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Same Fractal Geometry, Different Canvas: Pollock's Paintings and Golgi-Stained Neural Tissue Compared

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Article

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Abstract

Number 7A (1948) by Jackson Pollock and images of the cerebral cortex obtained with Golgi's neuro-histological staining method show a striking visual affinity: both display dense, branching networks, devoid of a hierarchical center, repeating across scales. Here we test this resemblance quantitatively for the first time, applying a common, coverage-controlled box-counting protocol to a verified sample of Pollock paintings and original Golgi-stained cortical preparations at two magnifications. Both domains occupy a comparable fractal-dimension regime (Pollock, D = 1.766; Golgi 10×, D = 1.743; Golgi 20×, D = 1.716), yet remain reliably distinguishable from one another, with the difference between the two Golgi magnifications alone exceeding that between either magnification and Pollock's paintings. A finer sampling of scales further revealed a two-regime phenomenon, previously reported for Pollock's paintings, in nearly all preparations from both domains. These results support a structural analogy, rather than a claim of shared process, between gestural painting and dendritic architecture, consistent with general geometric constraints on branching growth within a bounded space.

Introduction

Number 7A (1948) by Jackson Pollock, representing a dense weave of poured, dripped, and flung black lines over a pale ground, bears a striking resemblance to a Golgi-stained brain section, in which neurons and their dendritic processes emerge as dark, branching traces over a neutral background (Fig. 1). This simple observation motivated the present work. To our knowledge, no previous study has compared Pollock's work with Golgi-stained tissue.

The Golgi-staining method, the so-called “black reaction”, is a stochastic process that impregnates only a small fraction of neurons (roughly 1–5% of the tissue) for reasons still not fully understood [1], but stains them in their entirety: cell body, dendrites and, in part, axon (in a sort of all-or-none staining). It is precisely this random impregnation that renders the resulting image legible: were every neuron stained, the extreme density of nervous tissue would produce an indistinct dark mass. The Golgi preparations analyzed in the present study were obtained using the Golgi-Cox variant of the method, which relies on potassium dichromate and mercuric chloride [2], rather than the silver nitrate used in Golgi's original protocol, devised in 1873 [3]. Either way, both methods yield comparably sparse, all-or-none staining of a small subset of neurons, and the methodological distinction does not affect the quantitative analysis presented here.

Coming back to the comparison between Pollock's canvas and the Golgi-stained sections, at a purely perceptual level, they share three structural features: - the absence of a compositional focus, with the pattern distributed almost homogeneously across the whole surface, the quality art criticism has termed “all-over”; - an organization into local densifications (drops and pooled paint in the painting; cell bodies and dendritic arborizations in the histological image) connected by thin filaments crossing empty space; - an approximate self-similarity, whereby a magnified portion of the composition remains qualitatively similar to the whole (Fig. 1).

The aim of this work is to rigorously argue this comparison by bringing together two bodies of literature that are not usually considered together: the physics of complex systems as applied to abstract art and classical neuro-histology. Our aim is not to suggest that Pollock drew on neuroanatomical imagery (no biographical evidence supports this possibility) but to show that gestural painting (the so-called action painting) and nervous tissue, despite arising from radically different physical processes, may share a common geometric language: that of fractal patterns and branching structures with no privileged scale. It is important to state clearly what this study does and does not argue: the fractal nature of dendritic architecture has already been well established [4–7], as has the fractal geometry of Pollock's poured paintings [8, 9]. The genuine novelty of the present work is the direct, quantitative comparison between the two domains. The fractal geometry literature offers the most direct bridge between them. Taylor and colleagues [8] showed that Pollock's poured paintings possess a measurable fractal dimension that increased over time, ranging from almost 1.45 in paintings from the late 1940s to 1.72 in *Blue Poles* (1952), values comparable to those observed in natural structures, such as jagged coastlines or vegetation. They proposed the term “fractal expressionism” for a body of work that reproduces the statistical signatures of natural pattern formation without directly imitating nature [10]. On the neuro-histological side, quantitative studies report fractal dimensions that vary systematically by cell type and developmental or pathological state. Dendritic arbors of cerebellar Purkinje cells increase in fractal dimension over ontogenetic development, reaching about 97% of their adult value at birth [4]. Furthermore, in wild-type mice, the Purkinje cell dendritic arbors have $D \approx 1.72$, while reeler mice (mutants exhibiting cerebellar hypoplasia and disrupted laminar organization of the neocortex) have Purkinje cell $D = 1.25$ [5]. The dendrites of the cortical pyramidal cells have $D \approx 1.08–1.13$ [6] and of the retinal bipolar cells $D \approx 1.47$ [7]. This range overlaps, nontrivially, with the values reported for Pollock's paintings. A further important detail of Taylor's original analysis is that it does not yield a single fractal dimension for a painting, but two distinct values, each valid over a different range of scales: one governed by the physics of paint dripping at fine scales, the other by the artist's body movement at coarser scales. This two-regime phenomenon is one we will return to and test directly on our own sample.

The present study quantitatively compares Pollock's paintings with Golgi-stained preparations, applying the same box-counting procedure to a verified sample of paintings and to original Golgi-stained preparations from our own laboratory. Specifically, we ask: (i) whether the two domains occupy a comparable fractal-dimension regime once a common, coverage-controlled measurement protocol is applied; (ii) whether the two-regime phenomenon documented by Taylor may generalize, on closer scale sampling, to our full sample of 12 Pollock’s paintings and, in parallel, to our sample of 41 Golgi preparations; and (iii) what a structural analogy of this kind can, and cannot, be taken to establish about the relationship between two processes as physically distinct as action painting and dendritic growth.

Materials and Methods

Painting selection

The Pollock sample was constructed according to three binding criteria. First, a verifiable title and source from a museum institution or an official catalog maintaining a color palette compatible with the original work. Second, the image proportions had to be consistent with the real canvas dimensions reported by the institutions holding the work, within a 6% threshold. Such a value was derived empirically from our own verification process, since images later confirmed authentic never deviated by more than this percentage. Reproductions whose proportions deviated from this threshold were discarded, regardless of the magnitude of the deviation. Third, a minimum resolution of 512 px per side after square cropping, below which the range of scales available to box-counting narrows enough to introduce a systematic downward bias in the estimated D. Applying these three criteria, we selected 12 paintings: *Full Fathom Five* (1947), *Number 17A* (1948), *Number 1A* (1948), *Number 19* (1948), *Number 4* (Gray and Red) (1948), *Number 1* (1949), *Number 34* (1949), *Number 27* (1950), *One: Number 31* (1950), *Number 18* (1950), *Number 17* ("*Fireworks*", 1950), and *Number 32* (1950).

