw materials of its time.



The Purple Clavius

Mummy Portrait of a Bearded Man, Egyptian ca. 170-180 CE, encaustic on wood, The Walters Museum (32.6) (cc).

REFERENCES

- [1] Abdel-Kareem, O. (2012). History of dyes used in different historical periods of Egypt. *Research Journal of Textile and Apparel* (16/4), 79-92.
- [2] Cartwright, C., Spaabæk, L. R., Svoboda, M. Portrait mummies from Roman Egypt: Ongoing collaborative research on wood identification. *British Museum Technical Research Bulletin*, 5, (2011), 53.
- [3] Holloway, A. Unravelling the mystery of 'The Bearded Man'. *Ancient Origins*, N.p., 2014. Web. 13 Apr. 2015.
- [4] Laurie, A. P. (1957). The Fayum portraits painted in wax. *Technical studies in the field of the fine arts*, 4 (1), 17-18.
- [5] Stieglitz, R. R. (1994). The Minoan origin of Tyrian purple. *Biblical Archaeologist*, 57(1), 47.

FUTURE WORK

Going forward, our findings will be used to produce other pigments also to be worked into encaustic. Each of these will be tested for absorbance, transmittance, and fluorescence using a Cary 5000 UV/Vis/NIR Spectrometer and a Horiba Fluorolog-3 Fluorometer both before and after photodegradation. From this analysis we will compare our processed pigments to the sample from the Bearded Man this will let us find the process and ingredients that most resemble the piece. The results from our comparison will give us an indication into a couple of the most likely composition of the poor man's purple. The pigment most similar in color and chemical composition to the one on The Bearded Man will be used in our own reproduction mummy portrait.

END

