→ E-BOOK

Introduction to the

Universal Render Pipeline for advanced Unity creators

Unity®

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Introduction

This guide can help experienced Unity developers and technical artists develop as efficiently as possible with the Universal Render Pipeline (URP) in Unity 6.

URP and the High Definition Render Pipeline (HDRP) are two rendering solutions provided by Unity that are built on top of the Scriptable Render Pipeline (SRP) framework. These SRPs enable you to customize the culling of objects, their drawing, and the post-processing of the frame without having to use low-level programming languages like C++. You can also create your own fully customized SRP.

URP is Unity's default renderer for 2D and 3D games for mobile, XR, and untethered hardware. It's the successor to our Built-In Render Pipeline, designed to be efficient for you to learn, customize, and scale to all Unity-supported platforms. In Unity 6 it offers the same functionality as the Built-In Render Pipeline, and in a number of areas, exceeds its quality levels and performance.

Some of the areas this e-book provides expert guidance and best practices for include how to:

— Set up URP for a new project, or convert an existing Built-In Render Pipeline-based project to URP.

— Work with URP Quality settings.

— Use all lighting tools available in URP including new features like Adaptive Probe Volumes (APVs) for real-time global illumination and lighting scenarios that blend between day and night lighting.

— Use URP shaders for lit scenes and understand the differences between URP and Built-In Render Pipeline shaders.

— Use custom shaders, includes and HLSL includes.

— Use the URP post-processing framework, including adding a Local Volume and controlling post-processing with code.

— Use Rendering layers.

— Apply many kinds of performance optimizations with tools in URP, including the newly-released GPU Resident Drawer, GPU occlusion culling, and more.

— Customize the render pipeline using Renderer Features and the render graph system.

Multiplatform deployment is a key factor in the success of many games. Players often play the same game on different devices, such as console and mobile, meaning Unity developers require rendering options that scale up and down for numerous devices, with as few steps and complexity as possible.

With scalability, customizability, and a rich feature set, URP offers you creative freedom in any type of project, from stylized visuals to physically based rendering.

A scene made with URP

Author and contributors

Nik Lever, the author of this e-book, has been creating real-time 3D content since the mid-nineties and using Unity since 2006. For over 30 years he led the small development company, Catalyst Pictures, and has provided courses since 2018 with the aim of helping game developers expand their knowledge in a rapidly evolving industry.

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URP: The successor to the Built-In Render Pipeline

One of Unity's biggest strengths is its platform reach. The ideal for all game studios is to create once and efficiently deploy their game to their desired range of platforms, from high-end PCs to low-end mobile.

The Built-In Render Pipeline was developed to be a turnkey solution for all platforms supported by Unity. It supports a mix of graphics features and is convenient to use with Forward and Deferred pipelines.

However, as Unity continues to add support for more platforms, the shortcomings of the Built-In Render Pipeline have become more pronounced:

— The bulk of the code is written in C++ and can't be modified by developers, making it a blackbox system.

— The render flow and render passes are prestructured.

— The rendering algorithm is hardcoded.

— Unconstrained customization makes achieving good performance on all platforms difficult.

— It exposes callbacks in the rendering code that trigger sync points in the pipeline. Those callbacks prevent multithreaded rendering optimizations, enabling changes for injection of state at any point in the frame dynamically by calling to C#.

— Caching data to manage the persistence state for user injection is difficult.

The solution: Scriptable Render Pipelines

The SRPs were developed to support an efficient multiplatform workflow by providing:

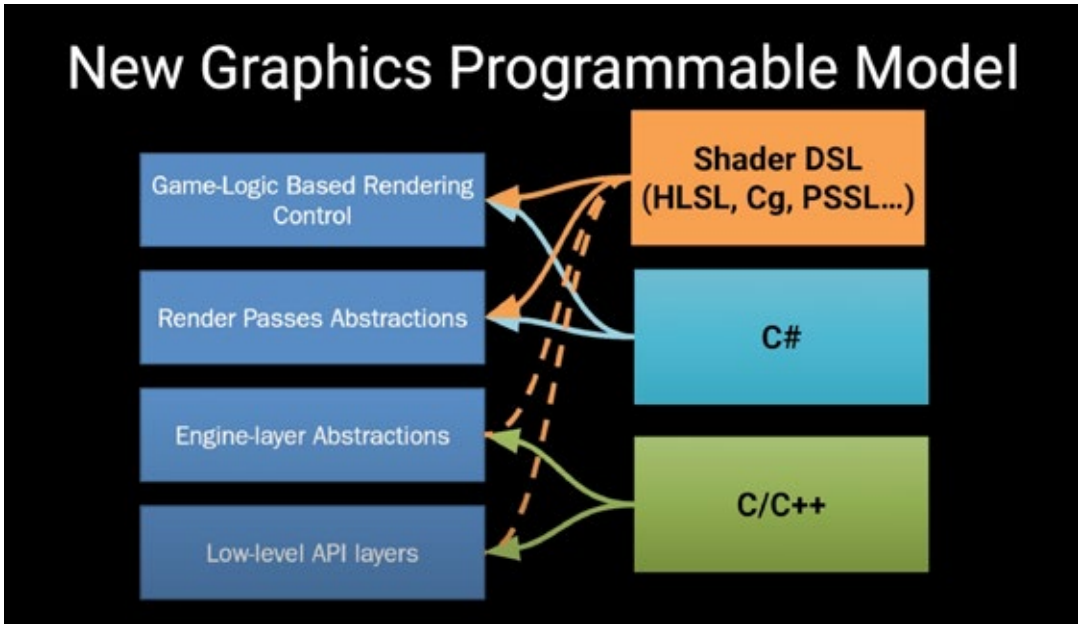
— Intelligent and reliable scaling for the maximum number of hardware platforms, from high- to low-end devices.

— The ability to customize rendering processes using C#, not C++. Using C# means a new executable does not need to be compiled for every change.

— Flexibility to support architecture evolution.

— Flexibility to create sharp graphics that are performant across many platforms.

The image below illustrates how SRPs work. With SRPs, you can use C# to control and customize render passes and rendering control, as well as HLSL shaders that can be created using artist-friendly tools such as Shader Graph. Shaders give you access to even the lower-level API and engine-layer abstractions.



The graphics programmable model for the Scriptable Render Pipelines

An advanced user can create a new SRP from scratch or modify the HDRP or URP. The graphics stack is open source and available for use on GitHub.

Why choose URP

— **Accessible to a wide range of users:** URP is configurable by artists and technical artists alike, providing more flexibility for prototyping and refining rendering techniques for full game production.

— **Extendable and customizable:** URP allows users to modify existing capabilities and extend the pipeline with new ones, making it a solid choice for advanced users, including Asset Store and third-party package creators, experienced studios, and advanced teams.

While the low-level rendering API is written in C++ for performance purposes, a URP developer can write a simple C# script to be called during the render pipeline, enabling high-level customization without sacrificing performance.

— **Multiple rendering options:** URP provides a Universal Renderer that supports Forward, Forward+ and Deferred rendering paths, as well as a 2D Renderer.

These renderers can be extended with additional features and Scriptable Render Passes. The Render Objects feature can be used to render objects from a given Layer Mask at

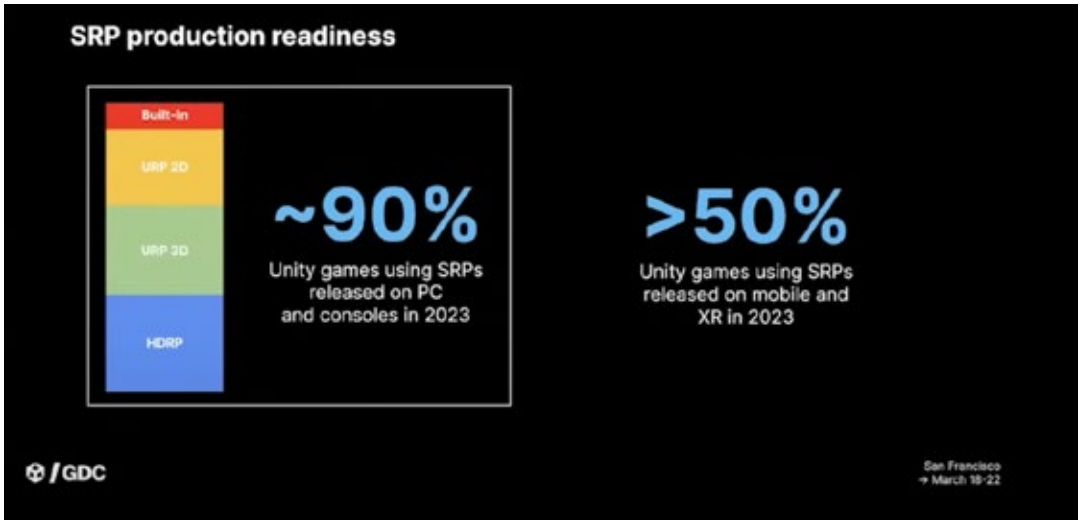
different events in the rendering pipeline. It also allows you to override material and other render states when rendering those objects, making it possible to customize the rendering without code. URP can be extended with custom renderers to suit specific needs.

The render graph system enables you to access and manipulate the various buffers used to render a frame; using the Renderer Features workflow means this can be injected at any stage in the render pipeline.

- **Excellent performance**: URP provides robust performance and provides many tools for you to adapt the balance between fidelity and frame rate on a wide range of devices. In particular:
  - URP evaluates real-time lighting very efficiently. In Forward rendering it evaluates all lighting in a single pass. Forward+ improves upon standard Forward rendering by culling lights spatially rather than per object. This increases the overall number of lights that can be utilized in rendering a frame. In Deferred rendering it supports the Native RenderPass API, allowing G-buffer and lighting passes to be combined into a single render pass.
  - There are CPU and GPU improvements when drawing meshes. The SRP Batcher helps ensure fewer draw calls and improves on how depth is handled, while GPU Resident Drawer and occlusion culling can significantly reduce the draw calls for some scenes.
  - URP makes more efficient use of tile memory on mobile devices, leading to less power consumption, a longer battery life, and therefore, the possibility of longer play sessions.
  - URP comes with an integrated post-processing stack that allows for better performance compared to the Built-In Render Pipeline. Using the Volume framework, you can create post-processing effects that are dependent on the Camera position without writing any code.
- **Compatible with the other key tools:** URP supports artist- and technical artist-friendly tools like Shader Graph, VFX Graph, and the Rendering Debugger.
- **2D rendering:** URP supports advanced 2D lighting, shadows, and post-processing effects, enhancing the visual quality of 2D games without compromising on performance.

Around 90% of Unity games on PC/console are using SRPs

The latest data available to Unity shows that URP is the most popular choice for games using Unity released on PC and console in 2023. The graph below shows that the Built-In Render Pipeline is now only used by a small fraction of development teams.

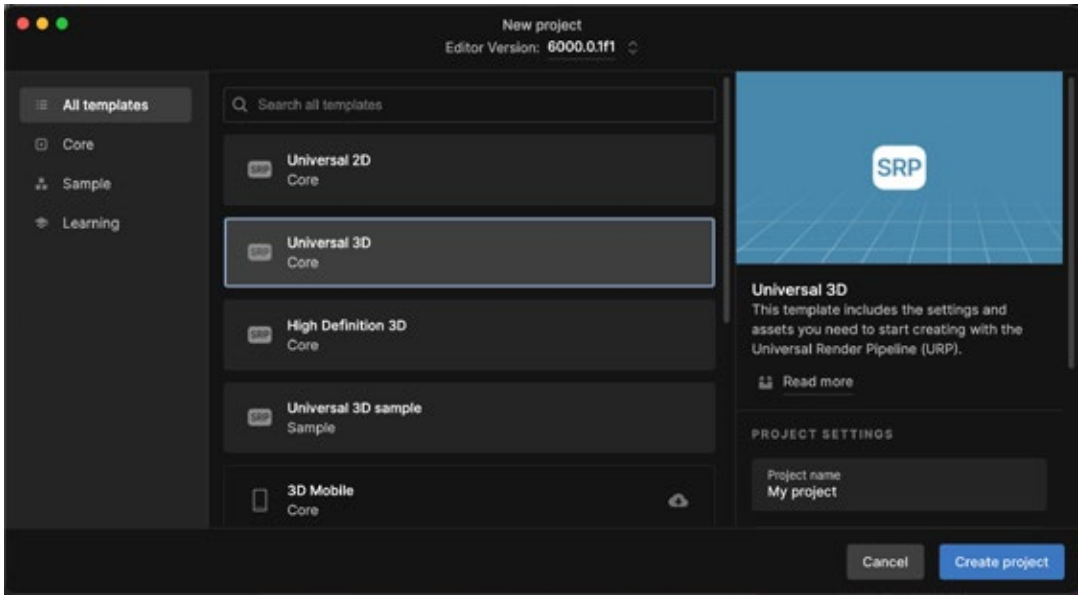


Proportion of games released using the different pipelines available from Unity

However, while most Unity projects are now being built on URP or HDRP, the Built-In Render Pipeline will remain an available option in Unity 6.

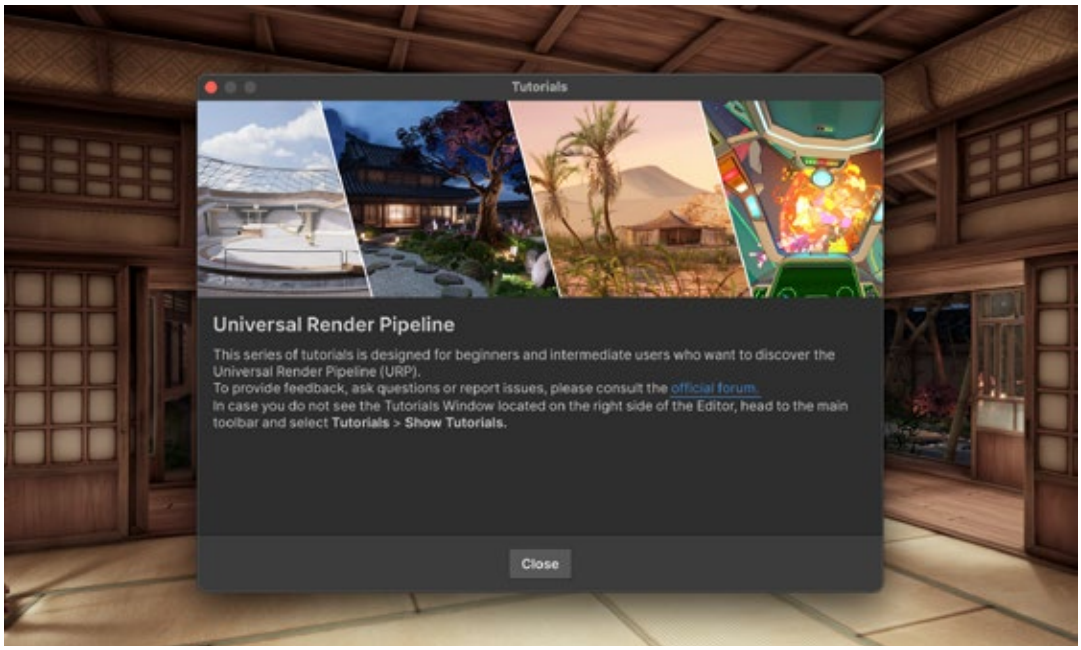
How to open a new URP project

Open a new project using URP via the Unity Hub. Click on **New** and verify that the Unity version selected at the top of the window is Unity 6 or newer. Choose a name and location for the project, select the **Universal 2D** or **Universal 3D** templates then click **Create**.



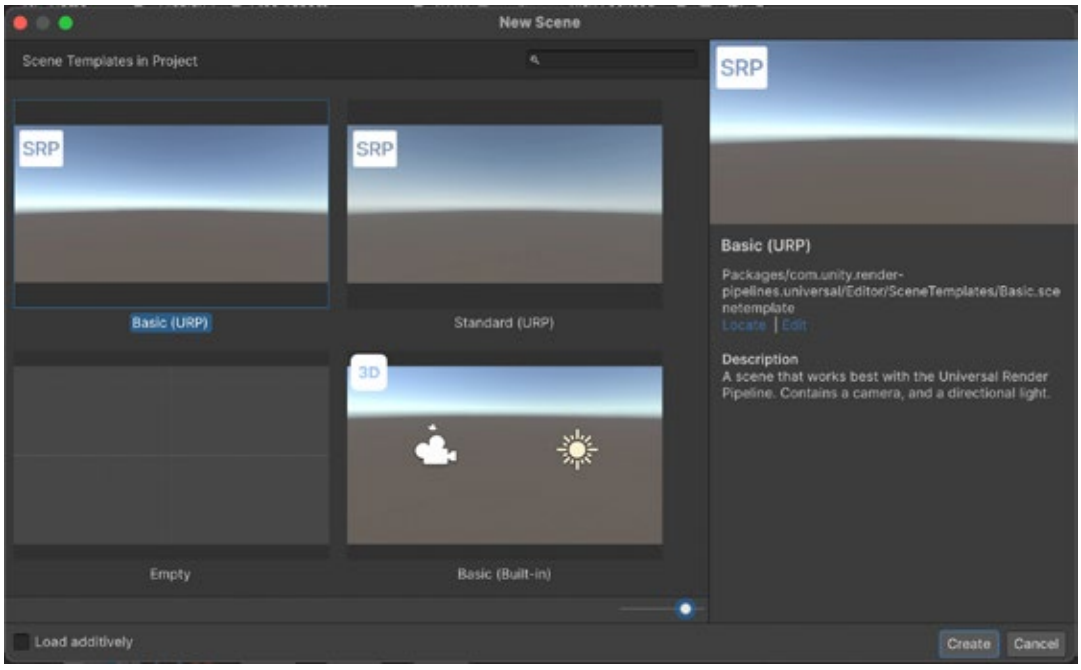
When you create a new project with the URP template, you might have to download the template for the first time.