As an example of this exclusion criterion, a preliminary measurement on *Number 7A* (1948), a cropped, low-resolution photographic reproduction (a 256×256 px strip after square cropping, versus the 512–1024 px of the images retained in the final sample), yielded D = 1.644 at controlled coverage, noticeably lower than the mean of the 12 paintings in the final sample. This is consistent with the reduced range of scales available to box-counting at low resolution, which can introduce a downward bias, the same reason this and other low-resolution images were excluded from the final sample.

The fractal dimension estimated via box-counting is generally sensitive to the effective resolution of the source image: sensitivity tests on artificially down-sampled images showed D shifts on the order of 0.06–0.10, an effect exceeding the difference observed between the Pollock and Golgi groups. This further motivated the adoption of a strictly verified minimum resolution threshold (512 px) for every image included in the sample, and discouraged expanding the Pollock sample beyond the 12 already-verified paintings at matching image-quality standards, in the absence of high-resolution sources comparable to those available for the Golgi preparations (uncompressed TIFF, 1600×1200 px).

Golgi-Cox Staining

Adult (2.5-month-old) C57BL/6J mice (Charles River, Italy) of both sexes were used in the present study. The animals were group-housed (4 mice/cage) with food (Mucedola, Milan, Italy) and water *ad libitum*, and kept under a 12-h light/dark cycle with the light on at 07:00 h, at a controlled temperature (22–23°C) and constant humidity (60 ± 5%).

All efforts were made to minimize animal suffering and to reduce their number, in accordance with the European Directive (Directive 2010/63/EU). The study was approved by the Life-Santa Lucia Committee for animal well-being.

The animals were anesthetized by using Zoletil 100 (tiletamine HCl 50 mg/mL + zolazepam HCl 50 mg/mL; Virbac, Milan, Italy) and Rompun 20 (xylazine 20 mg/mL; Bayer S.p.A, Leverkusen, Germany),

dissolved in a volume of saline of 4.1 mg/mL and 1.6 mg/mL, respectively and intraperitoneally injected in a volume of 7.3 mL/kg and then were sacrificed by cervical dislocation; their brains were immediately harvested and immersed in the Golgi impregnation solution. The Golgi-Cox staining solution comprised 100 mL of 5% potassium dichromate, 100 mL of 5% mercuric chloride, and 280 mL of 1.4% potassium chromate. Impregnation was carried out at room temperature in complete darkness for 6 days. Subsequently, brains were transferred to a 30% sucrose solution and cryoprotected at 4°C for 7 days. Coronal sections (100 µm thick) were then cut using a vibratome (VT1200, Leica, Wetzlar, Germany) and mounted onto gelatin-coated glass slides. The sections underwent an initial 1-min rinse in dH_2O, followed by a 30-min incubation in ammonium hydroxide. After a subsequent 1-min wash in dH_2O, slides were treated with Kodak Fixer Solution. After another 1 min in dH_2O, the sections were dehydrated sequentially in 50, 75, and 95% ethanol for 1 min each, followed by a 10-min immersion in 100% ethanol. Finally, sections were cleared using a 1:1:1 mixture of xylene, 100% ethanol, and chloroform for 15 min, followed by pure xylene for an additional 15 min. Slides were coverslipped with Eukitt mounting medium, dried, and stored at 4°C in the dark.

Acquisition of Golgi-stained preparations

The sample comprised 23 preparations at 10× magnification and 18 at 20× (uncompressed TIFF format, 1600×1200 px), all original to our laboratory, impregnated using the previously described Golgi-Cox (hereafter, Golgi) method. All 41 preparations were obtained from cortical tissue, drawn from various cortical areas. Restricting the sample to a single tissue type kept the comparison focused and isolated the effect of magnification (below) from potential confounds arising from comparisons between structurally distinct brain regions, such as the hippocampus or amygdala. No resolution-based exclusion criteria were required, as all images shared the same 1600×1200 px acquisition, well above the 512 px minimum threshold adopted for the Pollock paintings. The two magnifications were treated as independent samples throughout the analyses.

Box-counting protocol

Box-counting was conducted in pixel space and left uncalibrated to physical units; therefore, it effectively sampled two different physical-scale bands of the same tissue, rather than the same band with greater or lesser precision. Physical calibration (µm/pixel for the Golgi preparations, cm/pixel for Pollock's canvases) was not attempted for either image series: for the Golgi preparations, this would require a calibration reference (e.g. an image of a stage micrometer) acquired under the identical optical configuration used for each preparation, which was not part of the original acquisition protocol and cannot be reliably reconstructed after the fact. For the paintings, establishing a reliable correspondence between a digital reproduction's pixel dimensions and the canvas's physical size would require photographic conditions not guaranteed for images gathered from museum and auction archives of varying provenance. Both series were therefore analyzed in pixel space throughout. Pooling the two

groups would have meant mixing measurements obtained over different scale bands, obscuring rather than clarifying the comparison with Pollock's paintings; for this reason, the 10x and 20x magnifications have been treated as independent samples throughout the analyses.

Calculation of D

Each image was converted to greyscale and cropped to the largest square with a side equal to a power of 2, allowing an exact grid partition at every scale. The binarization threshold was calibrated individually for each image via bisection search to obtain a foreground pixel coverage of 20% (coverage-controlled method, motivated by the strong correlation between uncontrolled coverage and estimated D). Box-counting was performed on boxes with side lengths from 2 px up to half the image side, in powers of 2; D was estimated as the slope of the regression line of log N(ε) against log(1/ε), where N(ε) is the number of boxes of side ε containing at least one pixel of the traced pattern. Because box-counting plots can deviate from a single straight line when the pattern shows different scaling behavior at coarse versus fine scales (a "two-regime" phenomenon previously reported for Pollock's paintings [8]), we sampled 16 log-spaced box sizes per image and compared single-segment versus two-segment linear fits using AIC and BIC. Data points at which N(ε) reached its theoretical maximum (i.e., every pixel of the image falling within a box containing the traced pattern) were excluded from the fit, as such saturation is an artifact of image size rather than a genuine scaling property.

Statistical analyses

Between-group comparisons were performed using Welch's t-test rather than the classic Student's t-test, since the latter assumes equal variances between the groups. Such an assumption was clearly violated here (for example, the standard deviation of 10× images was 0.007, that of Pollock's paintings 0.029, a more than fourfold ratio). Welch's test does not require this assumption and is therefore the more robust choice for samples of markedly different sizes and variability. Alongside the p-value, Cohen's d is reported for each comparison, quantifying effect size independently of sample size, a useful caution, since with sufficiently large samples even numerically small differences can reach statistical significance without necessarily being substantively relevant.

To verify whether the two-segment model was genuinely justified and not simply an effect of the greater flexibility afforded by the two additional parameters (four versus the two of a single line), the two models were compared using the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC), both computed from the residual sum of squares (RSS) as

$$AIC = n \cdot \ln(RSS/n) + 2k$$

and

$$BIC = n \cdot \ln(RSS/n) + k \cdot \ln(n)$$

where n is the number of points used in the fit, and k is the number of model parameters.

