Mandelbrot Metal FAQ

General help and Version 3

Version 3 is available for iPhone and iPad. Explore free with the Infinity Engine, all 156 built-in palettes, and 56 curated starter bookmarks. Choose Pro for expanded creative tools and output. Requires iOS 26 or iPadOS 26 or later.

Getting started

What is Mandelbrot Metal?

Mandelbrot Metal is a fractal explorer and art studio for iPhone and iPad. Built on Apple's Metal graphics framework, it renders the Mandelbrot and Julia sets on your device, combining interactive navigation, adaptive precision, vivid palettes, deep zooming, and optional 3D lighting.

You can explore intricate mathematical structures, experiment with color and composition, bookmark discoveries, and save or share the images you create. Version 3 adds the Infinity Engine for dramatically improved deep Mandelbrot rendering performance and deeper zooms.

Who is it for?

- **Artists:** Create fractal compositions for screens and print, with 8K and larger custom PNG output in v3 Pro, within device limits.
- **Math and science enthusiasts:** Explore the Mandelbrot set and the infinite family of Julia sets using adaptive-precision rendering.
- **Power users:** Put Apple's graphics hardware to work on demanding, detailed scenes.
- **Casual explorers:** No mathematical expertise is needed. Pan, pinch, try a palette, and discover something beautiful.

What makes Mandelbrot Metal different from other fractal explorers?

Mandelbrot Metal combines Metal GPU rendering with an integrated creative workflow: Mandelbrot and Julia exploration, adaptive precision, saved scenes, color tools, and high-resolution capture. In v3, the Infinity Engine moves much of the ultra-deep Mandelbrot workload onto the GPU, with a high-precision CPU reference and an established fallback renderer.

- 156 built-in palettes, including 55 Ultra-Wide palettes with 768 source steps.
- sRGB and Display-P3 color workflows, with appearance depending on the display and color settings.
- Photo-derived and custom palettes, 3D lighting, and 8K and larger custom PNG capture in Pro, within device limits.
- Shareable bookmarks that preserve the scene's coordinates and creative settings.

Performance depends on the scene and device; a smooth interactive preview does not mean every deep final-quality frame finishes at 60 FPS. See the comparison guide and the measured v3 performance results. Saved state is repeatable, but exact pixels can vary across app versions, devices, renderer paths, and color-management systems.

What fractals does Mandelbrot Metal render?

Version 3 includes Mandelbrot and Julia sets. Julia mode opens an entire family of shapes by changing the constant *c*.

Version 3.5 targets a curated expansion, beginning with evaluation of Multibrot and Burning Ship. Each formula needs its own correctness, depth and performance qualification, plus consistent navigation, color, scene saving and export. These are future features.

What devices does Mandelbrot Metal run on?

Mandelbrot Metal 3 requires **iOS 26 or iPadOS 26 or later**. It is designed for iPhone and iPad.

Rendering speed, practical capture size, and heat during demanding work depend on the device. Newer hardware generally gives more headroom for deep exploration and large exports.

Is there a Mac version?

There is no separate native Mac edition yet. The version 3 series focuses on iPhone and iPad. A native Mac workspace is a possible 4.0 direction, subject to demand, capacity and qualification.

The iPhone/iPad app can also run on compatible Apple-silicon Macs when that version is offered in the Mac App Store. Check the listing for current availability and requirements.

Do I need an internet connection?

Core exploration, rendering, bookmarks, palettes, and local capture run on the device. Internet access is needed for App Store purchases and restoration, downloading app updates, opening online resources, and sharing through online services. Photo access is requested only when you choose an image-based palette or save to Photos.

Will deep rendering heat the device or use more battery?

It can. Very deep, high-iteration, supersampled, 3D, or high-resolution renders are sustained workloads. Bounded Metal scheduling helps control individual commands, but demanding work can still warm the device and use more battery. Performance depends on the scene, hardware, and thermal state.

Mandelbrot, Julia, and the mathematics

What are complex numbers?

A complex number has two parts: a real part and an imaginary part. Think of a map: “3 miles east, 4 miles north” describes one location using two coordinates. In the complex plane, the real part runs horizontally and the imaginary part vertically.

The imaginary unit, i, satisfies $i^2 = -1$, so a number such as $3 + 4i$ identifies a point on that plane. “Imaginary” is a historical name for this second direction, not a claim that the numbers are fake.