Note: The template ensures that your project is set to use a linear color space, which is required for calculating lighting correctly.



The URP 3D sample scene, which is covered at the end of this book, is available as a downloadable template.

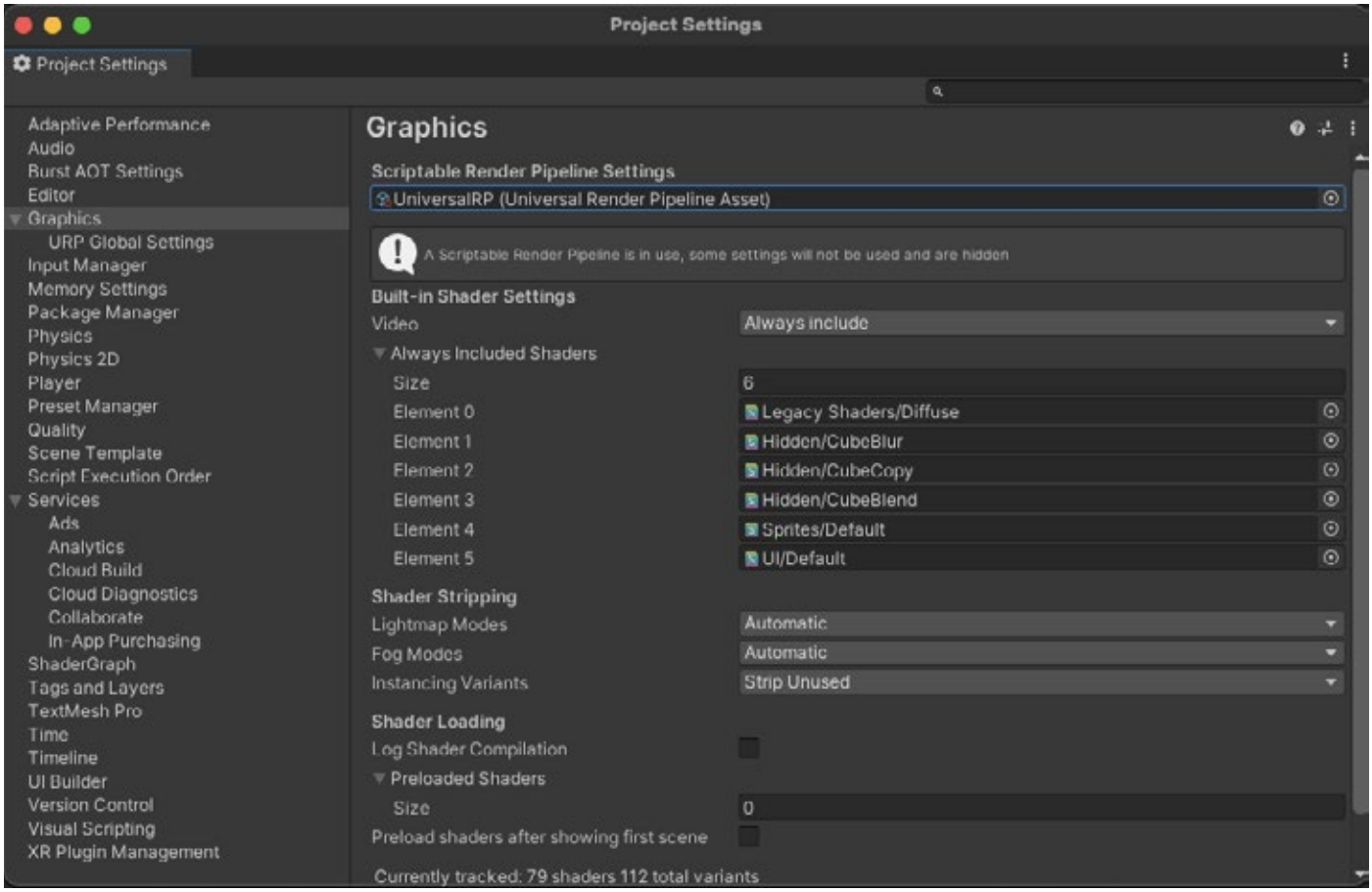
You can create new scenes via **File > New Scene**, with essential GameObjects such as Camera and Directional light, and even create your own scene template with prepopulated objects. Read more in the URP Scene Templates documentation.



The New Scene dialog displaying Scene Templates

Go to **Edit > Project Settings** and open the **Graphics** panel. To use URP in-Editor, you must select a URP Asset from the **Scriptable Render Pipeline Settings**. The URP Asset controls the global rendering and Quality settings of a project and creates the rendering pipeline instance. Meanwhile, the rendering pipeline instance contains intermediate resources and the render pipeline implementation.

PC_RPAsset is the default URP Asset selected on a desktop, but you can switch to **Mobile_RPAsset**.



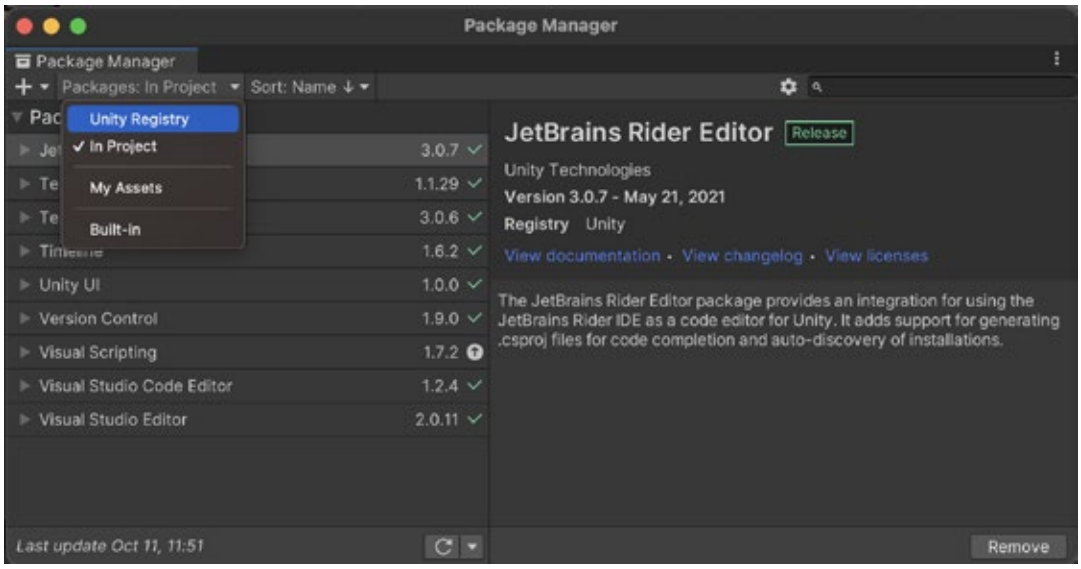
The Graphics panel in Project Settings

A later section of this guide details how to adjust the settings of a URP Asset.

How to add URP to an existing Built-In Render Pipeline project

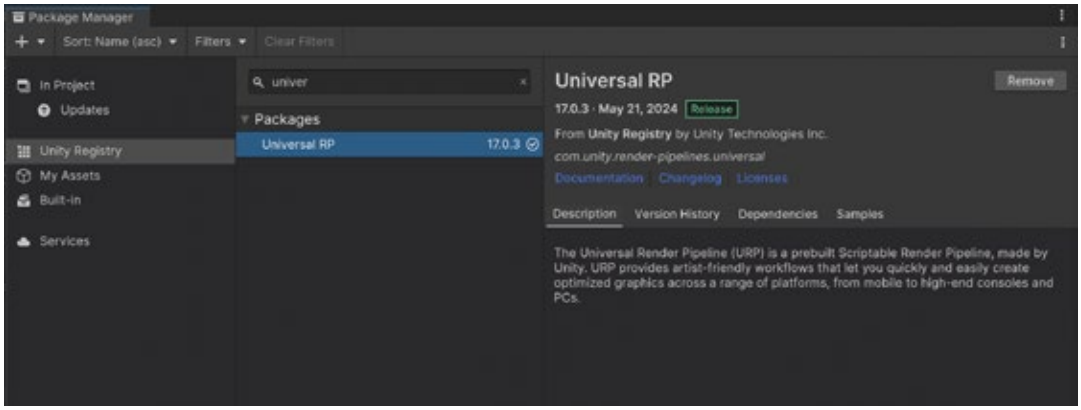
Important: Be sure to backup your project using source control before following the steps in this section. This process will convert assets, and Unity does not provide an undo option. If you use source control, you will be able to revert to previous versions of the assets if necessary.

If you upgrade an existing Built-In Render Pipeline project, you'll need to add the **URP package** to your project as it was not included in Unity before Unity 6.



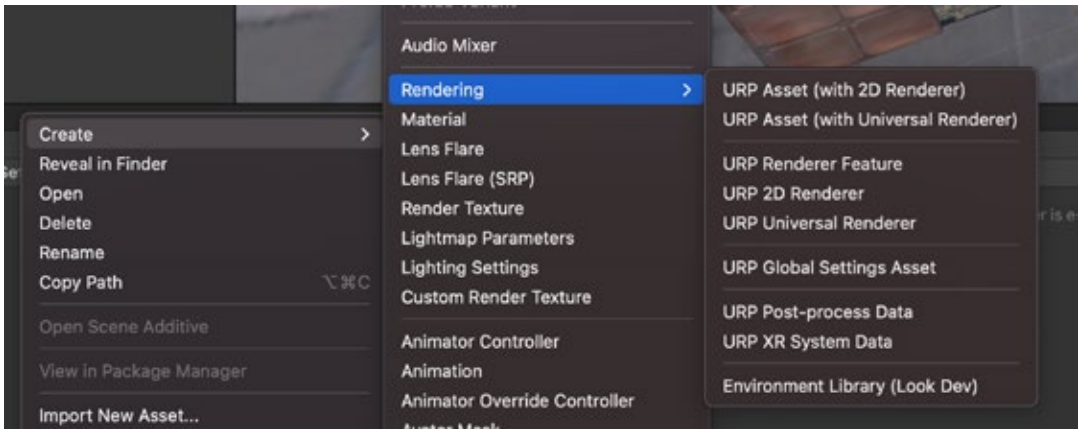
The Package Manager displaying the Unity Registry packages

Go to **Window > Package Manager** and click the **Packages** drop-down to add URP to your project. Make sure to select the **Unity Registry**, followed by **Universal RP**. Click **Download** in the lower-right corner of the window if the URP package is not yet installed on your development computer. Then click **Install** once it's downloaded.



Installing URP via the Package Manager

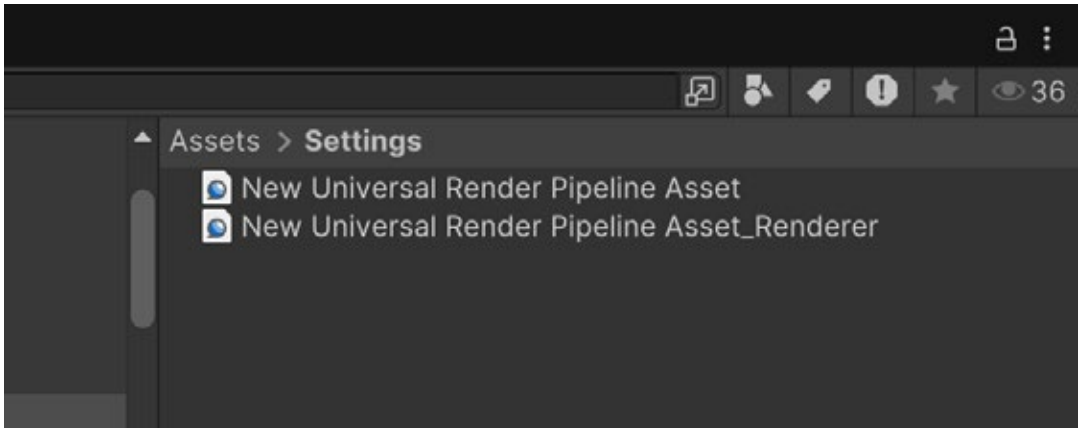
To create a URP Asset, right-click in the **Project** window and choose **Create > Rendering > URP Asset (with Universal Renderer)**. Name the asset.



Creating a URP Asset

Remember: If you create a new project using the Universal Render Pipeline or 3D (URP) templates, these URP Assets are already available in the project.

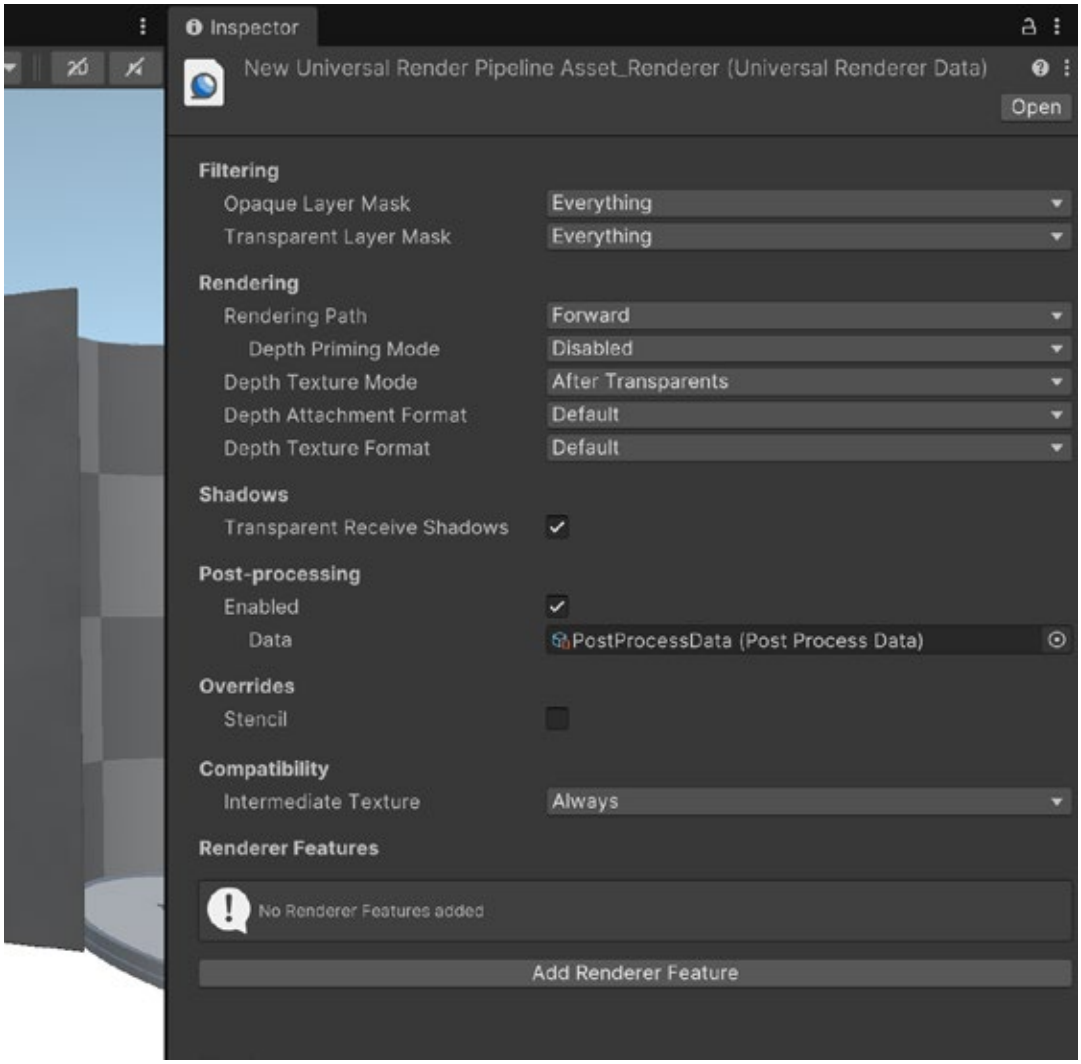
Rather than creating a single URP Asset, URP uses two files, each with an Asset extension.



Two assets in URP, one for URP settings and the other for Renderer Data

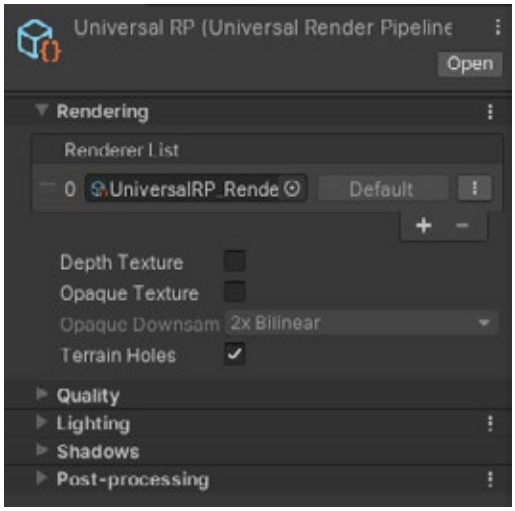
One is called **UniversalRP_Renderer**, a **Renderer Data Asset** that you can use to filter the layers the renderer works on, and intercept the rendering pipeline to customize how the scene is rendered. This way, you can facilitate the creation of high-quality effects. See the section on Pipeline callbacks for more information.

Additionally, the UniversalRP_Renderer controls high-level rendering logic and passes for URP. It supports Forward and Deferred paths, and a 2D Renderer that enables features such as 2D Lights, 2D Shadows, and Light Blend Styles. You can even extend URP to create your own renderers.