The ΔAIC and ΔBIC differences (single-line model minus two-segment model) were interpreted according to the conventional Kass and Raftery scale for BIC: differences between 2 and 6 indicate "positive" evidence in favor of the more complex model, differences between 6 and 10 "strong" evidence, and differences above 10 "very strong" evidence.

Results

Applying the automatic Otsu threshold, without coverage control, yielded D = 1.849 on average for Pollock's paintings (n = 12; standard deviation 0.110; range 1.570–1.989) and D = 1.779 on average for the Golgi-stained preparations (n = 41, magnifications pooled, as this preliminary analysis concerned coverage-dependence rather than between-group comparison; standard deviation 0.076) (Fig. 2). In both domains, foreground pixel coverage after thresholding correlated strongly with estimated D (Pollock, r = 0.84; Golgi, r = 0.985): since the Otsu threshold is not constrained to return the same coverage across different images, much of the observed variability reflects how much the threshold classifies as "signal" (itself dependent on brightness, contrast, and image exposure) rather than a genuine difference in geometric complexity between samples. This result, which was symmetric across both domains, motivated the adoption of the coverage-controlled method (20% in each image) for all subsequent analyses.

With the coverage-controlled method, the 12 Pollock's paintings yielded D = 1.766 on average (SD 0.029; range 1.736–1.833), while the 23 Golgi 10x preparations yielded D = 1.743 (SD 0.007), and the 18 Golgi 20x preparations yielded D = 1.716 (SD 0.012). Welch's t-tests indicate small but statistically robust differences across all three pairwise comparisons (Table 1), with Pollock's paintings differing more markedly from 20x than from 10x Golgi preparations.

Table 1
Cross-comparison of the three samples (D at controlled coverage, 20%)

10x Golgi preparations	**10x Golgi preparations**	**20x Golgi preparations**	**Pollock's paintings**
	n = 23; D = 1.743 ± 0.007	**Δ = 0.027; t = 8.22; p < 0.0001; d = 2.66**	**Δ = 0.023; t = 2.76; df = 11.7; p = 0.018; d = 1.11**
20x Golgi preparations		n = 18; D = 1.716 ± 0.012	Δ = 0.050; t = 5.74; df = 13.6; p < 0.0001; d = 2.29
Pollock's paintings			n = 12; D = 1.766 ± 0.029

Note: diagonal (shaded) = n (number) and D (fractal dimension) ± SD for each sample. Above diagonal = pairwise comparison: Δ = mean difference in mean D between the two samples, t = Welch's t-test, p = p-value, d = Cohen's d.

Comparing the two Golgi magnification groups revealed a significant difference between the 10x and 20x groups. Such an effect was more pronounced than that observed between Pollock's paintings and either Golgi group individually (Table 1). Because the two image series shared the same pixel resolution (1600×1200) but framed physically different portions of tissue, box-counting conducted in pixel space effectively sampled two distinct physical scale bands of the same tissue, rather than the same band at higher or lower resolution. This result is consistent with the observation that the fractal dimension is not a single, universal number for a given object, but can vary systematically depending on the physical scale range under observation.

Following Taylor et al.'s [8] report of two distinct scaling regimes in Pollock's work, the finer-scale sampling described above was applied to the full sample. Across all 53 images, the log–log plot showed a marked change in slope rather than a single line. A preliminary check revealed that, at coarser scales, the box count $N(\varepsilon)$ frequently reached the theoretical maximum number of boxes available in the grid (complete saturation), reflecting the grid's arithmetic rather than the image's content. The saturated points were excluded from the fit. After exclusion, the pattern was consistent: D at the coarse scale exceeded D at the fine scale in 41/41 Golgi preparations and in 10/12 Pollock paintings (Fig. 4).

To verify that this improvement in fit was not merely an artifact of the greater flexibility of the two-segment model, we compared the two models using AIC and BIC. The two-segment model is favored by BIC in all 41 Golgi preparations (very strong evidence in 39/41 cases) and in 9/12 Pollock's paintings (very strong evidence in 8 cases); according to the less conservative AIC, the two-segment model is favored in all 53 samples without exception (Fig. 5 shows three representative examples, selected as the closest to the group mean in D-fine/D-coarse space).

Number 32, 1950, enamel on canvas, Jackson Pollock, Kunstsammlung Nordrhein-Westfalen, Düsseldorf. © Pollock-Krasner Foundation / Artists Rights Society (ARS), New York. Reproduced with permission.

In summary, the present sample confirmed that: (i) both domains possess a well-defined and measurable fractal dimension, with excellent goodness of fit (R^2 typically > 0.995); (ii) once the confounding effect of the binarization threshold was controlled for, both the 41 Golgi preparations (for each magnification) and the 12 Pollock's paintings formed relatively narrow distributions; (iii) the distributions were close but not statistically superimposable, both against the 10x group and against the 20x group (Table 1); (iv) the magnification of the Golgi preparations produced a systematic and even more marked difference ($d = 2.66$), indicating that D was not an absolute constant but depended on the physical scale band observed; (v) a finer check across scales revealed that the two-regime phenomenon is ubiquitous in both domains, and its statistical robustness, verified via AIC/BIC, was confirmed in 41/41 Golgi preparations and 9/12 Pollock paintings, not reducible to the mere increase in model parameters.

Overall, the present results outline a unifying principle linking the behavior of Pollock's paintings and that of Golgi-stained neural tissue: both are strongly fractal and sensitive to the scale of observation.

Discussion

What the quantitative analysis adds to the visual comparison

The qualitative visual comparison suggested to us an intriguing structural similarity between Pollock's painted surface and Golgi-stained neural tissue. The subsequent quantitative analysis does more than confirm this impression; it sharpens it into a testable claim and, in doing so, complicates it in a productive way. Both domains occupy the same general geometric regime (a fractal dimension between 1.7 and 1.8, far removed from either a simple line (D = 1) or a space-filling area (D = 2), yet they are numerically distinguishable. The small but statistically robust difference (Table 1) varies with the physical scale band under observation: the gap between Pollock's paintings and Golgi preparations is smaller than the gap between the two Golgi magnifications themselves. This is precisely the kind of result a purely qualitative analogy could not have delivered. It replaces an impression ("these look similar") with a testable, quantitative statement ("these share a geometric regime, with a specific, measurable, scale-dependent departure from identity"), and it is this testability, more than the similarity itself, that gives the comparison its scientific interest.

