YEAR 0 · ΔE 0.0

YEAR 1 · ΔE 2.9

YEAR 10 · ΔE 17.6

YEAR 50 · ΔE 30.4

YEAR 100 · ΔE 33.5

YEAR 250 · ΔE 34.3

YEAR 500 · ΔE 34.3

SPECIMEN 00 · CINNABAR (α-HgS) · HARSH UV · 0 → 500 YEARS
EVERY BAND ON THIS COVER IS COMPUTED, YEAR BY YEAR, BY OUR AGING MODEL

# THE COLOR OF TIME

YOUTH INNOVATION CAMP · INTERACTIVE SCIENCE EXHIBIT · JULY 2026

# The color of *time*

Color is the memory of a civilization. Upload an image, choose a world, from a museum vault to the surface of Mars, and watch five centuries of fading happen in seconds, scored down to the last ΔE.

## PROJECT HANDBOOK

| | |
|---|---|
| NATURE | An interactive web exhibition + a live lab bench |
| WHAT IT MEASURES | Color change over time, in ΔE (a standard color-difference measure used in conservation) |
| MATERIAL LIBRARY | 50 materials · 27 pigments studied in depth |
| AGING SCENARIOS | 5 worlds, from a museum vault to a Mars habitat |
| VISIT | color-of-time.com |
| LANGUAGES | English · Chinese · Spanish · French · Portuguese · German · Japanese |

Every strip in this handbook's footers is a real pigment aging under our model, year by year.

ΔE

01 · THE IDEA

# Every color you love is quietly leaving We built a place to watch it go, and come back

The vermilion on palace walls and Pompeii frescoes has been sliding toward black for centuries. Van Gogh's pinks have already left his sunsets. Fading is one of the most universal things that happens to human art, and one of the hardest to see, because it happens slower than a lifetime.

Conservators solved half of the problem long ago: they measure color as a point in a precise three-dimensional space, and they measure change as the distance that point travels. The other half was never solved: nobody handed the public a way to **watch** it happen, to run the experiment yourself, on any painting you care about, at any speed.

The Color of Time fills in that other half. Give it any photograph of a painting. From its colors, it estimates a likely painting type and the closest studied pigment references, not a physical material analysis, then lets you send it five centuries forward under five different environments, or pull an aged work back toward the day it was painted. The image is moved by an aging model built from real accelerated-aging experiments and the published chemistry of 27 historical pigments, not redrawn by hand.

It runs in any browser, in seven languages, and asks for no background at all. Drag a slider, and watch five centuries pass.

BY THE NUMBERS

| | |
|---|---|
| ±500 | years of simulated time, forward and back |
| 5 | worlds, from a climate-locked vault to a Mars habitat |
| 27 | pigments studied in depth |
| 50 | materials modeled (pigments + papers) |
| 352 | laboratory aging measurements behind the model |
| 86 | real artworks in the gallery, from museum open collections |
| 7 | languages, one exhibition |

THE ONE-SENTENCE VERSION

**A time machine for color: it makes fading visible, explainable, and personal.**

OUR OBJECTIVES

OBJECTIVE 01

### Make it visible

Compress five centuries into seconds. Put the original and its aged self on one screen, with a seam you can drag, so slow change becomes something you can see with your own eyes.

OBJECTIVE 02

### Make it explainable

One explainable number, ΔE, the same unit conservation science uses, on every change the exhibit shows. Not "it looks older," but "it moved 24.7, and here is what that means."

OBJECTIVE 03

### Make it yours

Anyone can bring their own painting, drawing, or photo and run the experiment on it. Seven languages, no jargon at the front door, and a gallery of masterworks for anyone who arrives empty-handed.

OBJECTIVE 04

### Make it matter

Once fading is measured, it becomes a decision: what to display, what to shield, what to carry forward. We want visitors to leave thinking about what they would protect.

**“We are not forecasting the future. We are recording how the present forgets.”**

SPECIMEN 01/07 · **EOSIN Y** · HARSH UV 02 / 08

02 · THE EXPERIENCE

# Step into the webpage and watch pigments shift under the grind of time

**1** **The entrance** 3 SECONDS

Upon opening the webpage, the vermilion logo is veiled by a yellow overlay, symbolizing the aging of color.

**2** **A live colorimeter** DEMONSTRATING AGING

The opening page holds a colorimeter that presents aged cinnabar. Drag the year slider and the pigment's $\Delta E$ reading changes in real time — a century's worth of change in just a few seconds.

**3** **Five short chapters** THE STORY

We've structured our project introduction into five parts: aging environments, $\Delta E$, the four variables that drive aging, a showcase of key colors, and the artwork gallery. Each chapter builds on the last for a deeper understanding of our project.