The Inspector for UniversalRP_Renderer Data Asset

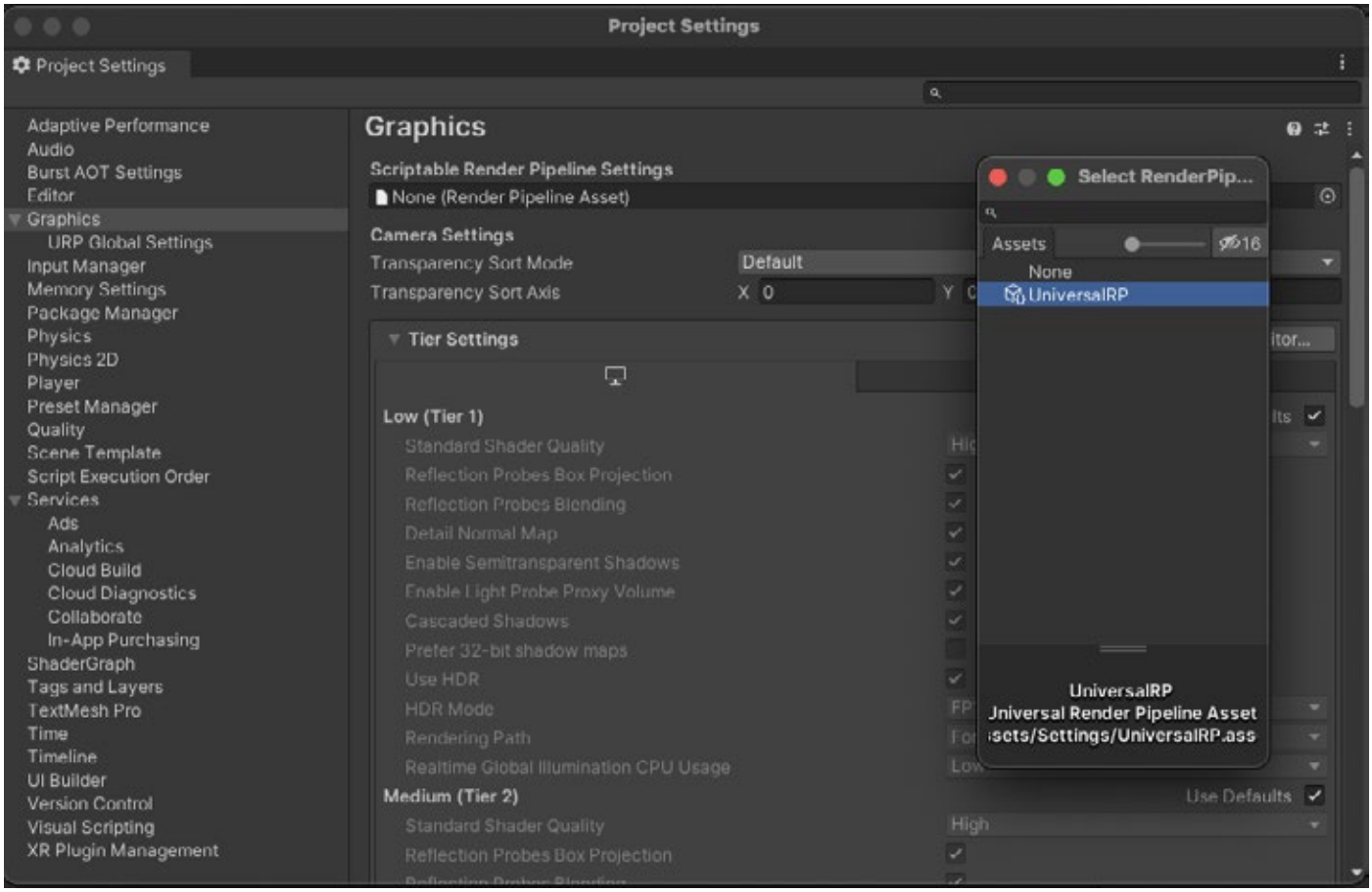
The other URP Asset provides options for controlling the Quality, Lighting, Shadows and Post-processing settings.. You can use different URP Assets to control the Quality settings, a process outlined further down in this section. This Settings Asset is linked to the Renderer Data Asset via the Renderer List. When you create a new URP Asset, the Settings Asset will have a Renderer List containing a single item – the Renderer Data Asset created at the same time, set as the default. You can add alternative Renderer Data Assets to this list.



A URP Asset in the Inspector

The default renderer is used for all Cameras, including the Scene view. A Camera can override the default renderer by selecting another one from the Renderer List. This can be done through the use of a script, as needed.

Despite following these steps to create a URP Asset, an open scene in the Scene or Game view will still use the Built-In Render Pipeline. You must complete one last step to make the switch to URP: Go to **Edit > Project Settings** and open the **Graphics** panel. Click the small dot next to **None (Render Pipeline Asset)**. In the open panel, select **UniversalRP**.



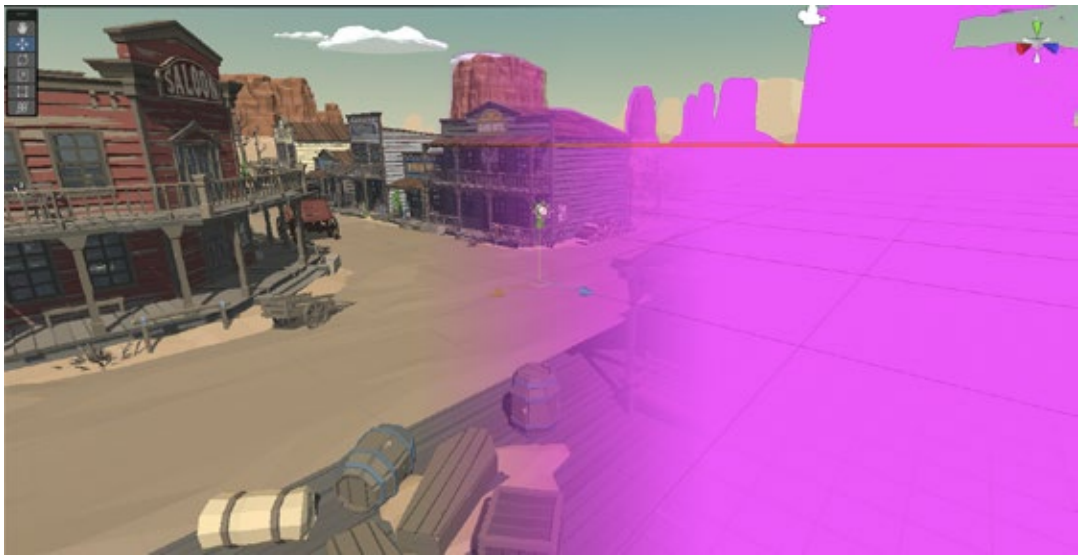
Selecting a Scriptable Render Pipeline Asset

A warning message will pop up regarding the switch, but just press **Continue**.

As there is no content in your project yet, changing the render pipeline will be almost instantaneous. You're now ready to use URP.

Converting the scenes of an existing project

After you complete the above steps, you'll find that your beautiful scenes are suddenly colored magenta. This is because the shaders used by the materials in a Built-In Render Pipeline project are not supported in URP. Fortunately, there is a method for restoring your scenes to their original quality.



Materials in a scene appear in magenta because their Built-In Render Pipeline-based shaders must be converted for use in URP.

Go to **Window > Rendering > Render Pipeline Converter**. Choose **Convert Built-In to 2D (URP)** for a 2D project, or **Built-In to URP** for a 3D project. Assuming that your project is 3D, you'll need to select the appropriate converters:

— **Rendering Settings:** Select this to create multiple Render Pipeline setting assets that will match Built-In Render Pipeline Quality settings as closely as possible. This lets you test different Quality Levels more efficiently. See the section on comparing Built-In Render Pipeline and URP Quality options for more details.

— **Material Upgrade**: Use this to convert materials from the Built-In Render Pipeline to URP.

— **Animation Clip Converter:** This converts animation clips. It runs once the Material Upgrade converter finishes.

— **Read-only Material Converter:** This converts the prebuilt, read-only Materials included in a Unity project. It indexes the project and creates the temporary .index file. Note that it can take significant time.

Converting custom shaders

Custom shaders are not converted using the Material Upgrade converter. The Shaders and Shader Graph sections outline the steps for converting custom Built-In Render Pipeline shaders to URP. Using Shader Graph is often the quickest way to update a custom shader to URP.

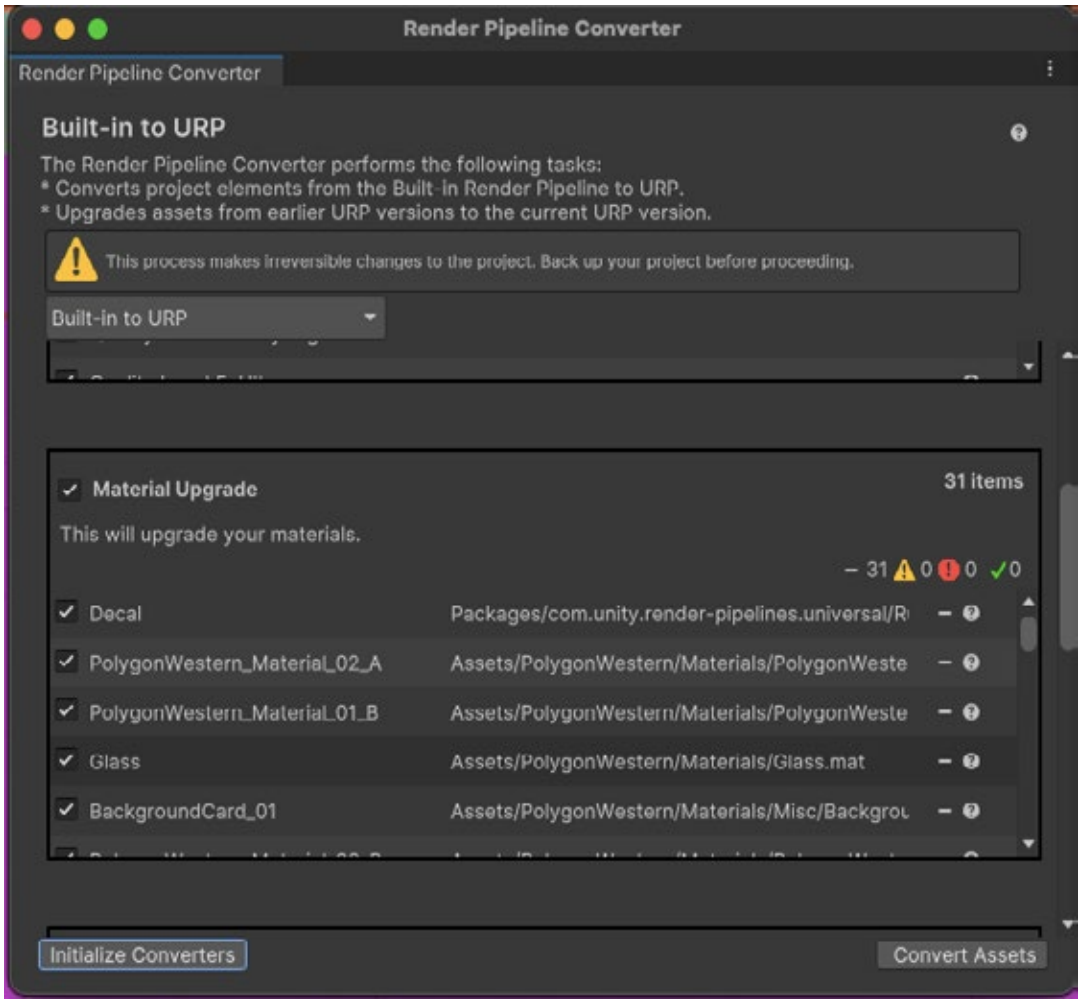
There are several different URP shaders including:

- **Universal Render Pipeline/Lit**: This physically based render (PBR) shader, similar to the Built-In Standard Shader, can be used to represent most real-life materials. It supports all the Standard Shader features with both metallic and specular workflows.
- **Universal Render Pipeline/Simple Lit**: This uses a Blinn-Phong model, and is suitable for low-end mobile devices or games that don't use PBR workflows.
- **Universal Render Pipeline/Baked Lit**: Use this shader for stylised games or apps that only require baked lighting via lightmaps, light probes and Adaptive Probe Volumes (APVs). This shader is not Physically Based and has no real-time lighting, so all real-time relevant shader keywords and variants are stripped from the shader code, making it faster to calculate.
- **Universal Render Pipeline/Complex Lit**: The Complex Lit shader contains all the functionality of the Lit shader and adds advanced material features. Some features in this shader might be more resource-intensive and require Unity Shader Model 4.5 hardware.
- **Universal Render Pipeline/Unlit**: This is a GPU performant shader that doesn't use lighting equations.
- **Universal Render Pipeline/Terrain/Lit:** This is suitable to use with the Terrain Tools package.
- **Universal Render Pipeline/Particles/Lit:** This particle shader uses a PBR lighting model.
- **Universal Render Pipeline/Particles/Unlit:** This unlit particle shader is light on the GPU.

Although Simple Lit replaces many legacy/mobile shaders, the performance is not the same. Legacy/mobile shaders only partially evaluate lighting, whereas Simple Lit considers all lights as defined by the URP Asset.

Refer to this table in our URP documentation to see how each URP shader maps to its Built-In Render Pipeline equivalent.

Once you select one or more of the above converters, either click **Initialize Converters** or **Initialize And Convert**. Whichever option you choose, the project will be scanned and those assets that need converting will be added to each of the converter panels. If you choose **Initialize Converters** you can limit the conversions by deselecting the items using the checkbox provided for each one. At this stage, click **Convert Assets** to start the conversion process. If you choose **Initialize And Convert**, the conversion starts automatically after the converters are initialized. Once it's complete you might be asked to reopen the scene that is active in the Editor.



The Render Pipeline Converter

Comparing Quality options between the Built-In Render Pipeline and URP

There are several default Quality options available in the Built-In Render Pipeline, from Very low to Ultra. The Quality settings impact the fidelity of the scene, including Texture resolution, lighting, shadow rendering, and so on.

Go to **Edit > Project Settings** and select the **Quality** panel. Here, you can switch between these Quality options by picking the current quality. This will change the render settings used by the Scene and Game views. You can also edit each of the Quality options from this panel.

If you select the **Rendering Settings** option while using the Render Pipeline Converter and switching from the Built-In Render Pipeline to URP, a set of URP Assets that attempt to match the Built-In Render Pipeline Quality options will be created. The first table below shows how the Built-In Render Pipeline maps to URP for Low settings, while the second table displays a comparison for High settings. In both the Built-In Render Pipeline and URP, settings are chosen via the Quality panel. The URP Asset settings are available via the Inspector when selecting a URP Asset. Refer to the URP documentation for more details.

Built-In Render Pipeline to URP: Low settings

Setting	Built-in Render Pipeline	URP	URP Asset settings
Rendering			
Pixel Light Count	0	Not applicable (NA) *	NA
Anti-aliasing	Disabled	NA	Disabled
Render Scale	NA	NA	1
Real-time Reflection Probes	No	No	NA
Resolution Scaling Fixed DPI Factor	1	1	NA
VSync Count	Don’t sync	Don’t sync	NA
Depth Texture	NA	NA	No
Opaque Texture	NA	NA	No
Opaque Downsampling	NA	NA	NA
Terrain Holes	NA	NA	Yes
HDR	NA	NA	Yes
Textures			
Texture Quality	Half res	Half res	NA
Anisotropic Textures	Disabled	Disabled	NA
Texture Streaming	No	No	NA
Particles			
Soft Particles	No	NA	NA
Particle Raycast Budget	16	16	NA
Terrain			
Billboards Face Camera Position	No	No	NA

Shadows			
Shadowmask Mode	Shadowmask	Shadowmask	NA
Shadows	Disabled	NA	NA
Shadow Resolution	Low resolution	NA	NA
Shadow Projection	Stable fit	NA	NA
Shadow Distance	20	NA	NA
Shadow Near Plane Offset	3	NA	NA
Shadow Cascades	No Cascades	NA	NA
Cascade splits	NA	NA	NA
Working unit	NA	NA	NA
Depth Bias	NA	NA	NA
Normal Bias	NA	NA	NA
Soft Shadows	NA	NA	NA
Async Asset Upload			
Time Slice	2	2	NA
Buffer Size	16	16	NA
Persistent Buffer	Yes	Yes	NA
Level of Detail			
LOD Bias	0.4	0.4	NA
Maximum LOD level	0	0	NA
Meshes			
Skin Weights	4 bones	4 bones	NA
Lighting			
Main Light:	NA	NA	Per pixel
Cast Shadows	NA	NA	No
Shadow Resolution	NA	NA	NA
Additional Lights:	NA	NA	Disabled
Per Object Limit	NA	NA	NA
Cast Shadows	NA	NA	NA
Shadow Atlas Resolution	NA	NA	NA
Shadow Resolutiontiers	NA	NA	NA
Cookie AtlasResolution	NA	NA	NA
Cookie AtlasFormat	NA	NA	NA
Reflection probes:	NA	NA	NA

Probe Blending	NA	NA	No
Box Projection	NA	NA	No
Post-processing			
Grading Mode	NA	NA	Low Dynamic Range
	NA	NA	16
Fast sRGB/Linear conversion	NA	NA	No

* In URP, Pixel Light Count is handled using **Additional Lights > (Per pixel) > Per Object Limit**.