A structural analogy, not an identity of process

For methodological clarity, we emphasize that the comparison we proposed is a second-order structural analogy (both systems share geometric and scaling properties), not a claim of equivalence between the two phenomena, still less a thesis about the artist's intentions. The risk, well known in the critical literature on Pollock's fractals, is overly generous pattern-matching: many natural and artificial structures (coastlines, vegetation, drainage networks) share similar fractal dimensions without being "the same thing" in any deeper sense. The strength of the argument proposed here lies in showing that the recurrence of branching geometries, whether sub-fractal or fractal, across independent physical domains (painting, tissue biology, dendritogenesis) is not coincidental, but stems from shared constraints of growth, diffusion, and efficient use of space that the physics of complex systems has begun to formalize since Mandelbrot's foundational work [11].

Divergent mechanisms, convergent geometries

Behind the geometric affinity we started from lie radically different causal mechanisms: dendritic growth responds to molecular signaling, energetic constraints, and optimization of synaptic space; the trajectory of paint responds to the dynamics of a viscous fluid and the gesture of the artist's body. Physiological research suggested why such divergent mechanisms might nonetheless converge on a similar geometric solution. West and colleagues [12] showed that the metabolic scaling laws observed across all living organisms, from the heartbeat of a mouse to that of a whale, derive from a common principle: biological distribution systems (the cardiovascular system, the respiratory tree, the vascular network of plants) are fractal networks that fill the available space hierarchically, keeping terminal units of constant size and minimizing the energy dissipated in transport. In other words, branching fractal geometry is not

an incidental by-product of biological growth but the most efficient solution to the problem of distributing a resource (blood, oxygen, nutrients) from a central source into a bounded volume.

It is plausible that a similar constraint governs the growth of the dendritic tree, which must collect multiple synaptic signals from a distributed volume of tissue in the most geometrically efficient way available to it [13–15]. Furthermore, an analogous, physical rather than biological, constraint operates in the distribution of paint poured by Pollock onto a bounded two-dimensional surface, a problem likewise resolved empirically with a branching geometry rather than a uniform fill. That two such heterogeneous processes converge on a similar class of geometries ($D \approx 1.7–1.8$, with a second regime at coarser scales) need not be coincidental: it is consistent with a general principle of efficient distribution networks, already formalized for coastlines, river networks, and other natural systems [11, 16], applied here to two domains, the dendritic arborization and the action painting, where it had not previously been tested together.

For clarity, the box-counting procedure applied to the Golgi preparations measures a field-level fractal dimension across the entire imaged cortical area, encompassing, within a single 10x or 20x field, several stochastically impregnated neurons of potentially different types (pyramidal cells, stellate cells, interneurons, among others), rather than the fractal dimension of a single, identified neuron traced in isolation, as in the cell-type-specific studies cited above [4–7, 13]. We chose this level of analysis, since it matches the one applied to Pollock's paintings, where D likewise characterizes the whole poured surface rather than a single isolated brushstroke. However, the field-level procedure means that a direct, cell-type-resolved test was not possible with the present data. Smith et al. [13] predicted that different neuron types settle at different D values depending on their specific connectivity needs, a claim our field-level measurements cannot directly test. The interpretation advanced may represent a reasonable theoretical motivation for why efficient branching geometry might be expected to recur across neuronal types and brain regions alike, not a mechanism tested directly on our own sample.

What might the coarse/fine transition mean biologically?

The two-regime phenomenon (i.e., two D at coarse versus fine scale), present in both Pollock's paintings and, even more consistently, in the Golgi preparations (41/41 Golgi vs. 10/12 Pollock), raises a question beyond its statistical significance: what does it correspond to physically? For Pollock's paintings, Taylor's account is compelling because it identifies two distinct physical processes: the coarse-scale regime is thought to reflect the sweeping, whole-body motion of the artist positioning paint across the large canvas resting on the floor, while the fine-scale regime is thought to reflect the finer physics of the poured paint itself as it lands, coils, and dries. These are genuinely different processes, operating at different scales and superimposed on the same canvas.

An analogous physical account is harder to advance for Golgi preparations. A candidate grounded in developmental neurobiology rather than fluid dynamics is that dendritic arbors are built in at least two distinguishable stages, leaving a comparable signature. An early, coarser scaffold of primary and secondary branches, whose overall topology is shaped largely by molecular guidance cues and

competition for territory during initial outgrowth [17], is followed by a finer-scale elaboration of terminal branches and spines, shaped more by activity-dependent refinement and local synaptic competition [18]. If these two developmental regimes leave distinguishable geometric signatures, a coarse/fine transition in box-counting would be a trace of two different growth processes, the coarse-scale patterning by molecular guidance and territorial competition, and the fine-scale refinement by synaptic activity, rather than a statistical peculiarity, in direct analogy with Taylor's account of Pollock's two-regime phenomenon.

However, another complementary possibility is worth noting. Because our box-counting measured a field-level D across 10× or 20× cortical areas rather than a single traced neuron, the coarse-scale regime might be substantially shaped by the spatial distribution of sparse, stochastically Golgi-stained neurons across the tissue field, an inter-neuronal, tissue-level pattern, whereas the fine-scale regime might reflect the branching geometry within individual dendritic arbors. In this regard, the breakpoint would mark not a transition internal to a single dendritic tree, but the point at which box-counting shifts from characterizing how stained neurons were arranged in the tissue to characterizing how each one branched internally. Distinguishing between a genuine two-stage growth process within each arbor and a signature of analyzing multiple neurons within one field was not possible with the current data. Doing so would isolate within-arbor geometry from inter-neuronal spacing: if the two-regime pattern persisted in a single reconstructed arbor, this would favor the developmental account; if it did not, this would point instead to the field-level explanation. Notably, existing single-neuron fractal studies [4–7, 13] report a single fractal dimension per neuron and do not appear to have tested for a two-regime pattern using formal model comparison; the question therefore remains genuinely open, not previously examined rather than previously ruled out. Such a dedicated analysis falls outside the scope of the present study.

The absence of a center as a unifying principle

Pollock's paintings typically lack a focal point or any clear division into central and peripheral areas: there is no compositional center, and the eye is encouraged to roam rather than rest. According to Rosenberg's account of action painting [19], this “all-over” quality causes the “*dissolution of the picture into sheer texture, sheer sensation*” through the accumulation of repeated gestures, rather than organizing it around a subject. Much the same can be said of the Golgi-stained slides: dendritic arborizations fill the visual field with comparable density throughout, without a privileged region of higher structural complexity.

This absence of a center is not merely a stylistic observation. It offers a plausible explanation for the specific quantitative pattern reported in the Results: at coarse scales, box counts tend to saturate, reaching the theoretical maximum for the grid, which is why these points were excluded from the fit throughout. The connection between saturation and the absence of a center is intuitive once one considers a coarse grid with only a few boxes: if the traced pattern is dispersed throughout the image, even a modest number of brush strokes (or dendritic branches) suffices to touch every box, driving the count to its theoretical ceiling. By contrast, the same number of elements concentrated in a single region of the image would leave the remaining boxes untouched, and the count would remain informative. In this sense, the all-over character that Rosenberg identified as Pollock's stylistic signature has a direct

geometric counterpart in the coarse-scale saturation and in the comparable all-over quality of Golgi-stained tissue, where dendritic fields likewise leave no region of the image untouched.