Adding complex numbers combines their two components. Multiplying them rotates and stretches them. Repeated multiplication and addition in the rule $z \to z^2 + c$ creates the Mandelbrot and Julia patterns you explore. Complex numbers also appear in signal processing, quantum mechanics, and graphics. Read Beyond Complex Numbers for more.

What is a Julia set?

A Julia set is a close relative of the Mandelbrot set, built from the same rule: $z \to z^2 + c$. Both z and c are complex numbers. The difference is which value stays fixed.

- **Mandelbrot:** Start at $z = 0$ and vary c across the image. The Mandelbrot set contains the values of c for which the sequence remains bounded.
- **Julia:** Fix one value of c and vary the starting value of z across the image. The points that remain bounded form the filled Julia set; its boundary is the Julia set.

Every choice of c gives a Julia set. The Mandelbrot set maps their connectedness: values of c in the Mandelbrot set, including its boundary, give connected Julia sets; values outside give disconnected dust. Exploring the two together reveals that relationship visually.

How are Julia sets different from the Mandelbrot set visually?

There is one Mandelbrot set, but an infinite family of Julia sets. Changing c can transform the entire Julia image: spirals tighten, branches split, swirls fold inward, and dragon-like curves appear.

- Parameters in the Mandelbrot set produce connected Julia sets, often with striking rotational symmetry.
- Parameters near its boundary can reveal seahorses, lace, dendrites, and intricate spirals.
- Parameters outside the Mandelbrot set produce totally disconnected patterns often called Julia or Fatou dust.

The Mandelbrot view shows the parameter map; the Julia view explores the dynamics of one chosen parameter.

How does Mandelbrot Metal create Julia sets?

For each pixel, the Julia renderer treats its position as a starting complex number z□ and iterates $z \to z^2 + c$, using the constant you selected. Escape information feeds the color pipeline; points that have not escaped within the chosen iteration budget receive the interior treatment. A finite render does not prove that every such point stays bounded forever.

Julia exploration shares the palette system, smooth coloring, bookmarks, and PNG capture workflow. Pro also supplies custom palettes, 3D lighting, and high-resolution output.

Version 3 distinction: Julia uses its direct Julia Metal kernel. The Infinity Engine's reference-orbit perturbation and validated $10^{25}\times$ deep-zoom claim apply to Mandelbrot rendering; they should not be read as equivalent Julia-depth guarantees.

How do I pick the value of c in Mandelbrot Metal?

While viewing the Mandelbrot set, **single-tap a location** to use that point as *c* and open its Julia set. Single-tap again in Julia mode to return to the originating Mandelbrot view. A double-tap zooms; dragging pans and pinching zooms.

Try a point near a seahorse valley, a miniature Mandelbrot, or a dendrite tip. Return to Mandelbrot and choose a nearby point to compare how the Julia shape changes. Save an interesting Julia view as a bookmark: its *c* value is stored along with the viewport, palette, and appearance settings.

See the User Guide for the full navigation workflow.

Why do small changes in c produce such dramatic shapes?

The parameter *c* is added at every iteration, so changing it changes the dynamics throughout the Julia image. Near the Mandelbrot boundary, small parameter changes can reveal very different spirals, branches, and dust-like structures, or change whether the Julia set is connected.

That sensitivity makes nearby points rewarding to compare. Bookmark discoveries so you can return to the chosen parameter and creative settings instead of trying to find them again by eye.

Palettes and color

What are Ultra-Wide palettes?

Ultra-Wide palettes are marked [UW] and contain 768 source stops. Standard definitions have varying stop counts. There are 55 Ultra-Wide palettes among the 156 built-ins available in Free.

Source stops and the active texture width are different. Named and custom palettes are rasterized at 256 or 1,024 texels according to Hi-res LUT. More gradient samples do not add coordinate precision, channel bits, or HDR output.

What is the High-Res LUT (1024) setting?

A lookup table is a row of colors sampled from the smooth escape coordinate. Hi-res LUT selects a 1,024-texel texture instead of 256; the renderer uploads that actual width.

Exact LUT assigns the nearest source stop while building each texel. Smooth draws a gradient. Metal linearly samples both textures. These settings affect color construction, not the fractal equation or zoom ceiling.

What happens when High-Res LUT is disabled?

The app builds and uploads a 256-texel palette texture. It does not force it back to 1,024 texels. Dense source ramps may lose some fine variation when represented by the smaller table.

Compare both settings on the same view with iterations and contrast fixed. A smaller table does not promise a noticeable speed improvement; the orbit work can dominate rendering cost.