Built-In Render Pipeline to URP: High settings

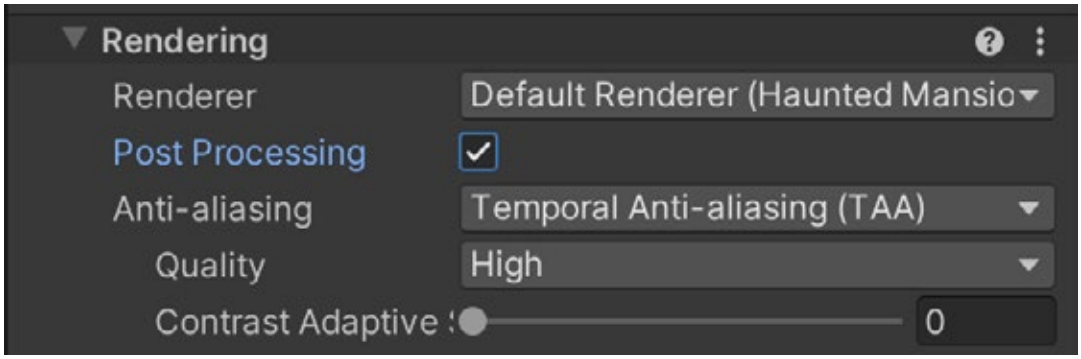
Setting	Built-In Render Pipeline	URP	URP Asset settings
Rendering			
Pixel Light Count	2	Not applicable (NA)	NA
Anti-aliasing	Disabled	NA	2x
Render Scale	NA	NA	1
Real-time Reflection Probes	Yes	Yes	NA
Resolution Scaling Fixed DPI Factor	1	1	NA
VSync Count	Every V Blank	Every V Blank	NA
Depth Texture	NA	NA	No
Opaque Texture	NA	NA	No
Opaque Downsampling	NA	NA	NA
Terrain Holes	NA	NA	Yes
HDR	NA	NA	Yes
Textures			
Texture Quality	Full res	Full res	NA
Anisotropic Textures	Disabled	Disabled	NA
Texture Streaming	No	No	NA
Particles			
Soft Particles	No	NA	NA
Particle Raycast Budget	256	256	NA

Terrain			
Billboards Face Camera Position	Yes	Yes	NA
Shadows			
Shadowmask Mode	Distance Shadowmask	Distance Shadowmask	NA
Shadows	Hard and Soft Shadows	NA	NA
Shadow Resolution	Medium resolution	NA	2048
Shadow Projection	Stable fit	NA	NA
Shadow Distance	40	NA	50
Shadow Near Plane Offset	3	NA	NA
Shadow Cascades	2 Cascades	NA	2
Cascade splits	33/67	NA	12.5/33.8/3.8
Working unit	Percent	Percent	Metric
Depth Bias	NA	NA	1
Normal Bias	NA	NA	1
Soft Shadows	NA	NA	Yes
Async Asset Upload			
Time Slice	2	2	NA
Buffer Size	16	16	NA
Persistent Buffer	Yes	Yes	NA
Level of Detail			
LOD Bias	1	1	NA
Maximum LOD level	0	0	NA
Meshes			
Skin Weights	Unlimited	Unlimited	NA
Lighting			
Main Light:	NA	NA	Per pixel
Cast Shadows	NA	NA	Yes
Shadow Resolution	NA	NA	NA
Additional Lights:	NA	NA	Per pixel
Per Object Limit	NA	NA	4
Cast Shadows	NA	NA	Yes
Shadow Atlas Resolution	NA	NA	2048
Shadow Resolution tiers	NA	NA	512/1024/2048
Cookie AtlasResolution	NA	NA	2048

Cookie AtlasFormat	NA	NA	Color high
Reflection probes:	NA	NA	NA
Probe Blending	NA	NA	Yes
Box Projection	NA	NA	No
Post-processing			
Grading Mode	NA	NA	Low Dynamic Range
LUT size	NA	NA	32
Fast sRGB/Linear conversion	NA	NA	No

Anti-aliasing

In URP in Unity 6 you can select Temporal Anti-aliasing (TAA) as an anti-aliasing option for the Camera, via **Camera > Rendering > Anti-aliasing**.



TAA selected

URP in Unity 6 improves the overall quality of TAA without impacting performance. It provides better edge anti-aliasing (removing odd edge artifacts seen with the previous implementation) and better retention of texture quality. The output quality is now comparable to the low and medium SMAA presets but with better performance.

How to work with Quality settings

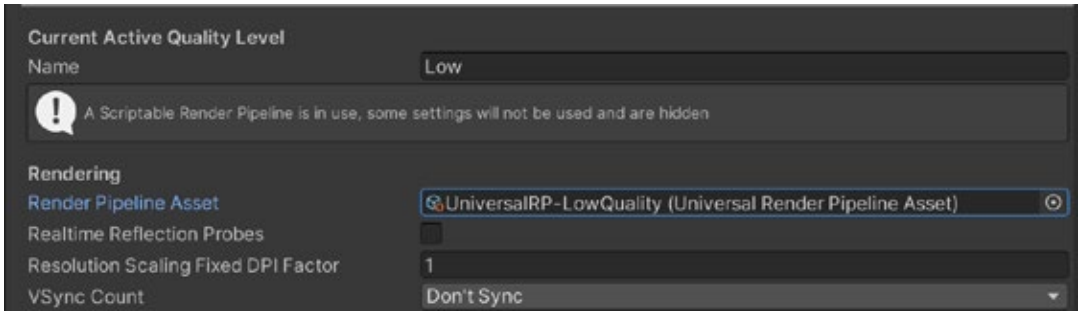
When using URP, quality settings are divided between the Quality panel and those for each URP Asset. The following table shows where each setting can be found.

Quality settings when using URP

Setting	Quality panel	URP Asset
Rendering		
Anti-aliasing		✓
Render Scale		✓
Resolution Scaling Fixed DPI Factor	✓	
VSync Count	✓	
Depth Texture		✓
Opaque Texture		✓
Opaque Downsampling		✓
Terrain Holes		✓
HDR		✓
Textures		
Texture Quality	✓	
Anisotropic Textures	✓	
Texture Streaming	✓	
Particles		
Particle Raycast Budget	✓	
Terrain		
Billboards Face Camera Position	✓	
Shadows		
Shadowmask Mode	✓	
Shadow Resolution		✓
Shadow Distance		✓
Shadow Cascades		✓
Cascade splits		✓
Working unit		✓
Depth Bias		✓
Normal Bias		✓
Soft Shadows		✓

Async Asset Upload		
Time Slice	✓	
Buffer Size	✓	
Persistent Buffer	✓	
Level of Detail		
LOD Bias	✓	
Maximum LOD level	✓	
Meshes		
Skin Weights	✓	
Lighting		
Main Light:		✓
— Cast Shadows		✓
— Shadow Resolution		✓
Additional Lights:		✓
— Per Object Limit		✓
— Cast Shadows		✓
— Shadow Atlas Resolution		✓
— Shadow Resolutiontiers		✓
— Cookie AtlasResolution		✓
— Cookie AtlasFormat		✓
Reflection probes:	✓	
— Probe Blending		✓
— Box Projection		✓
Post-processing		
Grading Mode		✓
LUT size		✓
Fast sRGB/Linear conversion		✓

If you switch between Quality options, choose a **Quality Level** for the Render Pipeline Asset in the **Quality** panel via **Project Settings**. Note that if the Quality Level is not set, the Render Pipeline Asset will default to the one set as the Scriptable Render Pipeline Asset in the Graphics panel. This can cause some confusion as you attempt to adjust the Quality settings of a URP Asset. For instance, you might accidentally assume that the Quality Level set in the URP Asset is the one currently used by the Scene and Game views.



Setting the Quality Level for the Render Pipeline Asset

Modifying a URP Asset

This image shows a URP Asset in the Inspector with all its available settings. See the URP documentation to learn more about each setting.

Note: If you have the URP 2D Renderer enabled, some of the options related to 3D rendering in the URP Asset will not impact your final app or game. The 2D Renderer Asset is available under **Scriptable Render Pipeline Settings** via **Edit > Project Settings > Graphics**.

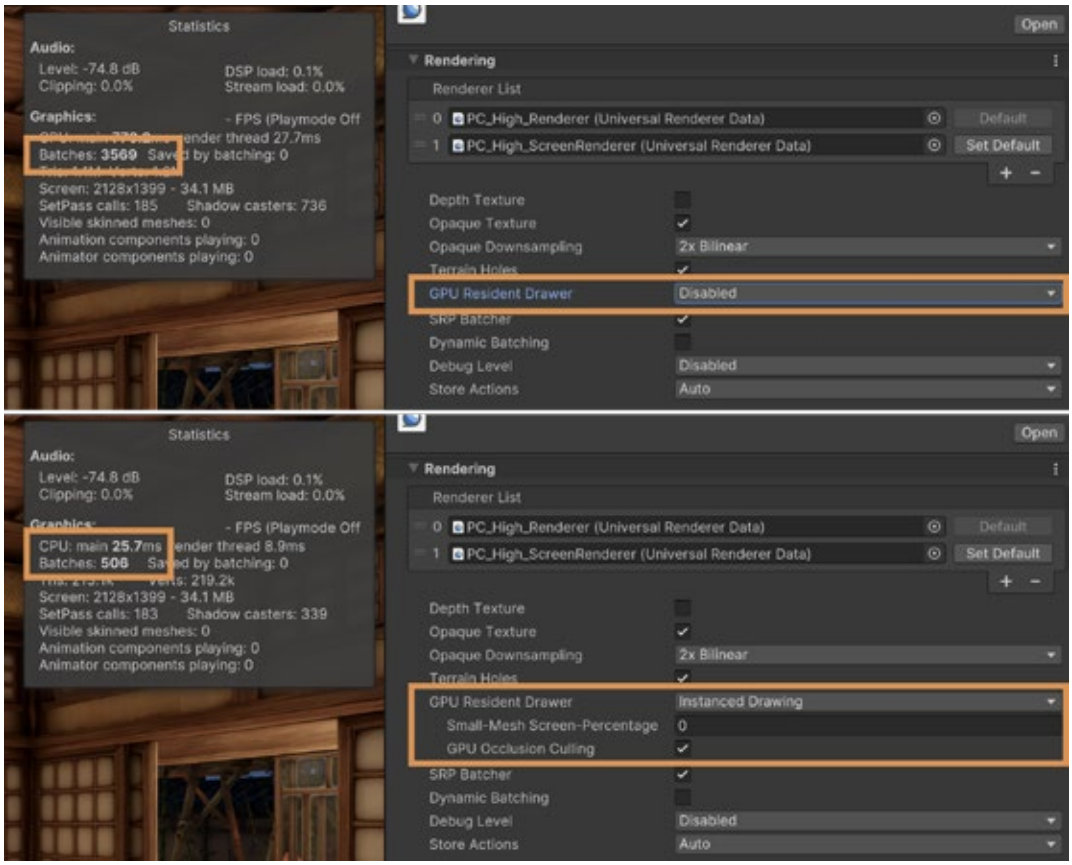
A URP Asset in the Inspector

The Quality panel for a URP Asset allows you to set the HDR format to 64-bit for better fidelity. However, be aware that this results in a performance hit and requires additional memory, so avoid this setting on low-end hardware.

Another feature of the Quality panel is the option to enable LOD Cross Fade. LOD is a technique to reduce the GPU cost needed to render distant meshes. As the Camera moves, different LODs will be swapped to provide the right level of quality. LOD Cross Fade allows for smoother transitions of different LOD geometries and avoids the harsh snapping and popping that occurs during a swap.

GPU Resident Drawer and GPU occlusion culling

GPU Resident Drawer is a new feature in Unity 6 that's available via the **Rendering** section of the URP Asset.



The GPU Resident Drawer and GPU Occlusion Culling options available via the URP Asset in Unity 6

Notice from the screengrabs above that the batches necessary to render the garden environment from the URP 3D Sample scene in Editor mode is 3569. When GPU Resident Drawer is set to **Instanced Drawing** this drops to just 506.

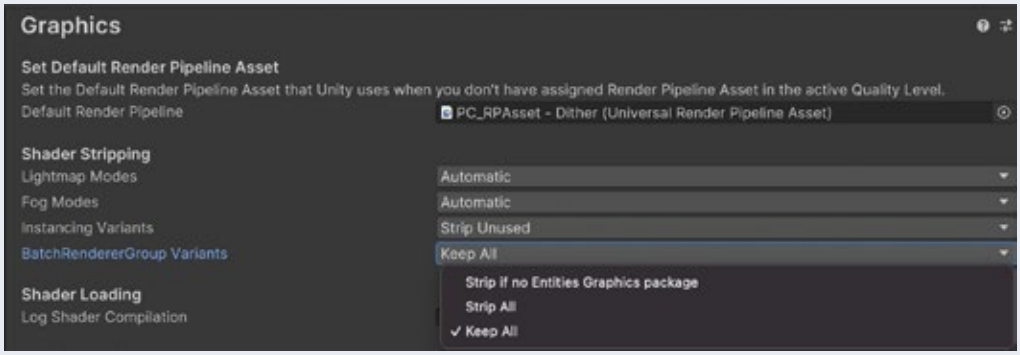
The GPU Resident Drawer is a GPU-driven rendering system that's designed to optimize CPU time. It enables GameObjects to take advantage of the BatchRenderGroup API, so they can benefit from its faster batching and improved CPU performance.

With GPU Resident Drawer, you can author your game using GameObjects, and when processed, they will be ingested and rendered via a special fast path that handles better instancing. When you enable this feature, games that are CPU-bound due to a high number of draw calls will see a reduction in this bottleneck as the amount of draw calls is reduced.

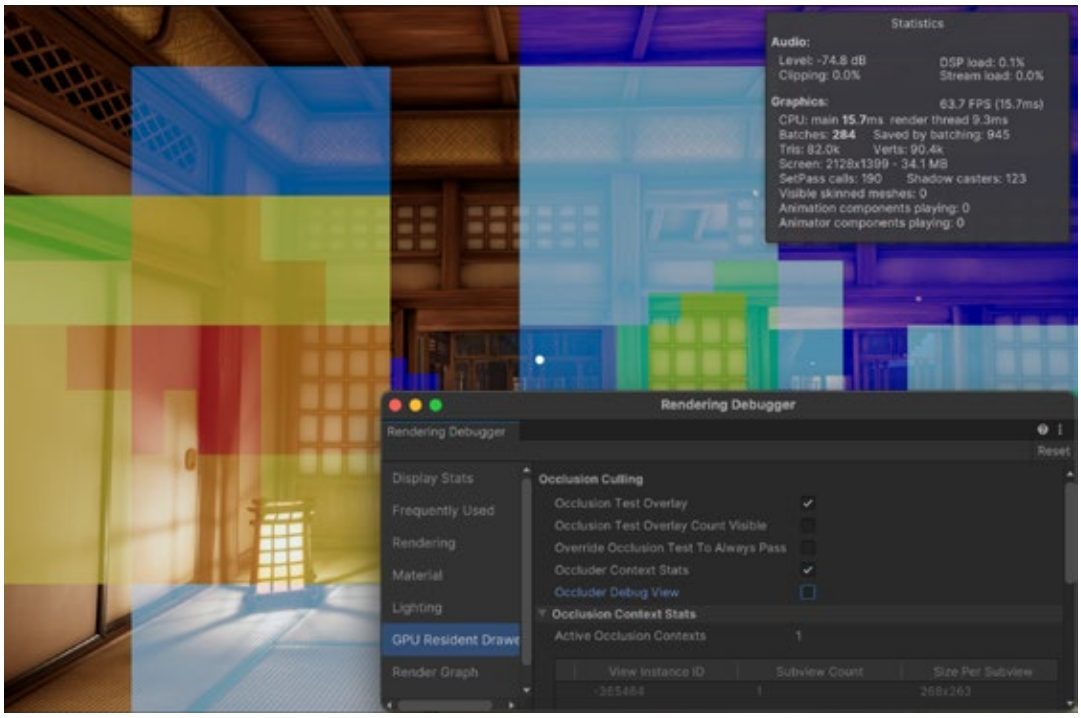
The improvements you will see are dependent on the scale of your scenes and the amount of instancing you utilize. The more instanceable objects you render, the bigger the benefits gain.

GPU Resident Drawer is targeted for MeshRenderers. It will not handle Skinned Mesh Renderers, VFX Graphs, particle systems, or similar effects renderers. No changes to your existing content are required to take advantage of it.

Note: GPU Resident Drawer requires the Forward+ renderer, and **Project Settings > Graphics > BatchRendererGroup Variants** needs to be set to **Keep All**.



When you enable GPU Resident Drawer, GPU occlusion culling also becomes available as an option. This uses a GPU-driven approach to ensure you don't render things you can't see on the screen; depending on your content, it can reduce CPU work dramatically.



Viewing the Occlusion Test using the Rendering Debugger

To see if GPU occlusion culling is effective for your scene go to **Window > Analysis > Rendering Debugger**, and select **GPU Resident Drawer > Occlusion Test Overlay**. This displays a heatmap of culled instances. The heatmap displays blue if there are few culled instances, through to red if there are many culled instances. If you enable this setting, culling might be slower.

Lighting in URP

This section shows how lighting in URP in Unity 6 works, including covering techniques you can use to achieve balance between graphic fidelity and performance.

Start with these resources if you are new to lighting in Unity:

- Lighting documentation
- The art of lighting game environments
- Real-time lighting in Unity
- Harnessing light with the URP and the GPU Lightmapper

Choose your renderer

URP offers different rendering techniques, each with its own strengths and weaknesses. The choice of rendering technique depends on the specific requirements and constraints of your project. Let's delve into the differences between Forward, Forward+, and Deferred rendering in (URP).

Forward rendering

How it works	Pros	Cons
Forward rendering is a traditional rendering technique where each object in the scene is rendered individually and each pixel computed separately. This means that for every pixel on the screen, Unity calculates the lighting and shading for each object in the scene that contributes to that pixel's final color.	The workflow is relatively straight-forward to understand. It works well in scenes with a small number of lights and simple materials.	It can be inefficient for rendering scenes with a large number of lights or complex materials. This is because it requires multiple passes over the scene for each light, leading to increased rendering overhead.