Fractal fluency: a shared aesthetic, with an honest complication

Beyond the purely geometric argument, a further body of research, known as the *fractal fluency* hypothesis, offers a candidate explanation for why fractal patterns of this kind are perceptually and aesthetically salient to observers. The hypothesis holds that the human visual system has adapted, through repeated exposure to the fractal geometry pervasive in the natural world (branching trees, coastlines, clouds), to process fractal patterns of intermediate complexity with particular efficiency [20]. Preference and physiological comfort are reported to follow an inverted-U curve across the range of D. In fact, processing overly simple patterns (D close to 1, approaching a straight line) is visually unstimulating, almost boring, while processing overly complex ones (D close to 2, approaching visual noise) is effortful, almost stressful. The real comfort peaks at a mid-range value, generally reported around D ≈ 1.3–1.5, the so-called perceptual 'sweet spot' [21]. Patterns within this range of D are associated with physiological markers of reduced processing effort, including increased alpha-wave activity [22] and lower values of physiological stress [23].

The hypothesis, however, comes with a well-known complication that directly bears on our results: the sweet spot sits comfortably below the D ≈ 1.7–1.8 we measured for both Pollock's paintings and Golgi preparations. Rather than treat this as a discrepancy to explain away, we noted that Taylor [23] reports a specific, previously documented resolution: when fractal images are viewed projected on the walls of a room, surrounded by the Euclidean simplicity of ordinary architectural space, rather than displayed in isolation on a monitor, the preferred D shifts markedly higher, toward D ≈ 1.6–1.7. The introduction of Euclidean simplicity in the surrounding visual field appears to increase the observer's tolerance for higher fractal complexity in the framed image itself. A painting hung on a wall bounded by plain walls, a frame, and architectural space more closely matches this ‘wall’ viewing condition than an immersive natural scene or an isolated image on a screen. This might help explain why the D range we measured for both Pollock and Golgi “canvas” sits comfortably above the classic sweet spot rather than in tension with it.

As a further point of contact between the literature on fractal fluency and the present analysis, it is worth noting that the fractal dimension of an artist's oeuvre has also been reported to track neurological change over time in the opposite direction. Forsythe et al. [24] analyzed over 2,000 paintings by seven artists and found that those who later developed Alzheimer's disease showed a significant decline in fractal dimension over time, a trend absent in artists who aged without a neurodegenerative disorder. Among the former was de Kooning, a leading exponent of action painting like Pollock, whose paintings declined in fractal dimension by about 0.003 per year relative to his own average. Interestingly, Pollock's trajectory moved in the opposite direction, with D values rising from about 1.45 in the late 1940s to 1.72 in *Blue Poles* (1952) [8]. Forsythe et al.'s work supports only tentative conclusions, given its small sample

of seven artists and a fractal measure normalized to each artist's own baseline rather than an absolute D directly comparable to ours. Still, the direction of change they report offers a suggestive parallel to the reeler-mutant findings of Kim and colleagues [5], where disrupted neuronal architecture is likewise associated with a reduced fractal dimension (D ≈ 1.25 versus D ≈ 1.72 in wild-type).

Limitations and future directions

The quantitative correspondence between Pollock's paintings and Golgi-stained neural tissue, at the core of this work, is well supported by the analyses presented above. Two questions remain open, however, concerning how far that correspondence extends.

The first question concerns physical scale. Because neither image series carried a physical calibration, the analysis was conducted in pixel space. The pixel-space result itself was robust: 10x and 20x Golgi preparations differed reliably in D under the identical, coverage-controlled protocol applied to both. What remains open is an interpretive question: whether this difference in D reflects a genuine physical dependence of dendritic geometry on the biological scale being observed, or instead a property of how box-counting behaves when the same pixel grid represents a different physical extent of tissue at each magnification. A decisive test for this question, and for whether the coarse/fine breakpoint documented throughout this work marks a genuine transition in the physical scale of dendritic branching rather than a pixel-grid artifact, would be to image the same Golgi-stained slide at multiple, calibrated magnifications (e.g., a nested series from 10x up to 100x, the range typically needed to resolve the finest terminal dendrites and spines, with known physical calibration retained throughout). Such a design would make it possible to track D as a continuous function of physical scale for the same tissue, rather than comparing two discrete, uncalibrated magnifications as done here.

The second question concerns tissue scope. The present sample was deliberately restricted to cortical tissue, keeping the tissue type constant throughout. This choice leaves open the possibility that the D ≈ 1.7–1.8 signature we reported may extend beyond the cortex. Applying the same protocol to preparations from non-cortical brain areas may be a direct next step for future work.

Neither limitation alters the main finding of the present study, which emphasizes that Pollock's paintings and Golgi-stained neural preparations share a scale-dependent fractal signature.

Conclusions

This work began with a simple resemblance: a single Pollock’s canvas that looked like a photograph of Golgi-stained brain tissue. Quantitative analysis has now given that resemblance a precise shape, including a shared fractal regime, a shared coarse/fine transition, and a set of candidate explanations for why two such different generative processes might arrive at comparable geometries, while also showing where the resemblance stops: they are two processes that remain, mechanistically, unrelated. Whether the correspondence extends further, to other brain regions or to a properly calibrated physical scale, is

for future work to establish. What the present study offers is a method for taking a visual intuition seriously enough to test it quantitatively, while reporting plainly both what held up and what did not.

Declarations

Conflicts of Interest:

The authors declare no conflict of interest.

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Author Contribution

L.P. and A.P. conceptualized the research, realized formal analyses, and wrote the manuscript. Both of them agreed to the published version of the manuscript.

Data Availability

The fractal-dimension values (D) computed for all 53 samples (12 Pollock paintings and 41 Golgi preparations), together with the analysis code, are available from the corresponding author upon reasonable request. The digital reproductions of Pollock's paintings analyzed in this study are subject to third-party copyright (Pollock-Krasner Foundation / Artists Rights Society) and cannot be redistributed; the original Golgi-stained preparations, produced in our laboratory, can be made available upon reasonable request.