**4** **The gallery walk** 86 ARTWORKS

A perspective corridor you scroll through like a museum hall: Vermeer, Hokusai, Dürer, and classical Chinese ink masters hang on two walls. Stop anywhere; every painting opens in the Lab carrying its own pigment dossier.

**5** **The Lab** THE CENTERPIECE

You can upload a painting of your own or choose a masterpiece from our library. The system reads the painting type and identifies its pigments. Pick a specific environment and aging duration, and the aged painting unfolds before you. Flip the switch to restore the painting to an earlier state.

FLOOR PLAN

| | |
|---|---|
| ENTRY | Grand entrance, a century in three seconds |
| CH. 1 | Five worlds, one pigment |
| CH. 2 | How big is one ΔE? |
| CH. 3 | Four forces of aging |
| CH. 4 | A fading library of pigments |
| CH. 5 | Walk the collection |
| LAB | Simulate centuries, in ΔE |
| METHOD | Every formula, derived and cited |

READING ORDER

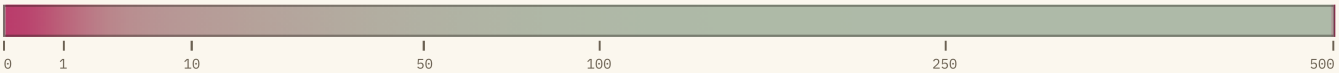
Read the chapters in order, or jump straight to whatever looks interesting. The exhibition was written for visitors with no color-science background, and it never tests you before it lets you play.

OPEN IT RIGHT NOW

It runs on the phone in your pocket: **color-of-time.com**

VISIT





03 · HOW IT WORKS · THE CORE PIPELINE

# Where do aged paintings come from

STEP 1

## Read the colors

The photograph is translated into CIELAB, the color space built around human vision. There, every color is a point with coordinates, and "this red, exactly" becomes a location rather than an opinion.

STEP 2

## Recognize the materials

The system estimates what kind of painting it is looking at, then matches each region of color to real pigments whose aging behavior we studied: cinnabar and carmine, malachite and gamboge, fifty materials in all.

STEP 3

## Let time work

Each pigment follows its own aging law under the world you chose, its yearly dose of light, heat, moisture, and radiation. Fragile dyes race ahead; mineral blues barely move. The paper beneath ages on its own clock. The strip below is eosin pink living five centuries outdoors:

STEP 4

## Present the results

Once the image is rebuilt, you'll see a before-and-after comparison of the painting, the $\Delta E$ change, and conservation advice.

THE SCIENCE IN THREE LINES

### How far did the color move?

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Delta E presents the color shift before and after aging as a straight-line distance. Below 1, it's hard to notice; above 20, the color has almost completely changed.

### How does a pigment age?

$$\Delta c(d) = \Delta c_\infty \left(1 - e^{-d/\tau}\right)$$

Color moves along a saturation curve: fast at first, then slower and slower, approaching an upper limit. That's why we chose this first-order kinetic model.

### How does a year become a dose?

$$d = \text{years} \times \text{dose per year}$$

d represents a cumulative dose — how much equivalent accelerated aging the pigment has endured in its environment. It's determined by your chosen environment and aging duration.

AND IT RUNS BACKWARD

The same model runs backward to sketch one possible younger state, not a measurement. It reports its own confidence alongside the image, because a good instrument tells you how sure it is.

GROUNDED, NOT GUESSED

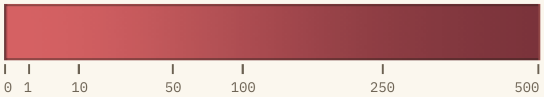
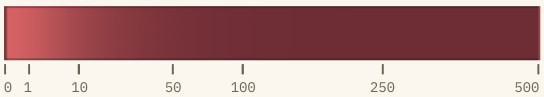
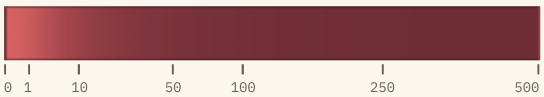
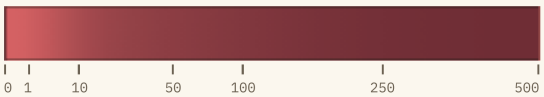
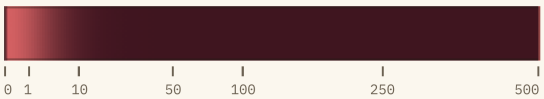
The model is calibrated on 352 laboratory aging measurements across 92 pigment samples, extended with the published lightfastness record of conservation science. Every number on screen traces to a formula and a source on the Method page.