Forward+ rendering

How it works	Pros	Cons
Forward+ rendering is an enhancement that addresses some of the limitations of Forward rendering, particularly when dealing with a large number of lights. In Forward+ rendering, lights are grouped into clusters, and only objects within each cluster are considered when calculating lighting, rather than processing every object in the scene for each light.	It improves performance compared to Forward rendering, especially in scenes with many lights. It allows for more efficient utilization of hardware resources by reducing the number of objects that need to be considered for each light.	It can still struggle with extremely large numbers of lights or very complex scenes. Additionally, implementing Forward+ rendering may require more effort and optimization compared to Forward rendering.

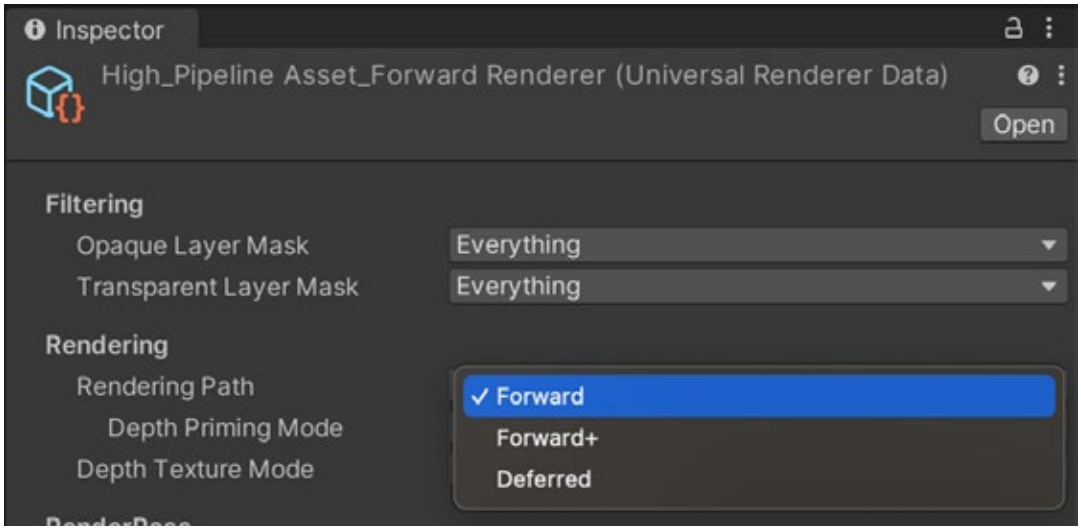
URP Deferred rendering

How it works	Pros	Cons
Deferred rendering decouples the lighting and shading calculations from the geometry rendering process. Geometry is first rendered to a set of buffers (e.g., G-buffer) that store information about each pixel's position, normals, and material properties. Then, lighting calculations are performed per-pixel based on the information stored in these buffers.	It's highly efficient for scenes with a large number of lights or complex materials because lighting calculations are performed per-pixel rather than per-object. This allows for a large number of lights to be rendered with minimal performance impact.	Deferred rendering has its own set of challenges, including increased memory usage due to the need to store additional buffers, limitations with transparent objects, and difficulty in handling certain types of lighting effects such as volumetric lighting.

The table below provides more detail about these three rendering options:

Feature	Forward	Forward+	Deferred
Maximum number of real-time lights per object	9	Unlimited; per-Camera limit applies	Unlimited
Per pixel normal encoding	No encoding (accurate normal values)	No encoding (accurate normal values)	Two options: — Quantization of normals in G-buffer (loss of accuracy, better performance) — Octahedron encoding (accurate normals, might have significant performance impact on mobile GPUs) For more information, see Encoding of normals in G-buffer.
MSAA	Yes	Yes	No
GPU Resident Drawer	No	Yes	No
Vertex lighting	Yes	No	No
Camera stacking	Yes	Yes	Supported with a limitation: Unity renders only the base Camera using the Deferred path; Unity renders all overlay Cameras using the Forward Rendering path

Use the Universal Renderer Data Asset to switch between the rendering paths.



Choosing a rendering path.

When using Forward+, a number of URP Asset Lighting settings are overridden:

— **Main light**: The value of this property is **Per Pixel**, regardless of the value you select.

— **Additional lights**: The value of this property is **Per Pixel**, regardless of the value you select.

— **Additional Lights > Per Object Limit**: Unity ignores this property.

— **Reflection Probes > Probe Blending**: Reflection probe blending is always on.

Light settings

You set light properties in the three places listed here:

1. **Window > Rendering > Lighting:** This panel allows you to set lightmapping and environment settings, and view real-time and baked lightmaps. It is unchanged from the Built-In Render Pipeline to URP.
2. **Light Inspector:** There are significant differences between the Built-In Render Pipeline and URP Inspectors. See the Light Inspector section for details.
3. **URP Asset Inspector:** This is the principal place where you will set shadows. Lighting in URP relies heavily on the settings chosen in this panel.

Quality settings are handled via **Edit > Project Settings > Quality** in the Built-In Render Pipeline. In URP, this depends on the URP Asset settings which can be swapped using the

Quality panel (see the Quality settings section).

As the focus here is on lighting, the methods apply to materials that use the shaders in the following table.

URP shaders for lit scenes

Shader	Description
Complex Lit	This shader has all the features of the Lit Shader. Select it when using the Clear Coat option to give a metallic sheen to a car, for example. The specular reflection is calculated twice – once for the base layer, and again to simulate a transparent thin layer on top of the base layer.
Lit	The Lit Shader lets you render real-world surfaces, such as stone, wood, glass, plastic, and metals with photorealistic quality. The light levels and reflections look lifelike and react across various lighting conditions, from bright sunlight to a dark cave. This is the default choice for most materials that use lighting. It supports baked, mixed, and real-time lighting, and works with Forward or Deferred rendering. It is a physically based shading (PBS) model. Due to the complexity of the shading calculations, it's best to avoid using this shader on low-end mobile hardware.
Simple Lit	This shader is not physically based. It uses a non-energy conserving Blinn-Phong shading model and gives a less photorealistic result. Nonetheless, it can provide an excellent visual appearance. It is more suited to use on non-physically based projects when targeting low-end mobile devices.
Baked Lit	This shader provides a performance boost for objects that don't need to support real-time lighting, including distant static objects that will never be affected by dynamic objects, real-time lights, or dynamic shadows.

Lit or Simple Lit?

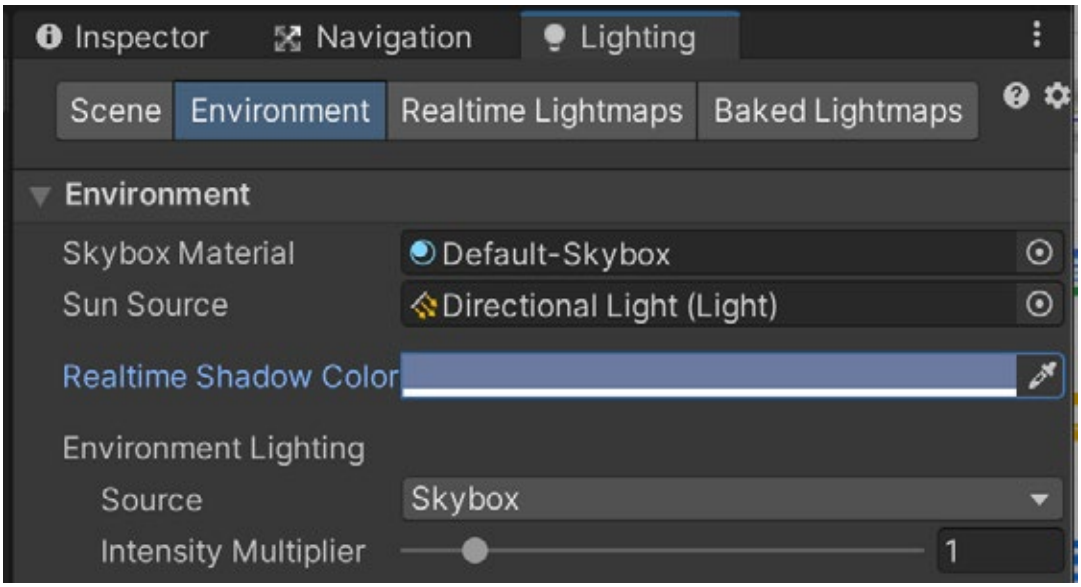
The choice between a Lit Shader and Simple Lit Shader is largely an artistic decision. It is easier for artists to get a realistic render using the Lit Shader, but if a more stylized render is desired, Simple Lit provides stellar results.

Comparing scenes rendered using different shaders: The top-left image uses the Lit Shader, the top-right, the Simple Lit Shader, and the bottom image, the Baked Lit Shader.

It's possible to implement your own custom lighting model by writing a custom shader or using Shader Graph (see the Additional tools chapter).

Lighting overview

Lights are divided into Main Light and Additional Lights in URP. The settings for the Main Light property affect the Directional Light. This is either the brightest light or the one set via **Window > Rendering > Lighting > Environment > Sun Source**.



Setting the Sun Source

Later in the guide, you'll learn how to use the URP Asset settings to set the number of dynamic lights that affect an object via the Object Per Light limit, which is capped at eight for the URP Forward Renderer, but Unlimited for Forward+ and Deferred. The number of dynamic lights that can be used per Camera is also limited by different hardware:

— **Desktop and console platforms**: 1 main light, and 256 additional lights

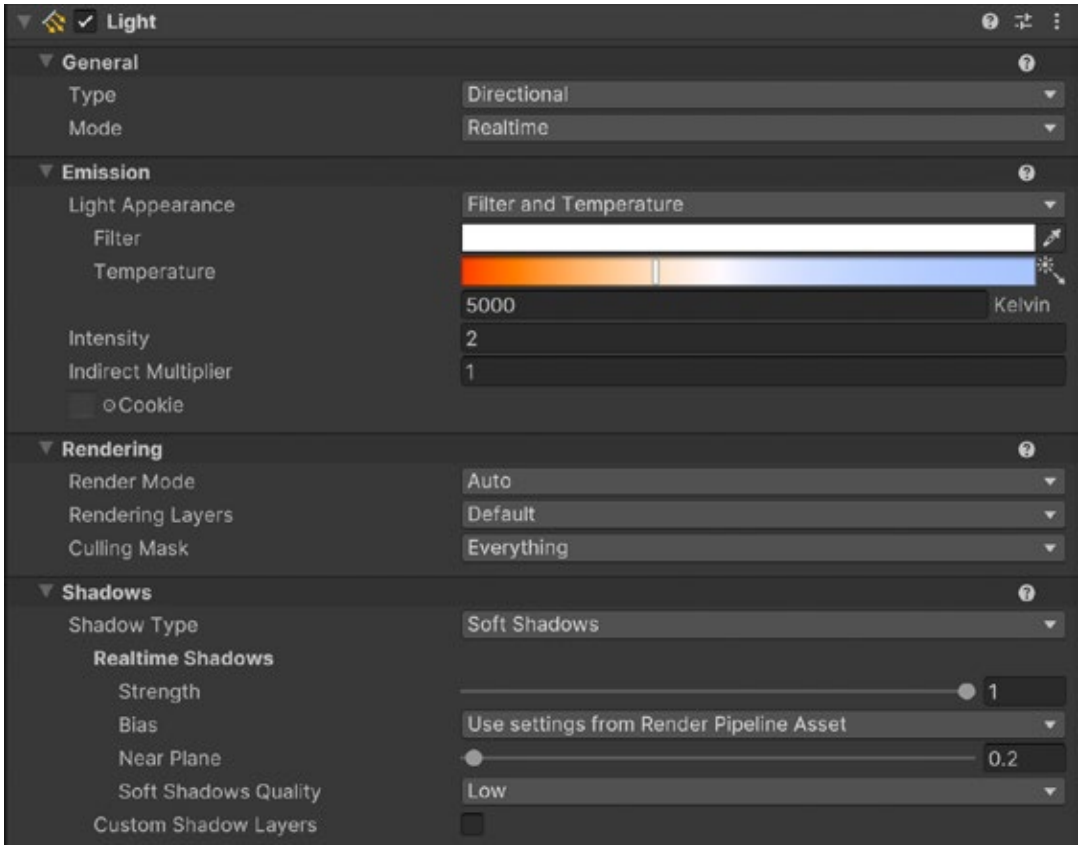
— **Mobile platforms**: 1 main light, and 32 additional lights

— **OpenGL ES 3.0 and earlier**: 1 main light, and 16 additional lights

Light Inspector

The Light Inspector is one of three places where you can set up lighting.

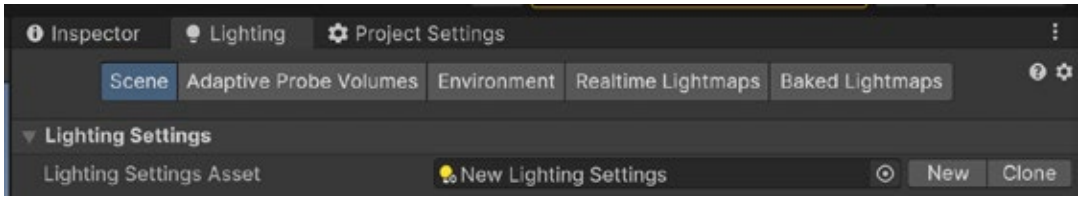
The available properties for lights in URP are Directional, Spot, Point, and Area, though area lights only work in Baked Indirect Mode. See the Light Mode section for more details.



The Light Inspector panel in URP

The image above shows how light properties are presented in the Light Inspector. The URP version has four groupings of controls, based on whether the light is Directional or Point, and an additional Shape grouping for Spot and Area lights.

Lighting a new scene

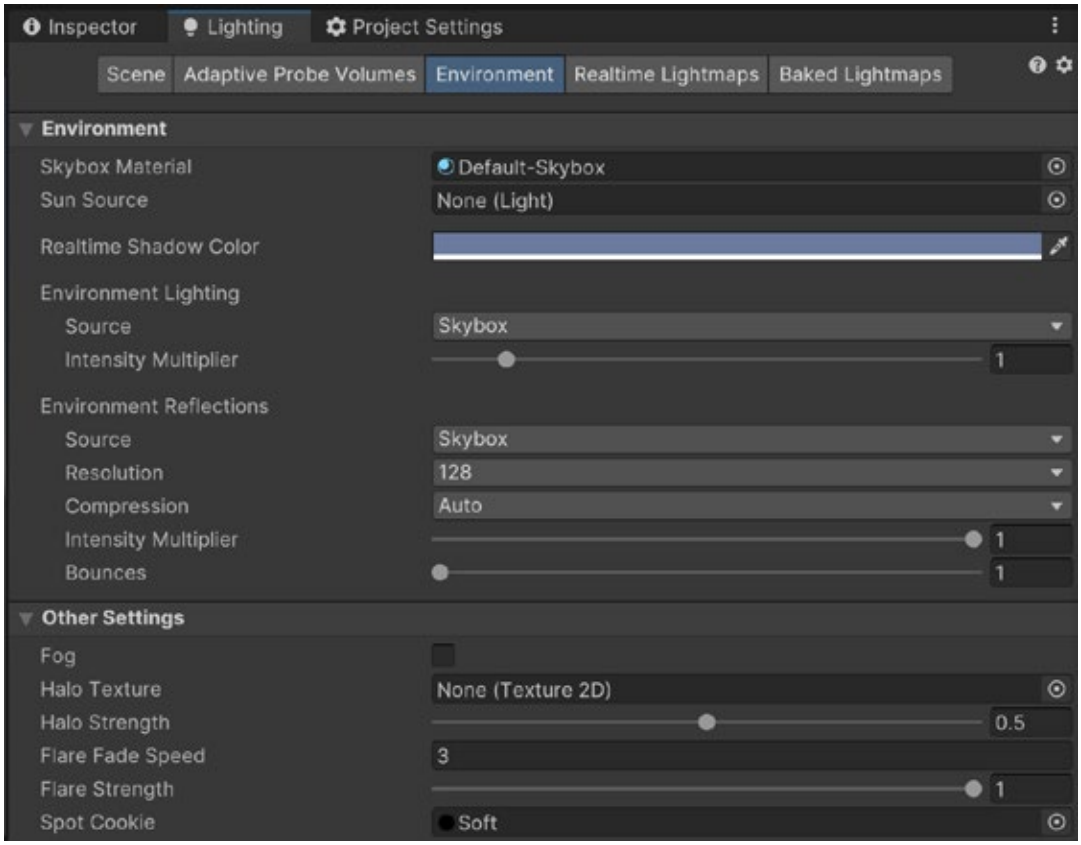


Creating a Lighting Settings Asset

The first step to lighting a new scene for URP is to create a new Lighting Settings Asset (see image above). Open **Window > Rendering > Lighting**, and once you're on the **Scene** tab, click **New Lighting Settings**, and give the new asset a name. The settings that you apply in Lighting panels are now saved to it. Switch between settings by switching the Lighting Settings Asset.