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Figures

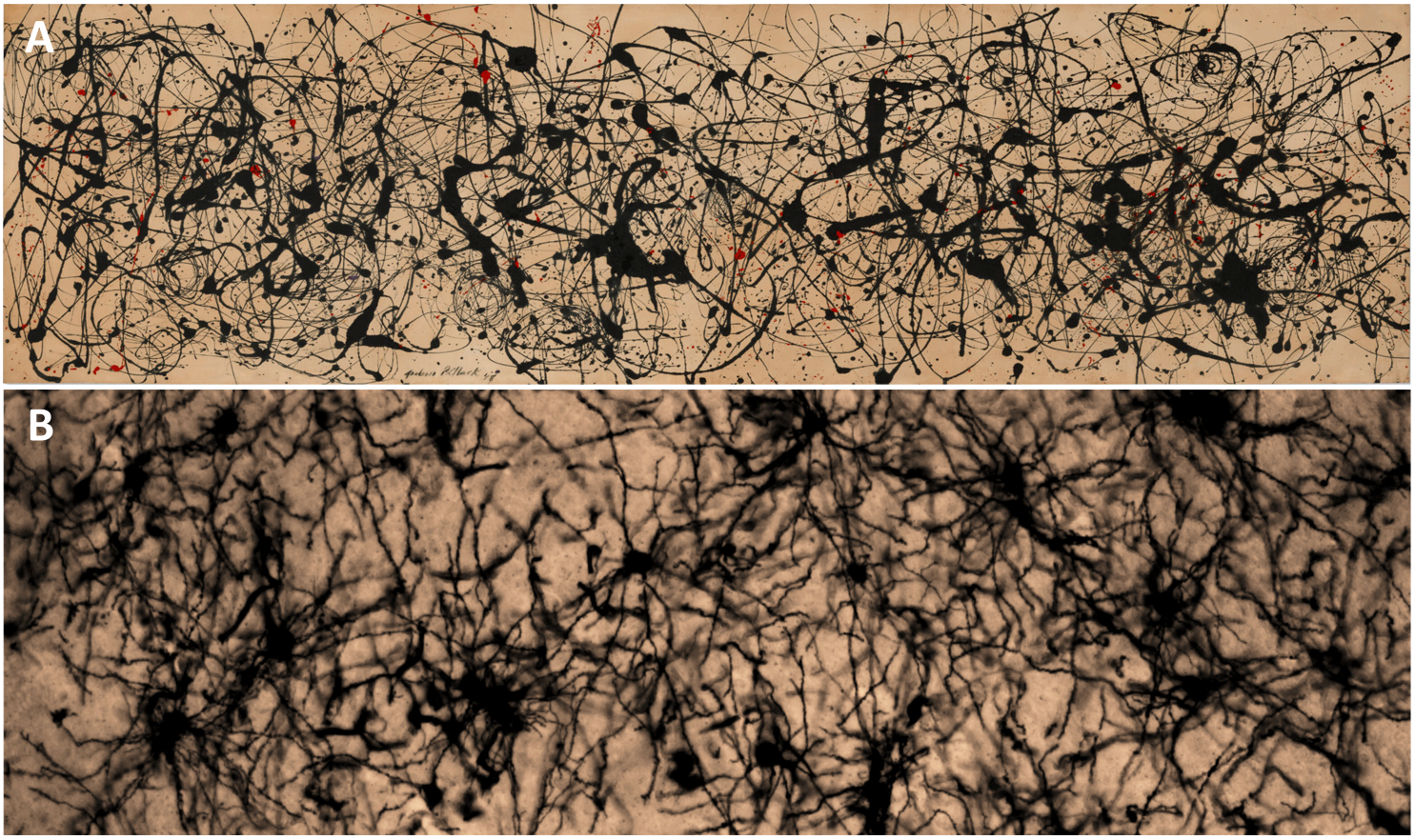


Figure 1

Visual analogy between Jackson Pollock's action painting and Golgi-stained neural tissue. (A) Jackson Pollock's *Number 7A* (1948), showing the characteristic "all-over" distribution of poured paint. (B) Image of Golgi-stained mouse neural tissue imaged at 20× microscope magnification, depicting the intricate network of stained neurons and dendritic processes. *Number 7A*, 1948, oil and enamel on canvas, Jackson Pollock. © Pollock-Krasner Foundation / Artists Rights Society (ARS), New York. Reproduced with permission.

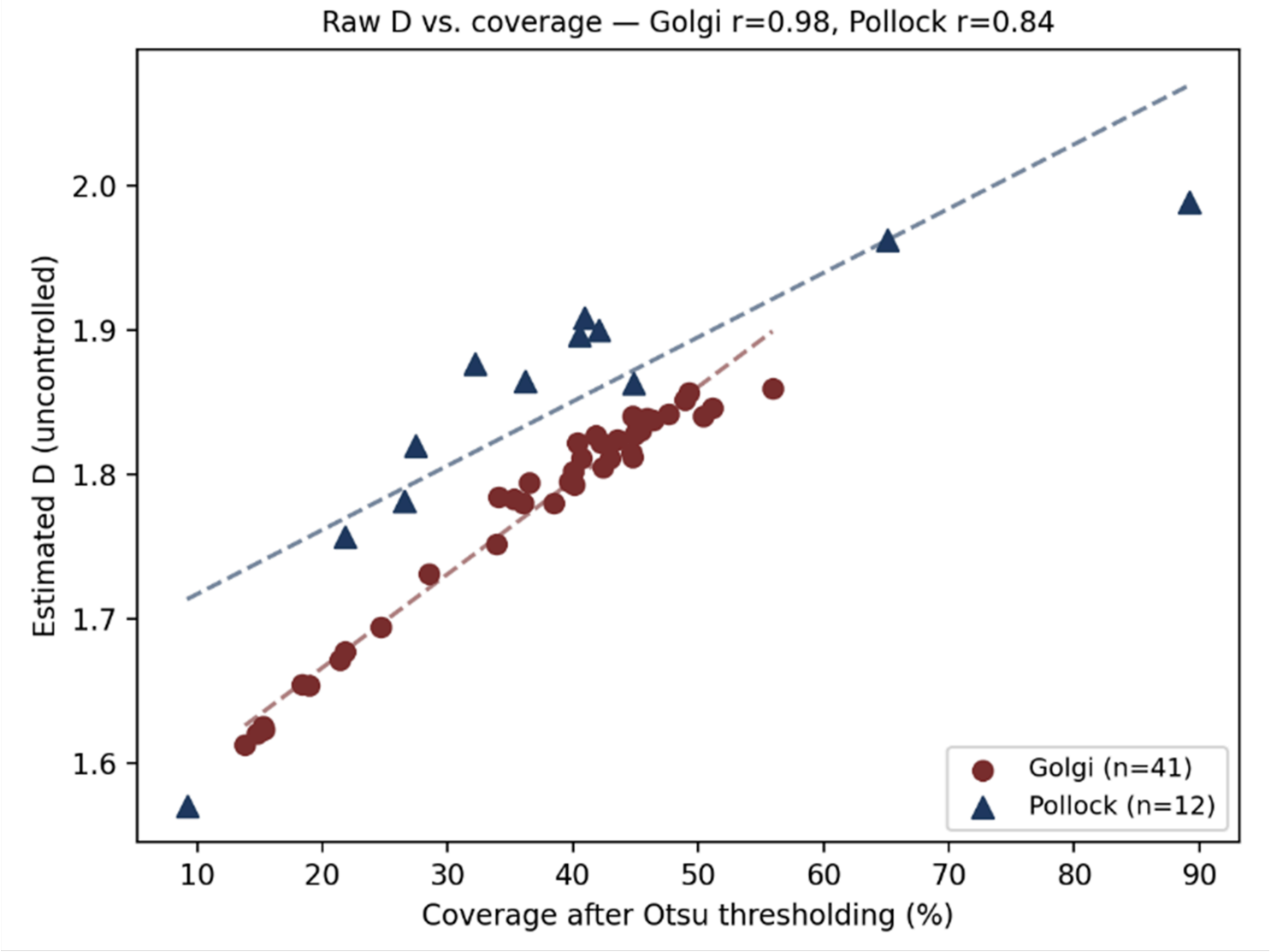


Figure 2

Uncontrolled D as a function of coverage after Otsu thresholding, for the 12 Pollock's paintings and the 41 Golgi preparations. The strong correlations in both domains (r = 0.84 and r = 0.985) motivate a shift to the coverage-controlled method.