04 · FIVE WORLDS

# One vermilion, five environments

Each environment carries its own annual aging dose — a unique blend of UV, heat, moisture, and radiation per year. Different doses send the same painting toward entirely different fates in five places. The five strips below are **the same pigment**, cinnabar red, living 0 to 500 years in each environment, matching what the model computes. On the right, how far it has drifted by year 500.

| | | | |
|---|---|---|---|
| **Museum vault**<br>CLIMATE-CONTROLLED GALLERY | UV 0.30 uv/yr<br>humid 0.10 /yr · dry 0.10 /yr<br>radiation ×1.00 |  | **12.8**<br>ΔE · 500 yr |
| **Harsh UV**<br>DIRECT SUNLIGHT | UV 8.0 uv/yr<br>humid 1.0 /yr · dry 1.0 /yr<br>radiation ×1.00 |  | **33.5**<br>ΔE · 500 yr |
| **Humid island**<br>WARM, HUMID, MARITIME | UV 2.0 uv/yr<br>humid 6.0 /yr · dry 0.5 /yr<br>radiation ×1.00 |  | **32.0**<br>ΔE · 500 yr |
| **Desert heat**<br>WIDE SWINGS, HOT TO COLD | UV 5.0 uv/yr<br>humid 0.2 /yr · dry 5.0 /yr<br>radiation ×1.00 |  | **27.7**<br>ΔE · 500 yr |
| **Mars base**<br>SOMEWHERE BEYOND EARTH | UV 12.0 uv/yr<br>humid 5.0 /yr · dry 6.0 /yr<br>radiation ×1.50 |  | **51.6**<br>ΔE · 500 yr |

## “Its light-driven slide toward black metacinnabar is one of the best-documented color changes in art.”

### WHAT ACTUALLY FADES

But within the same environment, different pigments meet very different fates. Cobalt blue is remarkably stable — stable enough to serve as a ceramic glaze colorant, holding up even after high-heat firing — while eosin pink can age rapidly under direct sunlight.

### FROM THE VAULT TO MARS

The first four environments can all be found here on Earth. Mars base is a small glimpse of the future instead, its parameters drawn from extensive research literature. Perhaps, in some distant future, we really will be living in space.





05 · SCIENTIFIC PRINCIPLES

# Real material change, told at walking speed

## Why paintings fade

Every pigment has its own unique structure. Cinnabar's aging is not simple fading at all — it darkens and blackens from light exposure, chloride ions, or oxidation. Eosin and other pink pigments photodegrade and fade under ultraviolet light like overexposed film. It isn't just pigments, either — the paper carrying them changes too: bamboo paper yellows, while mulberry paper endures. And so on.

## Four forces, acting on one surface

Ultraviolet light attacks the color-carrying molecules in the material directly; extreme temperatures tear at the painting's binder layer, making it brittle; high humidity's moisture feeds hydrolysis, unpicking the binder strand by strand; radiation breaks chemical bonds outright. To one degree or another, every painting bears all four of these forces from its environment.

THE SLOGAN THAT IS ALSO A PROMISE

**“Every number has a reason.”**

Any ΔE, any year, any verdict in the exhibition can be traced to a formula, a parameter, and a published source on the Method page.

## How we measure aging

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

ΔE is the unit we use to measure how much a pigment has aged. The scale becomes intuitive within minutes:

| ΔE | WHAT THE EYE SEES |
|---|---|
| < 1 | Imperceptible; identical to the original |
| ≈ 3 | Subtle; takes close observation to catch |
| ≈ 6 | Fairly obvious; clearly visible |
| > 20 | Already a different color; almost none of the original remains |

## Built on real measurements

Behind the exhibit stands a dataset of **352 accelerated-aging measurements across 92 pigment samples** (avg. ~13 per pigment, spanning different conditions: 315 ultraviolet, 24 dry-heat, 13 humid-heat), extended with the standard references of conservation science: CIE colorimetry (defines color and color difference), the Blue Wool lightfastness archive (calibrates aging severity), and NASA's studies of materials in space (informs the Mars scenario's parameters). The model was fitted from that evidence, and the Method page lays out every step of the derivation — formulas, parameter sources, the fitting process, references — for anyone who wants to check it.

A MODEL THAT KNOWS ITS LIMITS

Aging approaches a ceiling instead of running to infinity, timelines never move backward on their own, and the restore mode states its confidence out loud. We built the guardrails in, so the wonder never has to lean on exaggeration.





06 · THE LAB & THE COLLECTION

# Your bench
# Masterpieces gathered from across the world
# Five hundred years of experiment

The Lab is built like an instrument: a magnified before/after viewer with a draggable seam, and a rail of readouts that stay live while you work.

01 · SPECIMEN
**Specimen**
Drop in any PNG or JPG, or pick one of the 86 works in the collection.

02 · ANALYSIS
**Analysis**
A scan pass estimates the medium and lays out the closest studied pigments, with shares.