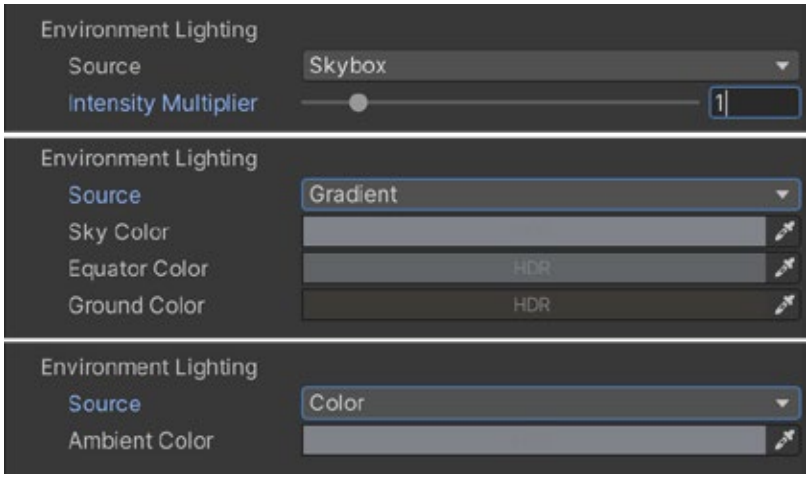
Ambient or Environment lighting

The main ambient light is calculated from the panel accessible via **Window > Rendering > Lighting > Environment**.



The available settings for lighting in the Environment panel

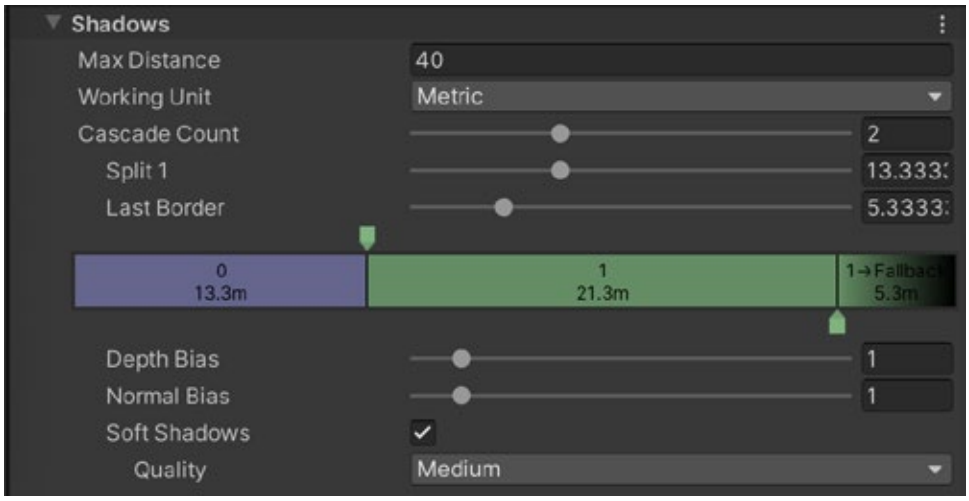
You can set Environment Lighting to use the scene's Skybox, with an option to adjust the Intensity, Gradient, or Color. Only the Gradient and Color modes update in real-time. The Skybox mode requires an on-demand bake to compute the ambient probe from the sky.



Environment Lighting options

Shadows

As discussed earlier, you need a Renderer Data object and a Render Pipeline Asset when using URP. The section on setting up a project for URP covers how to view your scene via Render Pipeline Asset, which you can use to define the fidelity of your shadows.



The URP Asset

Main Light shadow resolution

The Lighting and Shadow groups in the URP Asset are key to setting up shadows in your scene. First, set the **Main Light Shadow** to **Disabled** or **Per Pixel**, then go to the checkbox to enable **Cast Shadows**. The last setting is the resolution of the shadow map.

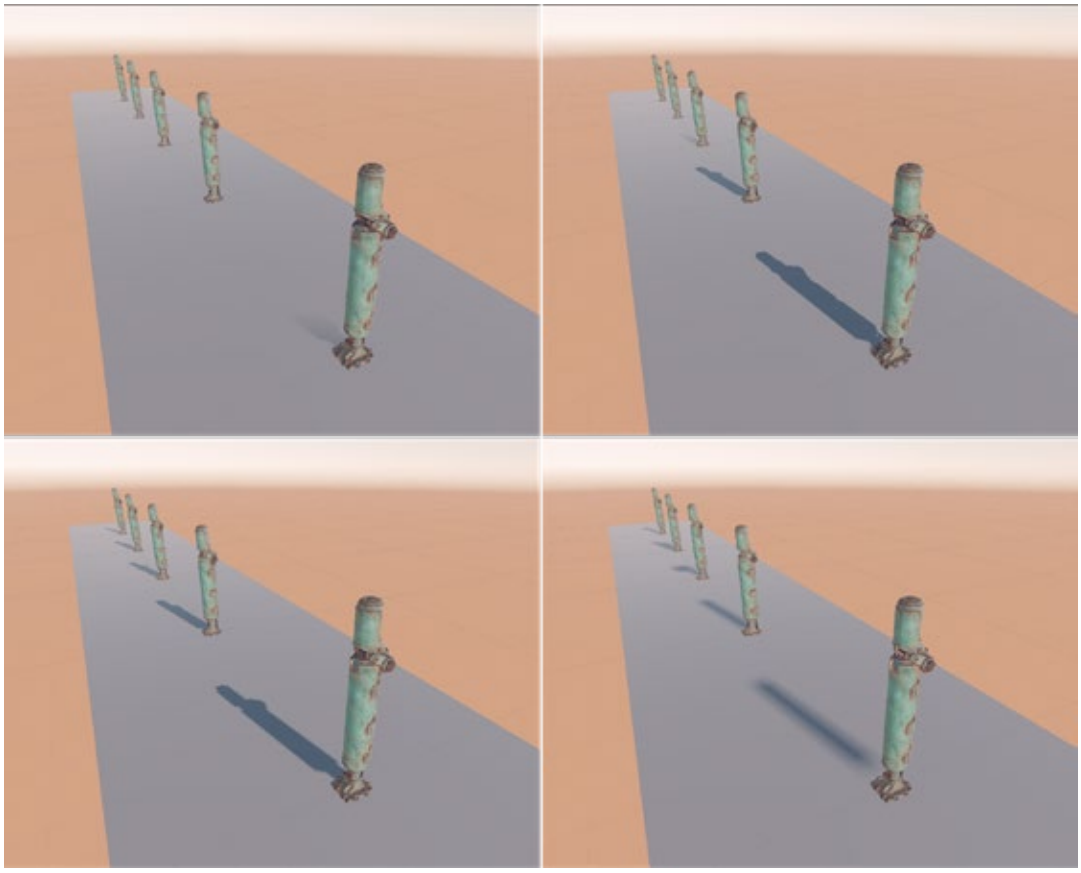
If you've worked with shadows in Unity before, you know that real-time shadows require rendering a shadow map that contains the depth of objects from the perspective of the light. The higher the resolution of this shadow map, the higher the visual fidelity – though both more processing power and increased memory are required. Factors that increase shadow processing include:

1. The number of Shadow Casters rendered in the shadow map – this number for the Main Light depends on the Shadow Distance (far plane of shadow frustum)
2. Shadow Receivers that are visible (you have to encompass them all)
3. Shadow Cascades splits
4. Shadow filtering (soft shadows)

The highest resolution isn't always ideal. For example, the **Soft Shadows** option has the effect of blurring the map. In the following image of a cartoon-like haunted room, you can see that the chair in the foreground casts a shadow on the desk drawers, which appears too crisp when the resolution is greater than 1024.

Setting the shadow resolution for the Main Light: The resolution is set to 256 in the top-left image, 512 in the top-right image, 1024 in the middle-left image, 2048 in the middle-right image, and 4096 in the bottom image.

Main Light: Shadow Max Distance



Varying Max Distance for the Main Light Shadow: Top-left image – 10, top-right image – 30, bottom-left image – 60, bottom-right image – 400

Another important setting for the Main Light Shadow is Max Distance. This is set in scene units. In the image above, the poles are 10 units apart. The Max Distance varies from 10 to 400 units. Notice that only the first pole casts a shadow, and this is cut short at 10 units from the Camera location. At 60 units (bottom-left image), all shadows are in view – the shadow fidelity is adequate. When the Max Distance is much greater than the visible assets, the shadow map is being spread over too large an area. This means that the region in-shot has a much lower resolution than required.

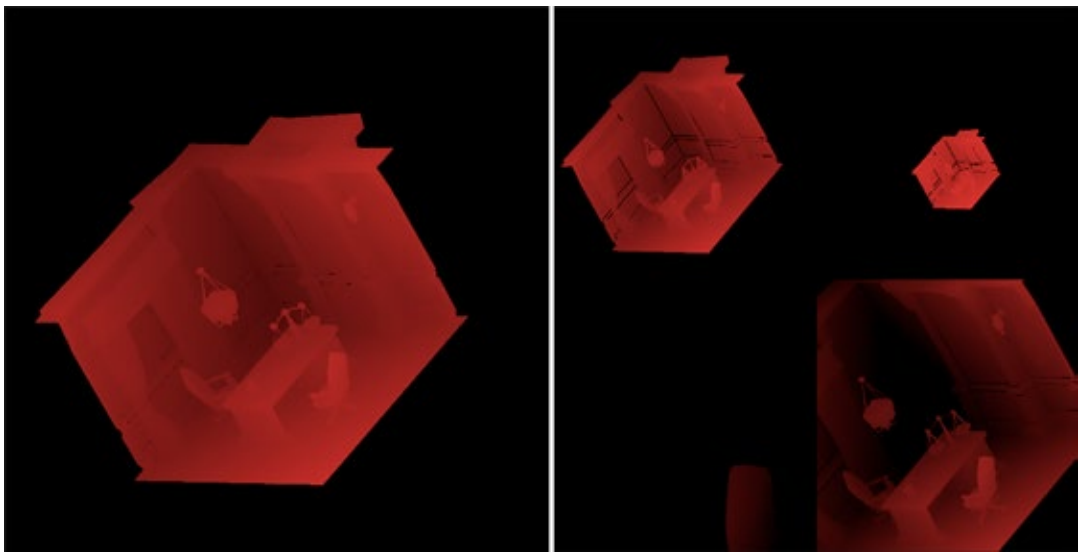
The Max Distance property needs to relate directly to what the user can see, as well as the units used in the scene. Aim for the minimum distance that gives acceptable shadows (see note below). If the player only sees shadows from dynamic objects 60 units from the Camera, then set Max Distance to 60. When the Lighting Mode for Mixed Lights is set to Shadowmask, the shadows of objects beyond Shadow Distance are baked. If this was a static scene then you would see shadows on all objects, but only dynamic shadows would be drawn up to the Shadow Distance.

Shadow Cascades

As assets disappear into the distance due to perspective, it is convenient to decrease Shadow Resolution, thereby devoting more of the shadow map to shadows closer to the Camera. Shadow Cascades can help with this.

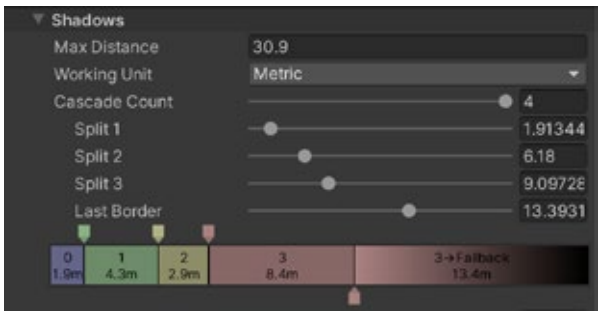
The images below show the shadow map of the scene with the chair and desk in the haunted room. The cascade count is 1 in the image to the left. The map takes up the whole area. In the image to the right, the cascade count is 4. Notice that the map includes four different maps, with each area receiving a lower resolution map.

A cascade count of 1 is likely to give the best result for small scenes like this. But if your Max Distance is a large value, then a cascade count of 2 or 3 will give better shadows for foreground objects, as these receive a larger proportion of the shadow map. Notice that the chair in the left image is much bigger, resulting in a sharper shadow.



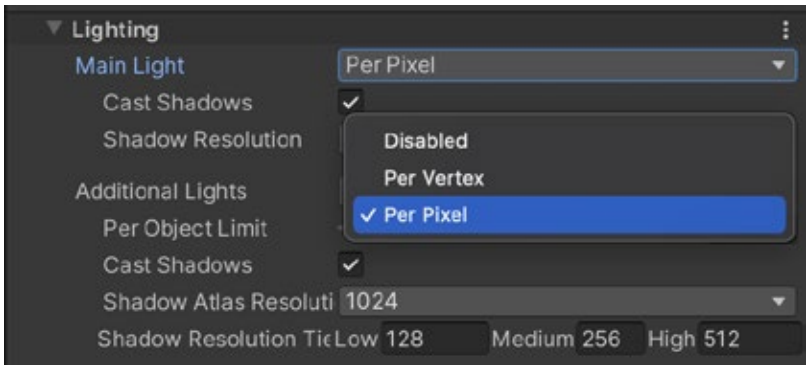
Shadow map when cascade count is set to 1 (left image) and 4 (right image)

You can adjust the start and end ranges for each section of the cascade using the draggable pointers, or by setting the units in the relevant fields (see following image). Always adjust Max Distance to a value that is a close fit for your scene and choose the slider positions carefully. If you use metric as the working unit, always choose the last cascade to be, at most, the distance of the last Shadow Caster.



Adjusting the range of a Shadow Cascade

Additional Light Shadows

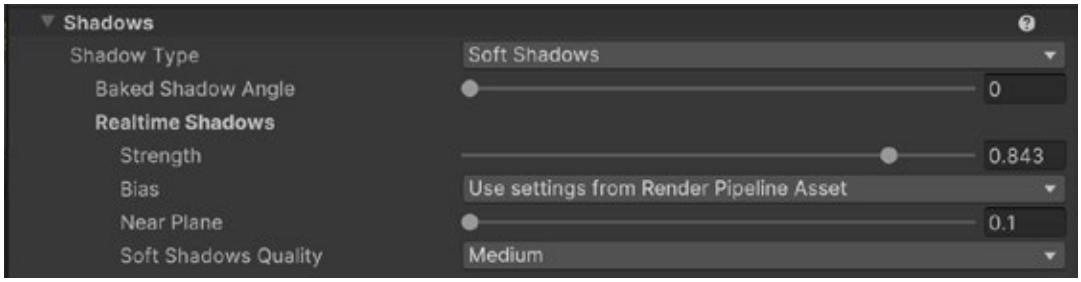


Settings available for Additional Lights in URP Asset

Having sorted the shadows for the Main Light, it's time to move on to **Additional Lights Mode**. Enable additional lights to cast shadows by setting the Additional Lights Mode for the URP Asset to **Per Pixel**. While the mode can be set to Disabled, Per Vertex, or Per Pixel (see above image), only the latter works with shadows.

Note: URP does not support shadows for additional directional lights. Remember, the Main light is always the brightest Directional light. For additional lights with shadows, use a Point or Spot light.

Check the **Cast Shadows** box. Then, select the resolution of the **Shadow Atlas**. This is the map that will be used to combine all the maps for every light casting shadows. Bear in mind that a Point light casts six shadow maps, creating a cubemap, since it casts light in all directions. This makes a Point light the most demanding performance-wise. The individual resolution of an additional light shadow map is set using a combination of the three Shadow Resolution tiers, plus the resolution chosen via the Light Inspector when selecting the light in the Hierarchy window.



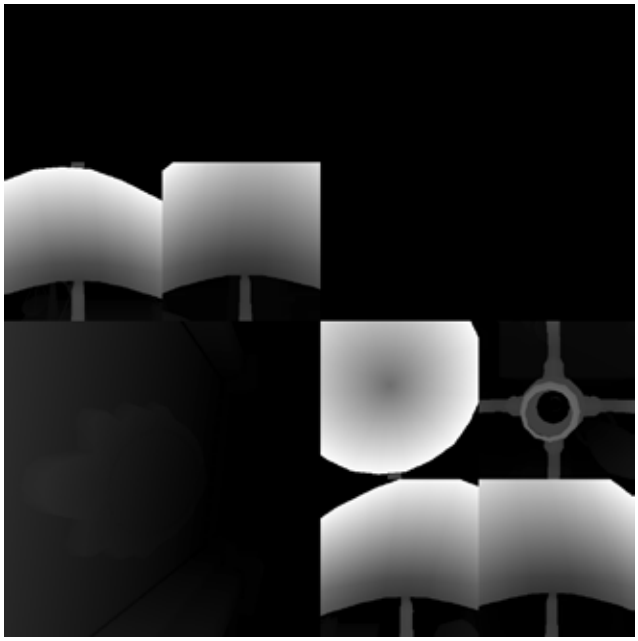
Shadows group in the Light Inspector

Setting **Shadow Type** to **Soft Shadows** enables the **Baked Shadow Angle** slider. This property adds some artificial softening to the edges of shadows and gives them a more natural look. A new option in Unity 6 is available to switch the **Soft Shadows Quality** between Low, Medium, and High.

In the haunted room, there is a Spot light over the mirror and a Point light over the desk. There are also seven maps. To fit these seven maps onto a 1024px square map, the size of each map needs to be 256px or smaller. If you exceed this size, the resolution of shadow maps will shrink to fit the atlas, resulting in a warning message in the console.