Can I import my own color palettes?

Yes. All 156 built-in palettes are available in Free. Pro adds custom palettes, photo-derived gradients, and palette import/export.

Tap Import Gradient and choose a photo. Portrait images use a vertical center slice; other images use a horizontal center slice. Adjust saturation, gamma, contrast stretch, and Exact LUT, then tap Apply and name the palette. You can import the same image again.

Use Manage Palettes to import compatible palette files. Advanced users can also use the photo2palette command-line utility.

Saving, sharing, and backups

Can I bookmark my favorite locations?

Yes. A bookmark preserves the fractal family, precise center, scale, iterations, palette identity, contrast, Julia parameter, 3D state, and related appearance settings. Version 3 also preserves compensated center data needed beyond ordinary Double precision.

Version 3 comes with 56 curated Mandelbrot and Julia starter bookmarks, ready to explore from your first launch. Free includes five personal bookmarks in addition to the starter collection; Pro removes the personal bookmark limit. The starter collection is added once on new installs and upgrades. Your existing bookmarks are kept, matching bookmarks are not duplicated, and starters you delete stay deleted. Export individual bookmarks or a complete pack to back up or share them. Include any custom palettes they use in your backup as well. Equivalent saved state can still render somewhat differently across app builds, devices, renderer paths, and color-management pipelines.

Can I save or share my fractal images, and at what sizes?

Yes. Tap Capture, choose a resolution, and tap Capture Now. Free includes Canvas; Pro adds 4K, 6K, 8K, and Custom. Every option renders a separate complete PNG and reports progress.

The 4K, 6K, and 8K presets use longest edges of 3,840, 5,760, and 7,680 pixels, preserving the canvas aspect ratio. Custom dimensions can exceed the 8K preset, within device memory and practical render time. Large exports take more time and memory. When the share sheet opens, save to Photos or Files, or send to another app. PNG exports are SDR.

Share a bookmark when you want someone to continue exploring from the saved scene.

How does sharing work in Mandelbrot Metal?

You can share a finished image, a bookmark that lets someone continue exploring, or a custom palette that supplies a reusable color gradient. Bookmark and palette files work between iPhone and iPad and can be sent through AirDrop, Mail, Messages, Files, or another compatible sharing service.

Bookmarks carry coordinates, scale, fractal mode, Julia parameter when relevant, palette identity, iterations, and appearance settings. Custom-palette files carry their name, color stops, and color-space metadata. Share the custom palette as well when a bookmark depends on it; a bookmark's palette name alone is not a complete gradient.

Files contain scene or palette data, including names you have assigned. They are not account or photo-library exports, but avoid putting personal information in item names if you intend to share them publicly.

The Community Portal already offers downloadable bookmarks and palettes. Use it to find starting points and check the available ways to contribute. In v3, custom-palette import and export require Pro.

How do I share or back up my bookmarks and palettes?

Bookmarks

- Open Manage Bookmarks from the bookmark button or More (…).
- Swipe right on a bookmark to reveal Export, or choose Export All to back up the collection.
- Use the share sheet to AirDrop, send, or Save to Files.
- On the receiving device, open Manage Bookmarks → Import and choose the saved file.

Custom palettes

- Open Manage Palettes from More (…).
- Swipe right on a custom palette to Export it, or use Export All.
- Use Import in the same sheet to load a received or backed-up palette file. This workflow requires Pro in v3.

Imports add to your collection and preserve built-in palettes. Name conflicts may receive a new unique name, so check the imported items before reorganizing your library. Free's five-personal-bookmark allowance is separate from the included starter collection. For a complete creative backup, export both your bookmarks and any custom palettes they use.

Where are exported files stored, and what file types do they use?

The app prepares an export and opens the share sheet. Choose **Save to Files** to select the destination, such as a folder under On My iPhone/On My iPad or iCloud Drive. Sending through AirDrop, Mail, or Messages uses that service instead; exports are not automatically permanent backups in a fixed app folder.

- Single bookmarks use names beginning with **Bookmark** and ending in **.json**; a full backup begins with **Bookmarks-All**.
- Single custom palettes use **.mandelpalette.json**; palette collections use **.mandelpalettes.json**.
- Captured images use **.png**.

Import a received file from Manage Bookmarks or Manage Palettes. Where iOS offers Open in Mandelbrot Metal from Files or a message, you can use that route too. Keep the complete filename and extension intact.

Will my existing bookmarks and palettes still work?