03 · ENVIRONMENT
**Environment**
Five worlds, each previewing its full 500-year ΔE before you commit.

04 · TIMELINE
**Timeline & sliders**
A year slider, plus separate sliders for UV, temperature, humidity, and radiation.

05 · ΔE CURVE
**500-year curve**
The full arc of change, drawn against the thresholds a human eye can detect.

06 · VERDICT
**Verdict**
A conservation-style cue for the state you chose, in plain words.

07 · DRIFT
**Color-space drift**
A 3D view of the journey each color takes as the years pass.

08 · SURFACE
**Surface**
The craquelure and surface wear that arrive with age, illustrated at 500× magnification.

The verdict, graded across six degrees of change:

| Imperceptible | Just noticeable | Clearly visible | Pronounced | Strong shift | Severe |
|---|---|---|---|---|---|
| low risk | rotate normally | control the light | limit exposure | take off view | dark storage advised |

## The collection

**86 artworks** hang in the gallery corridor: Vermeer's Girl with a Pearl Earring, Hokusai's Great Wave, Dürer's Young Hare, the Mona Lisa, six Van Goghs, and classical Chinese ink paintings from Song fan leaves to Qing masters.

Nearly every work is in the public domain or open access, from the Met, Cleveland, the National Gallery of Art, the Smithsonian, Tate, the Albertina, the Mauritshuis, the Shanghai Museum and more; one contemporary scroll is shown with its artist's attribution. Each hangs with a curated pigment dossier and a modeled aging curve of its own.

## Look under the hood

For visitors who want to see the model's formulas at work, the Method page derives every formula in the exhibit, from the color-space transform to the aging law, with citations into the conservation literature. The exhibition isn't built on one sentence — it stands on mathematics, literature, experiments, and research.

THE LAB

YOUR THREE-MINUTE TOUR

0' – 1'
**The entrance**
Watch the counter climb as the veil of age sweeps the wordmark. Skim the five chapters.

1' – 2'
**The Lab**
Pick Girl with a Pearl Earring, send her to Mars, drag to year 100, then flip to restore and watch time return.

2' – 2.5'
**Method**
Pick any number on screen and follow it down to its formula and its source.

2.5' – 3'
**Gallery walk**
Stroll the corridor of 86 works. Click one; it will follow you back to the Lab.



CLOSING

# “Measured, fading is no longer only loss, it becomes a choice: which colors we carry forward, and which we surrender to time.”

## TEAM

| | |
|---|---|
| Richard | Backend · aging model · deployment · frontend implementation · visual design QA · manual production |
| Amily | Visual and frontend design · Promotional video |
| Jenney | KT board production · Materials and literature research · Behind-the-scenes material support |
| Sophia · Martina | Materials and literature research · Behind-the-scenes material support |
| Leo | Engineering collaboration |

## MILESTONES

| | |
|---|---|
| **Before JUN 25** | Multiple aging prediction trials; extensive research to identify patterns and build experience |
| **JUN 25** | Kickoff, growing out of months of iterative research in a paint-aging modeling competition; team roles assigned |
| **JUN 27** | Confirmed paintings as core research vehicle; finalized technical implementation approach |
| **JUN 29** | Surveyed painting types, aging environment types, and influencing factors; summarized pigment fading patterns |
| **JUN 29** | First release: the model and a five-language exhibition |
| **JUL 01** | Finalized eight painting categories, standard aging environments, and the full parameter system |
| **JUL 01** | Rebuilt the site's narrative logic; established sourcing standards tracing every figure and formula to its literature |
| **JUL 01** | Proofread the bilingual copy, organized reference materials, and built a standardized project resource library |
| **JUL 03** | Searched literature on aging in extreme interplanetary environments, filling in theory for the special scenarios |
| **JUL 03** | Studied dozens of core papers; extracted material, substrate, environment, and aging-factor data |
| **JUL 03** | Refined pages against the literature for scientific rigor; the Lab became a full instrument bench |
| **JUL 05** | Conducted field research trip at Fengxian Museum; connected with oil painting and paper conservation professionals |
| **JUL 09** | The collection reaches 85 works; three pigments re-fit from published measurements |
| **JUL 12** | An 86th work joins the collection; the exhibition adds a seventh language, and the site gets a full check |
| **JUL 14** | Brochure review and binding; website rehearsal; presentation strategy |

VISIT

**color-of-time.com**

Phone and desktop · English / Chinese / Spanish / French / Portuguese / German / Japanese

SCAN TO VISIT

Typeset with the project's own aging model: every footer specimen strip is real year-by-year model output. Set in Fraunces, IBM Plex Sans, and IBM Plex Mono.



THE COLOR OF TIME

ΔE

# The Color of *Time*

*“Color is the memory of a civilization.”*

color-of-time.com