Number of maps	Atlas tiling	Atlas size (multiply shadow tier size by)
1	1×1	1
2–4	2×2	2
5–16	4×4	4

Setting the Shadow Atlas size based on the number of Additional Lights shadow maps and the tier size chosen per map



Shadow Atlas for Additional Lights

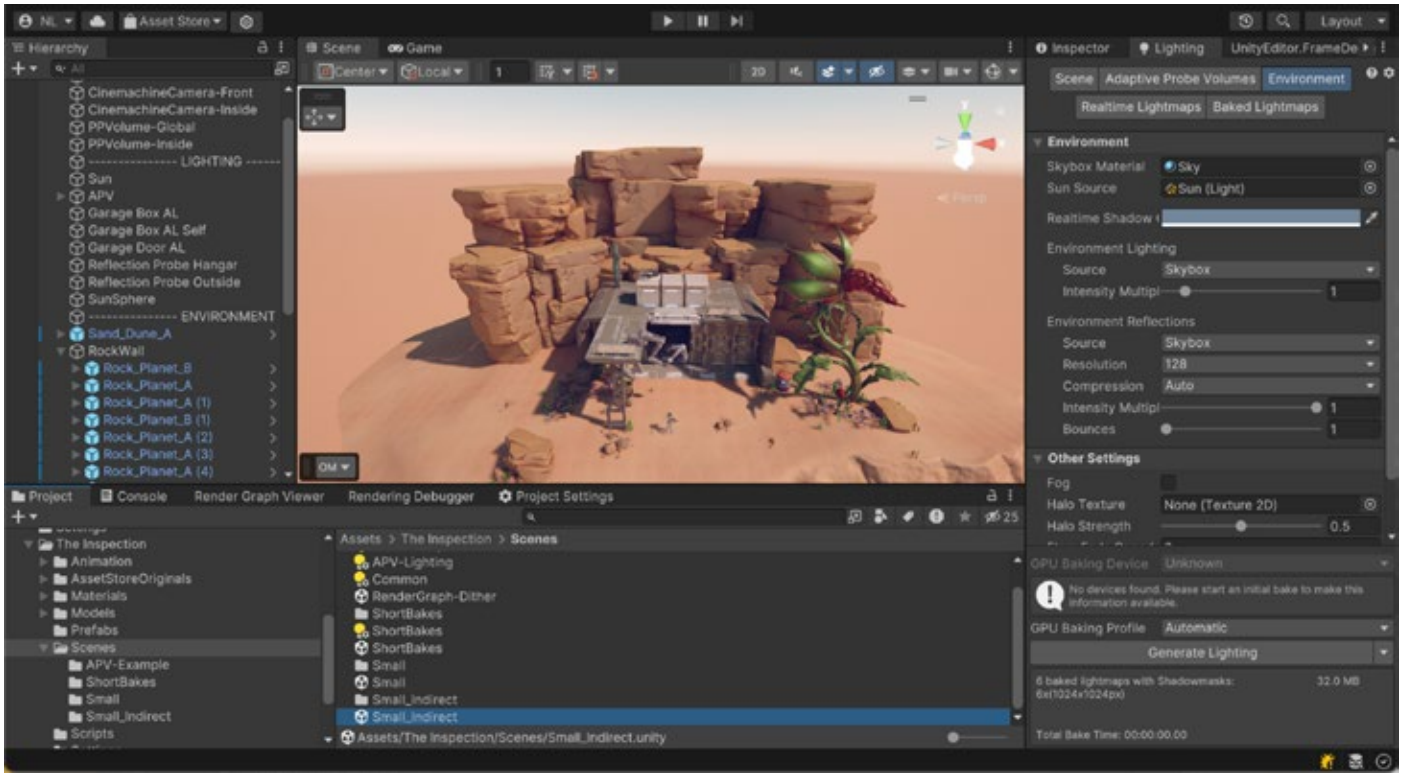
The image above shows the six maps used by the Point light where the resolution is set to medium and the tier value to 256px. The Spot light has a resolution set to high, with a tier value of 512px.

This is a low-polygon version of the haunted room, lit with a Main Directional light, a Point light over the desk, and a Spot light over the mirror. All lights are real-time and casting shadows.

Light modes

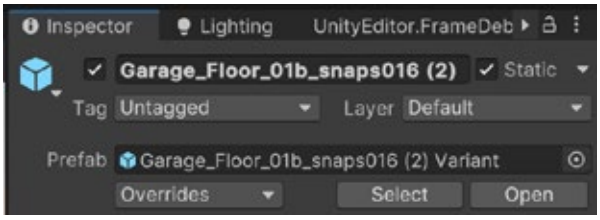
Environments have predominantly static geometry, so that if a light is static, you don't need to calculate the lighting and shadows for it repeatedly. You can calculate this once at design time, and then use that data when rendering the geometry. This is called lightmapping or baking.

Let's go through the steps for lightmapping using an FPS Sample project by Unity. The following screenshots are from this project, which you can download here. The scene via **Inspection > Scenes > Small Indirect** demonstrates how to use real-time and baked lighting in URP.

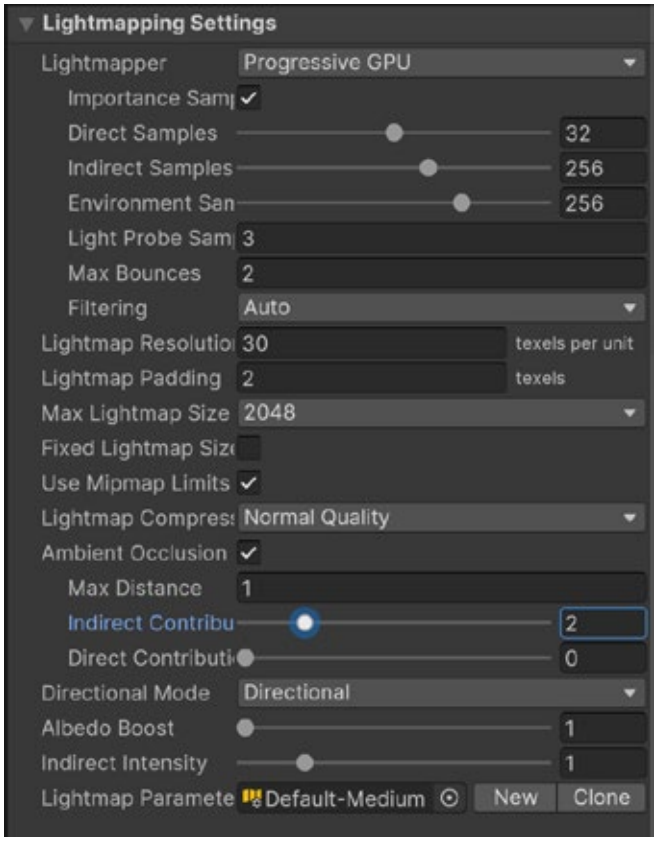


The Inspection > Scenes > Small Indirect scene from the Unity 6 URP e-book repository on GitHub.

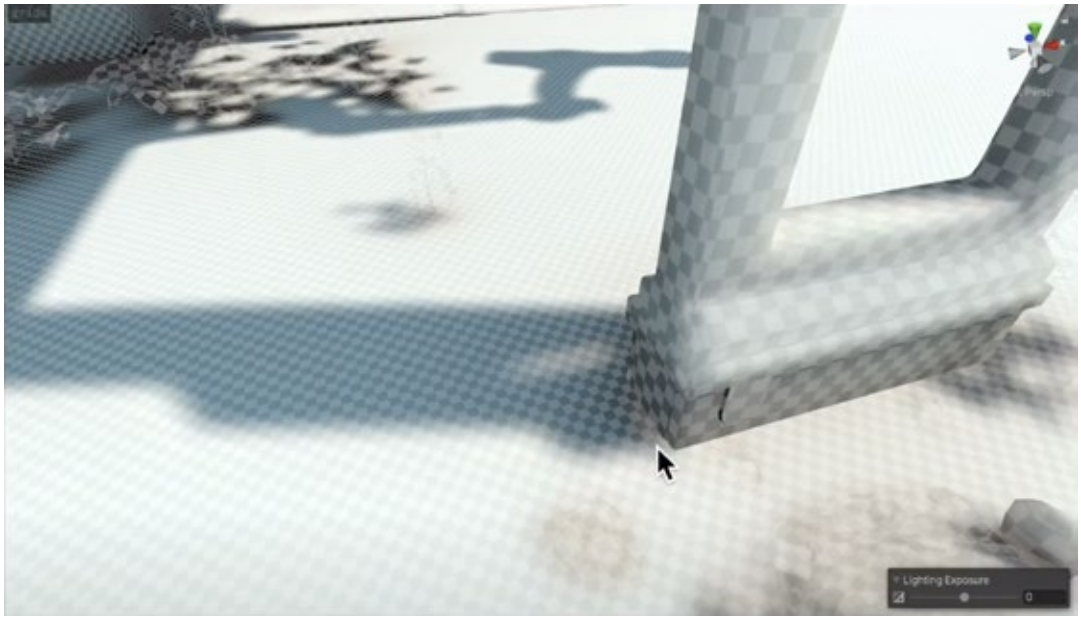
1. The scene from the FPS Sample project contains largely static geometry. To include the geometry in lightmapping, click the **Static** box to the right side of the Inspector.



2. Choose the lightmapping settings via **Window > Rendering > Lighting > Scene**. Keep the Lightmap Resolution low while adjusting the settings. Once you have your desired settings, increase the value when generating the final lightmaps. Choose **Progressive GPU** to speed up the lightmap generation, if your GPU supports it.

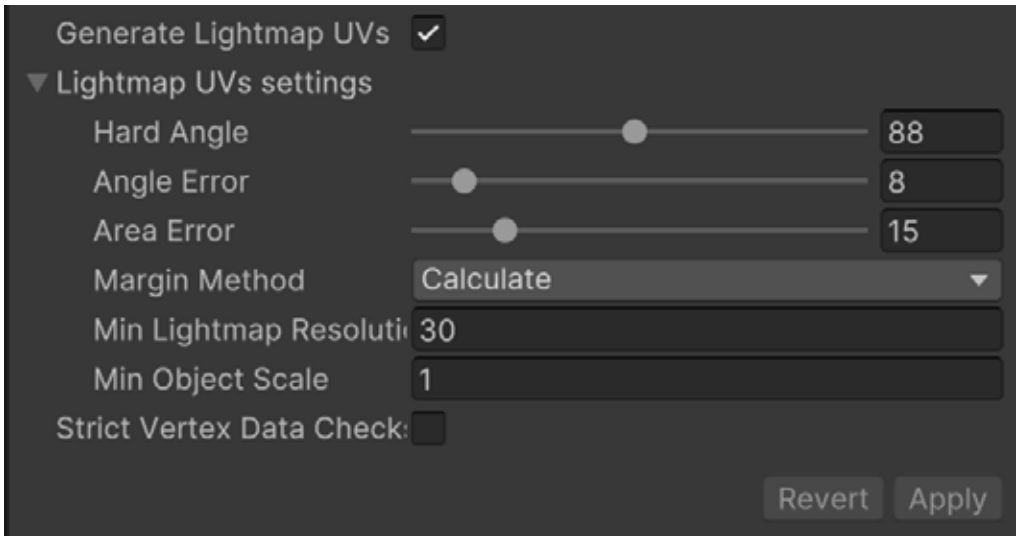


3. Filtering blurs the map to minimize noise. This can result in gaps in a shadow where one object meets another. Use **A-Trous** filtering to minimize this artifact. See Progressive Lightmapping documentation for more details on the settings available for lightmapping.

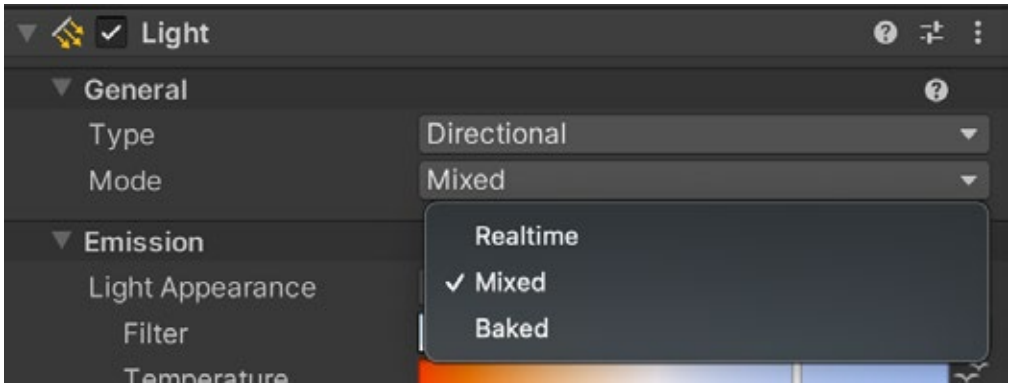


How filtering affects the shadow between objects

4. Make sure all static geometry has no overlapping UV values, or is generating lighting **UVs** on import.



5. Set **Light Mode** to **Baked** or **Mixed**. Select the light in the **Hierarchy** window and use the **Inspector**. Mixed lights will illuminate dynamic objects as well as static ones.

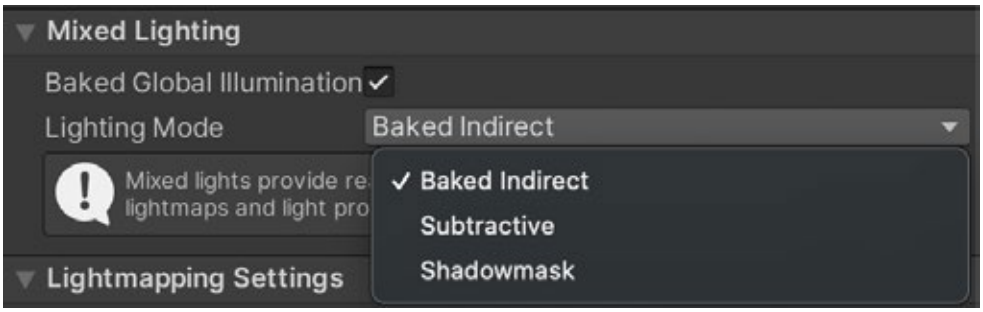


6. When using mixed lights, set the **Light Mode** to **Baked Indirect**, **Subtractive**, or **Shadowmask** via **Window > Rendering > Lighting > Scene**.

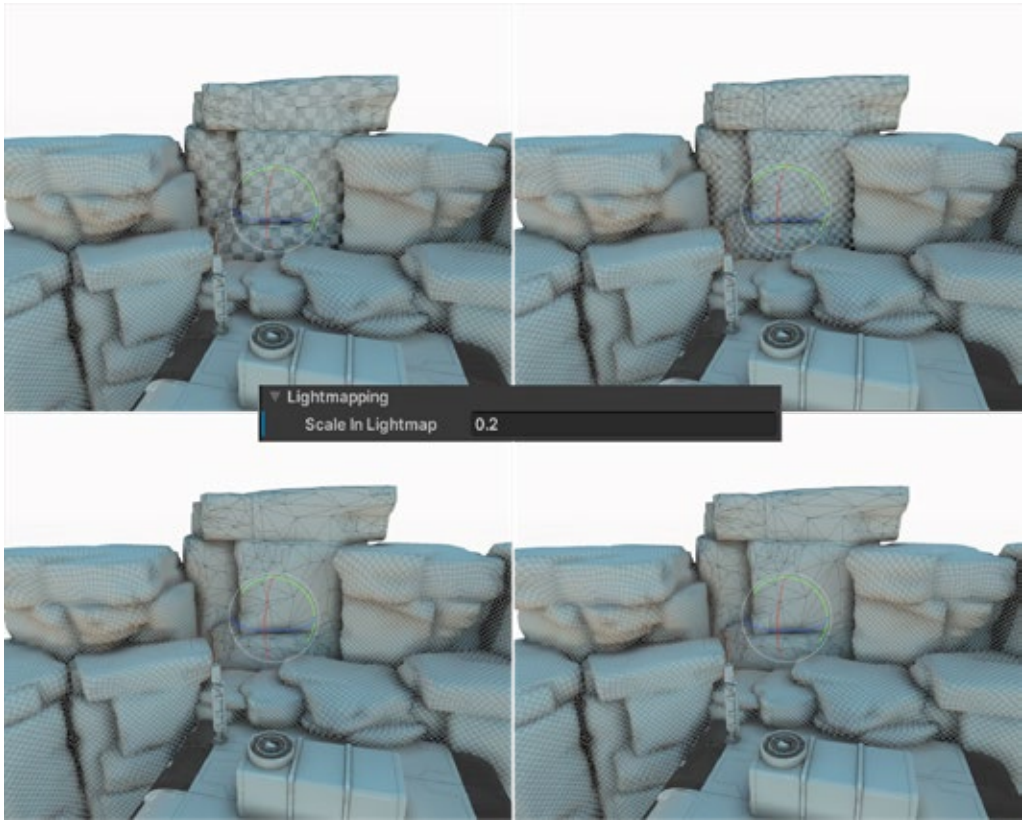
    a. **Baked Indirect:** Only the indirect light contribution will be baked into the lightmaps and light probes (the bounces of the lights only). Direct lighting and shadows will be real-time. This is an expensive option and not ideal for mobile platforms. However, it does mean that you get correct shadows and direct light for both static and dynamic geometry.

b. **Subtractive:** Here, you bake the direct lighting from a Directional light set to Mixed into the static geometry, and subtract the lighting from shadows cast by dynamic geometry. This results in the static geometry unable to cast a shadow on dynamic objects, unless light probes or Adaptive Probe Volumes (APV) are used, which can cause unpleasant visual discontinuities. URP calculates an estimate of the contribution of the light from the Directional Light and subtracts that from the baked Global Illumination. The estimate is clamped by the Real-time Shadow Color setting in the Environment section of the Lighting window, so the color subtracted is never darker than this color. Then choose the minimum color of your subtracted value and the original baked color. While this mode is the most suitable option for low-end hardware, it cannot correctly combine baked and real-time shadows at runtime, leading to artifacts. This trade-off prioritizes performance over quality.

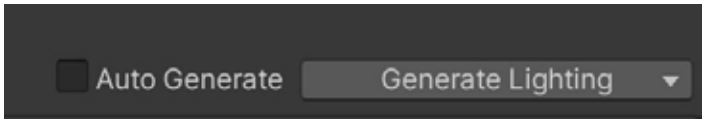
c. **Shadowmask:** Though similar to Baked Indirect Mode, Shadowmask combines both dynamic and baked shadows, rendering shadows at a distance. It does this by using an additional Shadowmask texture and storing additional information in the light probes. This provides the highest fidelity shadows, but is also the most expensive option in terms of memory use and performance. Visually, it's identical to Baked Indirect for shots up close. The difference is apparent when looking in the far distance, making it well-suited for open-world scenes. Due to the processing cost, it's recommended for mid- to high-end hardware only.