Version 3 reads existing bookmark and palette data and retains legacy defaults when newer precision fields are absent. The migration goal is to preserve coordinates, manual iterations, palette identity, and appearance. Later scene-document releases extend this state rather than invalidating the existing library.

Exploration History

What is Exploration History?

Exploration History is an automatic Back/Forward stack for the current app session. It keeps up to **50 recent states** after completed navigation steps, so you can revisit a view or recover from an unintended move.

History restores the full creative state, including precise viewport, scale, iterations and Auto mode, Mandelbrot or Julia mode, Julia constant, palette, contrast, 3D settings, and loaded-bookmark context.

How is history different from a bookmark?

History is automatic and temporary. It clears when the app session ends and is designed for quick comparison and recovery. Bookmarks are named, persistent scenes that you can organize, export, back up, and share.

Use Back and Forward while experimenting; create a bookmark when you want to keep a discovery. In v3, free includes five personal bookmarks in addition to the starter collection; Pro removes the personal bookmark limit.

What happens after I go Back and start exploring again?

The old Forward branch is cleared, just as in a web browser. Your Back history remains available within the 50-state session limit, and the new exploration becomes the path you can follow forward.

Save a bookmark first if you want to keep both versions of a scene for later.

Version 3 at a glance

What is Mandelbrot Metal 3?

Mandelbrot Metal 3 begins with the Infinity Engine and Free + Pro in version 3.0. The planned 3.1-3.6 series then strengthens performance, deep-zoom 3D, precision, creative controls, scenes, motion, formula variety and organization. Reliability and accessibility are requirements in every release.

Is Version 3 available now?

Version 3.0 is available now. Later releases have no committed dates or fixed eight-week schedule. The intended sequence is 3.1 performance and clearer deep-zoom 3D; 3.2 deeper precision; 3.3 the color and 3D studio; 3.4 motion; 3.5 more fractals; and 3.6 library and optional sync. Research may change the order. See the detailed roadmap for features, dependencies and release criteria.

Infinity Engine and deep zoom

What is the Infinity Engine?

The Infinity Engine is Mandelbrot Metal's GPU-first deep Mandelbrot renderer. Its main benefits are **dramatically improved performance and deeper zooms than earlier Mandelbrot Metal versions**.

It builds a high-precision reference orbit on the CPU, uploads that orbit to Metal, and evaluates reference-relative perturbations for each pixel on the GPU. Difficult pixels use higher-precision recovery. Failed or unusable Metal work falls back to the established deep renderer, while shallow and intermediate views retain their existing Metal paths.

How deep can I zoom, and what is the v3.0 ceiling?

The previous Mandelbrot magnification limit was **10^{16}×**. Version 3.0 raises the validated **Mandelbrot ceiling to 10^{25}×**, a billion times the former magnification limit. Navigation, bookmarks, history, the HUD, and rendering share that enforced boundary.

Useful detail within the range still depends on the location, coordinate and reference precision, pixel step, iteration budget, device, and rendering time. This is a finite validated range, not unlimited or arbitrary-precision zoom, and it is not an equivalent depth guarantee for Julia rendering. See the roadmap for planned work.

Does v3 use arbitrary-precision math?

No. Infinity Engine v1 uses adaptive finite precision: a CPU double-double reference orbit and Metal quad-single expansion arithmetic for per-pixel perturbation and recovery. This goes beyond ordinary Double precision and supports the validated 10^{25} range, but it is not a general arbitrary-precision library.

How much faster is the Infinity Engine?

In a ten-scene, full-frame physical-device benchmark on an iPhone 17 Pro Max, v3.0 averaged 42.419 seconds versus 203.890 seconds for the previous release: a **4.81× aggregate speedup** and a 79.2% reduction in elapsed time. Earth Elephants improved from 12.245 seconds to 3.714 seconds (3.30×). Shallow GPU scenes remained close to parity.

The test used 1320 × 2868 screen renders on iOS 26.6.1 with v3 build 548. It measures completed screen rendering, not high-resolution export speed or a ranking against competing apps. Results vary with device, operating system, scale, iterations, lighting, thermal state, and scene complexity. The technical white paper describes the benchmark.

What happens if the new renderer is slower or cannot complete a scene?

Correctness comes first. Infinity work is benchmark-gated and monitored. A valid completed frame is kept even when it is slower than a diagnostic target; a failed or unusable Metal command opens a fallback circuit and redraws with the established deep renderer. Shallow and intermediate Metal paths are not replaced unless the new path meets its output and performance requirements.