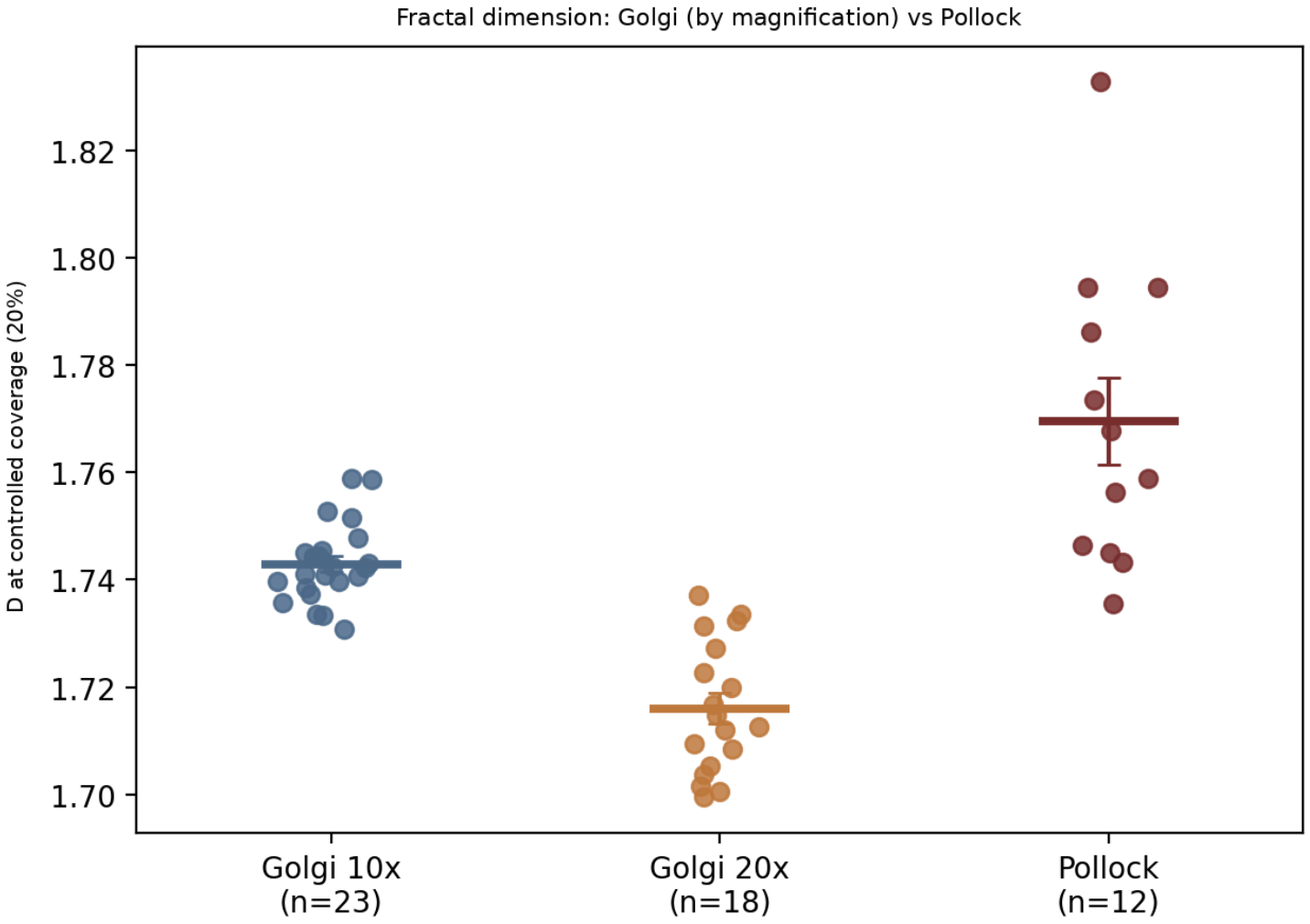


Figure 3

Controlled-coverage D (20%) for the Golgi preparations at 10× (n=23) and 20× (n=18) magnification, and for the sample of 12 Pollock paintings. Horizontal bars indicate the group means; error bars represent the standard error of the mean.

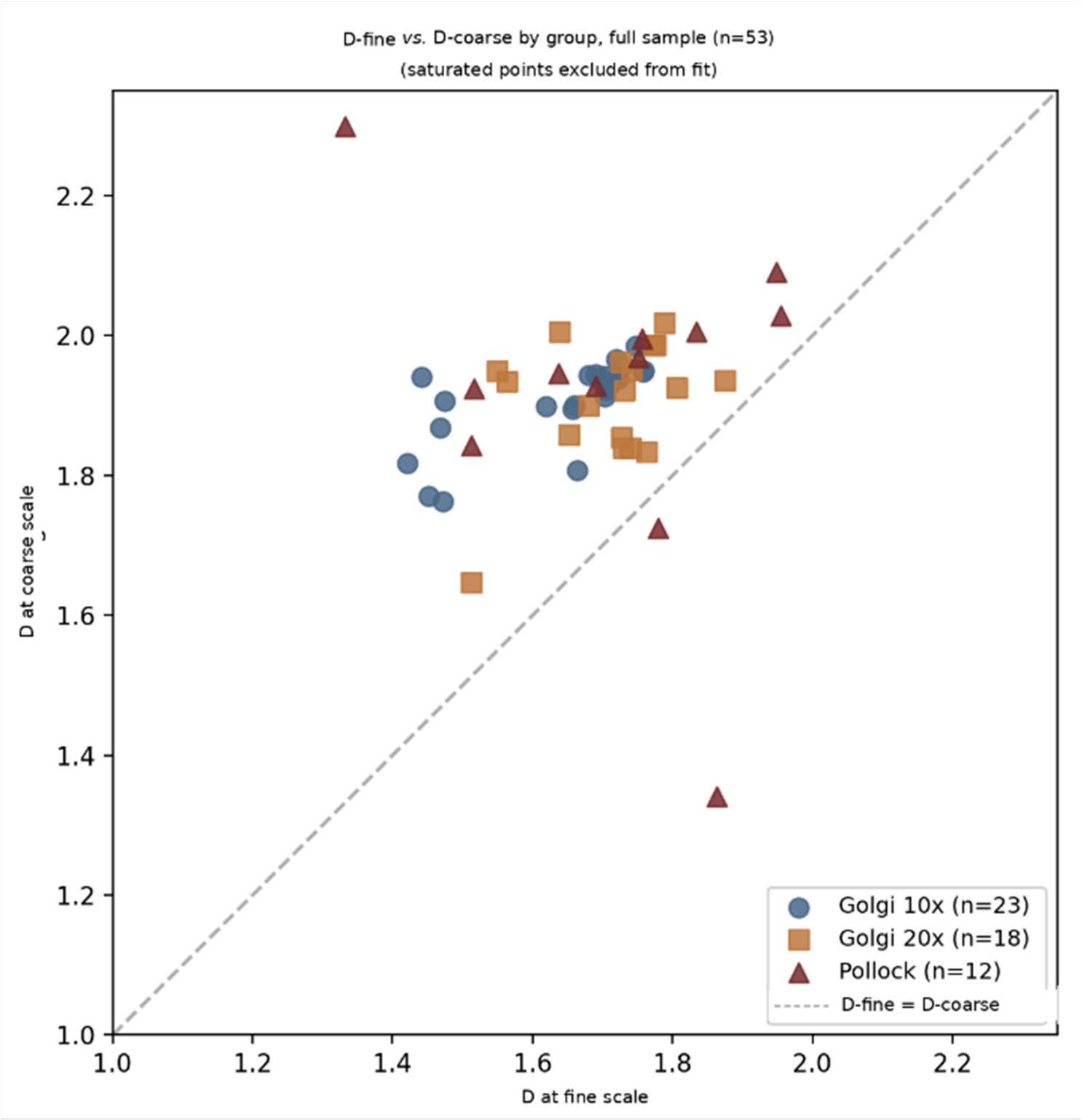


Figure 4

D at fine scale vs. D at coarse scale for all 53 samples (saturated points excluded from the fit), colored by group. The dashed line indicates D-fine = D-coarse: nearly all points fall above the diagonal, visually confirming the phenomenon described in the text.

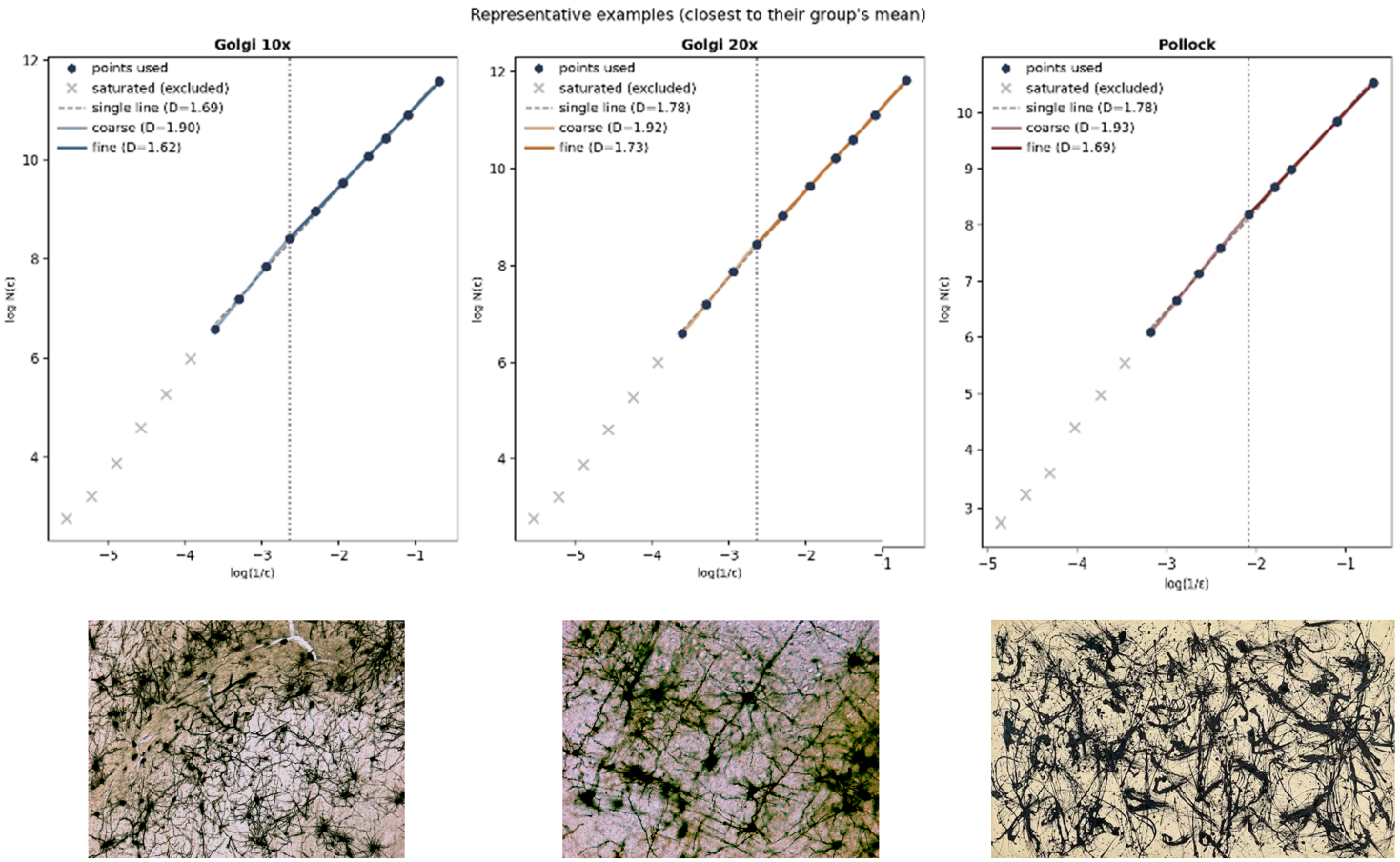


Figure 5

Two-segment analysis for three representative samples (closest to their group's D-fine/D-coarse mean): Golgi 10×, Golgi 20×, Pollock (*Number 32*). Saturated points (grey) are excluded from the fit. The vertical dotted line marks the breakpoint between the coarse- and fine-scale regimes estimated for each sample.

Number 32, 1950, enamel on canvas, Jackson Pollock, Kunstsammlung Nordrhein-Westfalen, Düsseldorf. © Pollock-Krasner Foundation / Artists Rights Society (ARS), New York. Reproduced with permission.