Do Free and Pro use different rendering quality?

No. Free and Pro use the same rendering engine, precision selection, built-in palettes, and Infinity safeguards. Zoom depth, numerical correctness, and rendering speed are not paid gates. Pro adds authoring, organization, lighting, and production-output capabilities.

Free, Pro, and existing customers

What is included in Free?

Free includes full-speed Mandelbrot and Julia exploration, adaptive-precision zoom beyond the former 10^16 boundary, the complete built-in palette library, 56 curated starter bookmarks, five personal bookmark slots, and canvas-resolution PNG capture. It does not use a reduced-quality version of the Infinity Engine.

What does Pro add?

Pro removes the bookmark limit and adds photo-derived and custom palettes, palette sharing, 3D Look, and 4K, 6K, 8K, and custom-size PNG capture. Scene documents and motion/video authoring are future work, not currently delivered Version 3.0 tools.

How much does Pro cost?

The current U.S. reference prices are $2.99 per month, $19.99 per year, or $39.99 for a one-time Pro Lifetime purchase. The price shown by the App Store in the upgrade screen is authoritative and may vary by storefront, currency, tax, or future catalog changes.

I bought Mandelbrot Metal before Version 3. Do I have to pay again?

Verified owners whose original App Store acquisition predates the Version 3 Free + Pro boundary receive permanent Legacy Pro at no additional charge. It grants the same Pro features as Lifetime.

If access does not appear automatically, choose Restore Purchases from the Pro screen using the Apple Account associated with the original purchase. The app synchronizes purchases and, if still needed, refreshes the signed original app-ownership record. Apple may ask you to authenticate. A failed or canceled check does not create an entitlement; you can retry restoration.

What is the difference between Monthly, Annual, Lifetime, and Legacy Pro?

Monthly and Annual provide the same Pro features while the subscription remains current. Lifetime is a one-time purchase that permanently unlocks Pro. Legacy Pro is the permanent entitlement granted to verified pre-v3 owners. The plans differ in billing and duration, not in rendering or feature quality.

Can I cancel a subscription or restore a purchase?

Yes. Monthly and Annual subscriptions can be managed through the App Store, and access continues through the paid period. Restore Purchases asks the App Store to re-check current subscriptions, Lifetime, and Legacy Pro eligibility. Existing bookmarks are preserved if Pro access ends; Free simply prevents creating more once the five-personal-bookmark limit has been reached; included starter bookmarks do not count toward that limit.

Does Pro support Family Sharing?

The v3 commerce design enables Family Sharing for eligible Pro purchases, subject to the purchaser's Apple Family Sharing settings and App Store rules in the current storefront.

The rest of the v3 release series

Are scene documents, animation, and video export included in v3.0?

Not as finished user-facing tools. Version 3.0 provides bookmarks, palettes, 3D Look and still-image capture. Version 3.3 targets self-contained scenes with embedded custom palettes and 3D settings, plus autosave and recovery. Version 3.4 targets editable journeys, keyframes and video export, starting with 1080p and qualifying 4K separately.

The existing Pro still-image workflow already supports 4K, 6K, 8K and larger custom PNGs within device limits. Those dimensions do not imply video export support.

What is planned after v3.0?

Version 3.1 prioritizes faster exploration, more visible fine-detail 3D at deep zooms, easier initial lighting controls and stronger large-image export handling. Version 3.2 targets a qualified extension of Mandelbrot depth and acceleration. Version 3.3 adds the color and 3D studio, richer light and relief controls, complete scenes and autosave. Version 3.4 adds journeys and animation of supported palette, lighting and relief settings. Version 3.5 broadens the fractal collection; 3.6 targets library improvements, optional iCloud sync and batch still exports.

3D Look is surface relief derived from the 2D fractal, rather than volumetric 3D. A native Mac workspace is a possible 4.0 direction. These are plans, with scope and order subject to testing. Read the detailed roadmap.

Is v3 localized and accessible?

The v3.0 interface and commerce text are localized across the app's 16 supported languages. Accessibility, localization, VoiceOver, Dynamic Type, appropriate keyboard and pointer support, reduced motion, contrast and focus order remain requirements in every release, including the new 3D controls. This work is not reserved for a final qualification release.

Where can I find the technical details?

The technical white paper documents the v3.0 architecture, mathematics, precision, rendering, color, persistence and benchmark method. The current roadmap covers planned 3.1-3.6 work and the possible native Mac direction; it supersedes earlier release sequencing in dated documents.