7. Adjust the **Lightmap Scale** via **Asset > Inspector > Mesh Renderer > Lightmapping > Scale In Lightmap**, so that distant objects take up less space on the lightmap. The following image shows the texel size of the background rock lightmap with a setting varying from 0.05 to 0.5.



8. Click **Generate Lighting** to bake. The baking time depends on the number of static objects, lights set to mixed or baked mode, and the settings chosen for lightmapping, particularly the Max Lightmap Size and the Lightmap Resolution. Baking time is proportional to the number of rays used in baking so Sample Count (Direct Samples, Indirect Samples and Environment Samples) also have a direct effect on baking time.



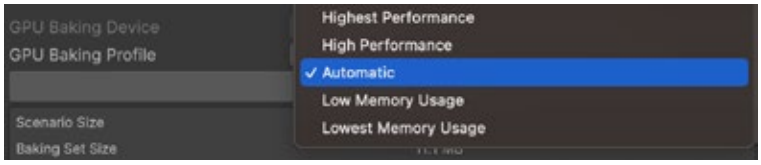
Bake your lightmap via **Window > Rendering > Lighting > Generate Lighting**.

9. An interactive baking feature is new in Unity 6 with Draw Modes active (1)* and Baked Lightmap selected (2). A new panel is displayed with a Preview option (3). While you are in this mode the changes made do not affect the generated data. This feature enables a technical artist to tweak the properties and see how changes could affect the rendering without destroying a previous bake that might have taken a long time to calculate.

   *Numbers refer to the image below.

Activating interactive preview mode

Unity also now provides a **Baking Profile**. This can be found in the **Lighting** window when using the GPU backend in on-demand mode, and offers users a tradeoff between performance and GPU memory usage.



GPU Baking Profile

Note:

Since the 2019 release, Unity has provided a system for automatically generating baked environment lighting in scenes that haven't been baked explicitly. This system was known as the SkyManager. However the SkyManager was causing confusion for users as the automatic behavior wasn't clear, and was only present in a few specific situations. Additionally, the system caused differences in the behavior of the Editor and built Player, sometimes leading to the environment lighting being unexpectedly missing.

In Unity 6 the SkyManager is replaced with a new default Lighting Data Asset in the Editor, which is assigned to newly created scenes. The asset contains environment lighting matching the default settings for environment lighting. If you change these settings using the Skybox Mode, you'll have to manually rebake lighting using the **Generate Lighting** button in the Lighting Window.

More resources:

- Lightmapping documentation
- Lighting Settings Asset documentation
- Lighting Explorer documentation
- 5 common lightmapping problems and tips to help you fix them

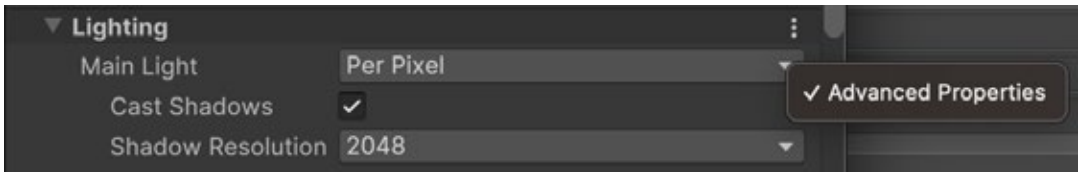
Rendering Layers

The Rendering Layers feature lets you configure certain lights to affect only specific GameObjects so you can emphasize and draw attention to them in a scene. In the image below, the syringe, a key collectable, appears in a shaded part of the scene. With a Rendering Layer, it becomes visible and helps ensure that the player doesn't miss picking it up.

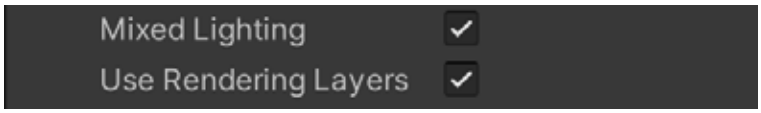
Highlighting an object using Rendering Layers

Here are the steps for setting up Rendering Layers.

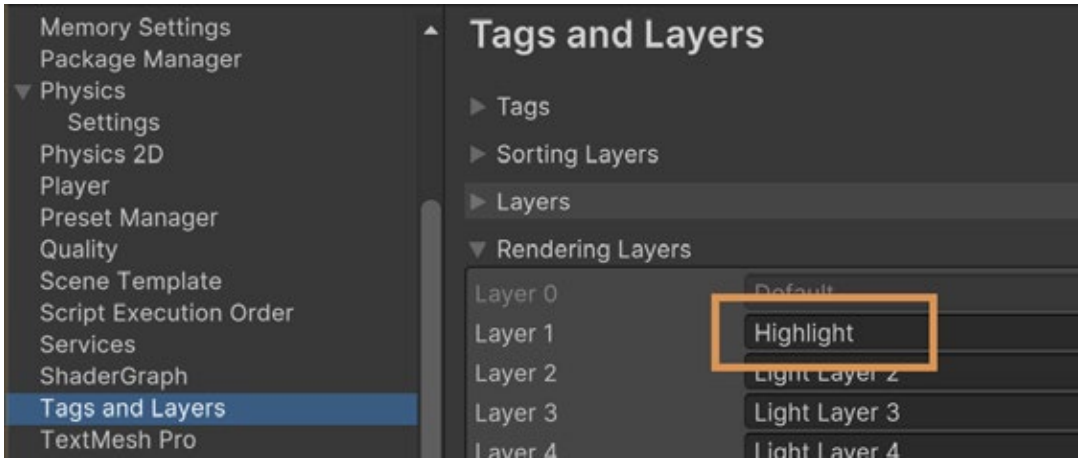
1. Select the **URP Asset**. In the Lighting section, click the vertical ellipsis icon (⋮) and select **Advanced Properties**.



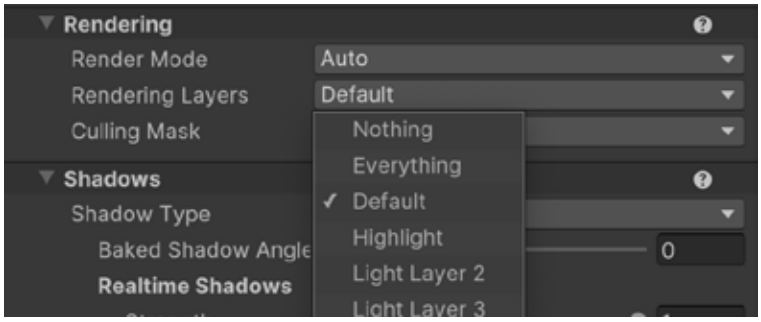
2. A new setting, **Use Rendering Layers**, will appear under the Lighting section.



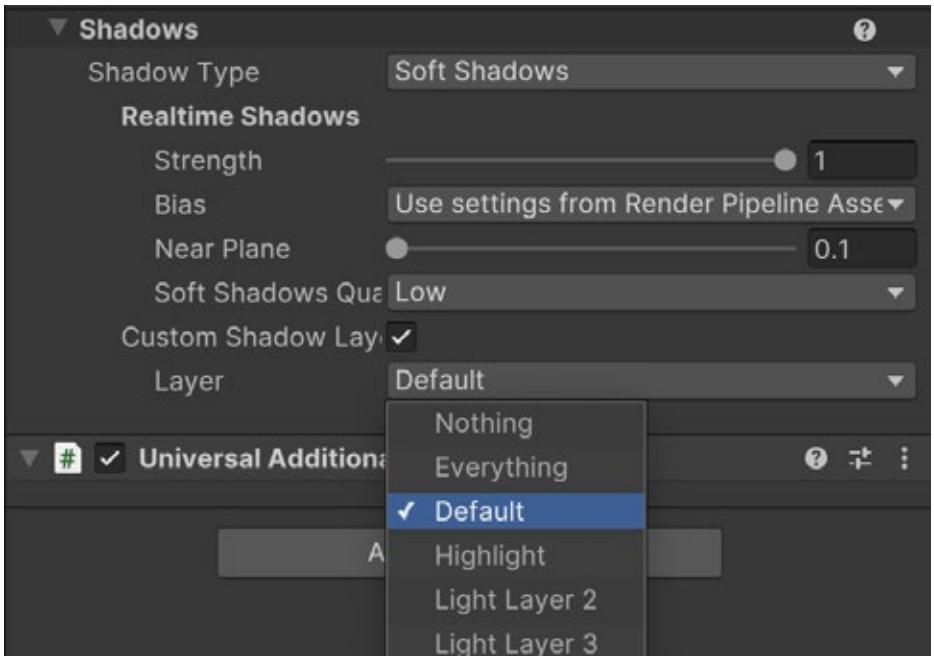
3. Rename a Rendering Layer via **Project Settings > Tags and Layers > Rendering Layers**.



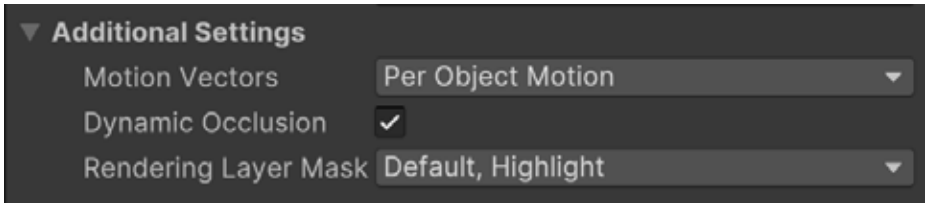
4. The **Light Inspector > Rendering** section includes a **Rendering Layers** drop-down. A light can contribute to more than one layer.



5. With Rendering Layers enabled, create a new light and set up a custom shadow layer. The new light can cast shadows from the scene's **Main Light** or from its own frustum.



6. Lastly, select the object this applies to in the **Hierarchy** window and then set the **Rendering Layer Mask**.



This can also be dynamically set in code.

```
Renderer renderer = GetComponent<Renderer>();
int layerID = 1;
int mask = 1 << layerID;
renderer.renderingLayerMask = (uint)mask;
```

Light probes

As covered in the light modes section, you can combine baked and dynamic objects using Mixed Lighting Mode. When using Mixed Lighting Mode it's recommended to also add probes to your scene. With Unity 6 there are two options: light probes and the new Adaptive Probe Volumes (APV). The two options solve the same problem, namely allowing dynamic objects to move through a scene and be affected by global illumination.

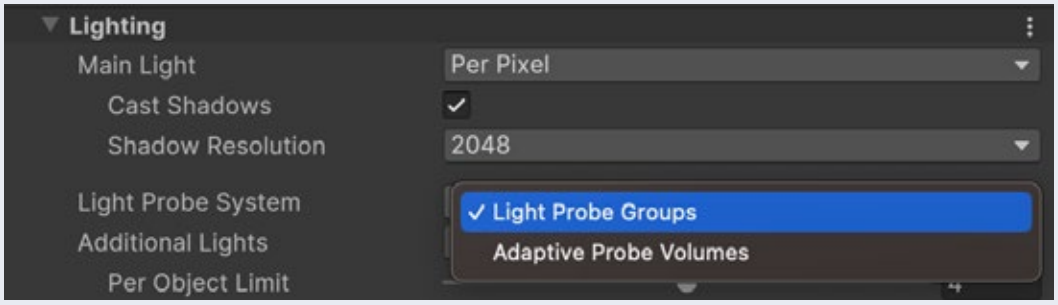
A probe is simply a point in your scene. At design time the global illumination at this location is calculated. At run time, when rendering a frame, a URP shader that includes lighting calculations uses a blend of the nearest probes for global illumination values.

Note: Global illumination (GI) is a system that models how light bounces off surfaces onto other surfaces, to create indirect light, rather than being limited to just the light that hits a surface directly from a direct light source.

Light probes

Light probes save the light data at a particular position within an environment when you bake the lighting by clicking **Generate Lighting** via **Window > Rendering > Lighting** panel. This ensures that the illumination of a dynamic object moving through an environment reflects the lighting levels used by the baked objects. In a dark area it will be dark, and in a lighter area it will be brighter. Sampling is per object so for large objects this can lead to lighting anomalies if an object extends from a dark to a light area. If this is a problem for your scene then consider using APVs, which are sampled per pixel (see the section on APVs later on in the guide).

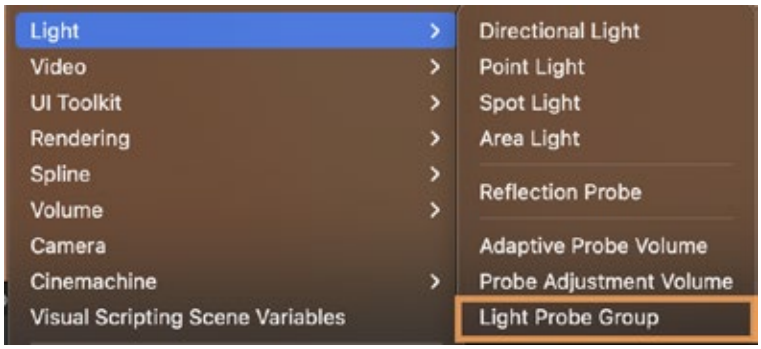
Note: You'll need to ensure that active URP Asset has **Lighting > Light Probe System** set to **Light Probe Group** when using light probes:



Below, you can see the robot character inside and outside of the hangar in the FPS Sample: The Inspection.

The robot inside and outside of the cave, with lighting level affected by light probes

To create light probes, right-click in the **Hierarchy** window and choose **GameObject > Light > Light Probe Group**.



Creating a new GameObject for the Light Probe Group

Initially, there will be a cube of probes, eight in total. To view and edit the positioning of the probes and add additional ones, select the **Light Probe Group** in the **Hierarchy** window, and in the Scene view click **Tools > Edit Light Probes**. Be sure to activate the light probes gizmos.

Add or remove light probes and modify their position from the Inspector.

The Scene view will now be in an editing mode where only light probes can be selected. Use the Move tool to move them around.

Moving a light probe

Light probes should be positioned, first, in an area where a dynamic object might move to, and second, where there is a significant change in lighting level. When calculating the lighting level for an object, the engine finds a pyramid of the nearest light probes and uses those to determine an interpolated value for the illumination level.

The nearest light probes for the selected crate

Positioning probes can be time-consuming, but a code-based approach such as this one can speed up your editing, especially for a large scene or for super quick placement switch to using APVs.

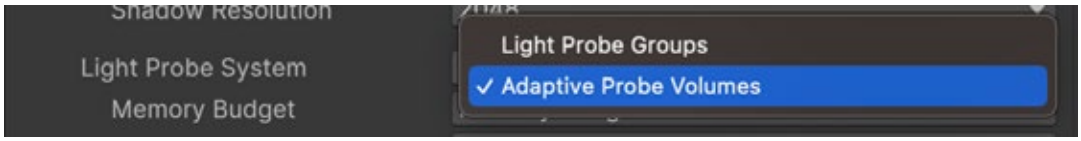
Creators often build modular content for their projects in scenes. These scenes are then repositioned at runtime in a “hub” scene. However, when building modular content including light probes, creators were unable to reposition these together with their Scene, because the positions of the probes were read-only. This issue is solved in Unity 6 with a new API that allows the repositioning of light probes at runtime.

Further details on how a Mesh Renderer works with light probes and how to adjust the configuration can be found in this documentation.

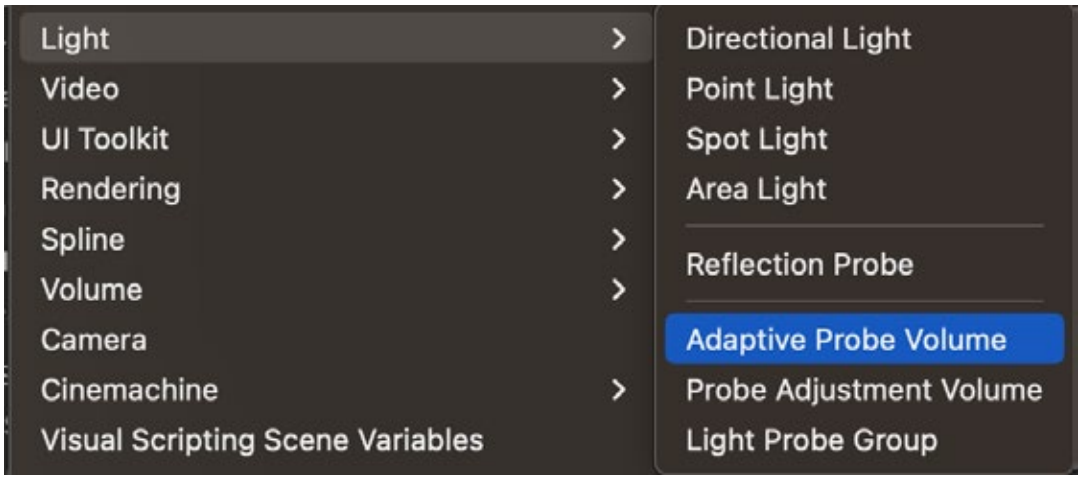
Adaptive Probe Volumes

Any technical artist who has carefully positioned light probes for a scene only to find the scene layout has changed will immediately see the benefits of Adaptive Probe Volumes (APVs). For many scenes you can now place all the probes in a matter of seconds. Let’s look at a practical example using the FPS Sample: The Inspection again. This example is found via **The Inspection > Scenes > APV-Example**

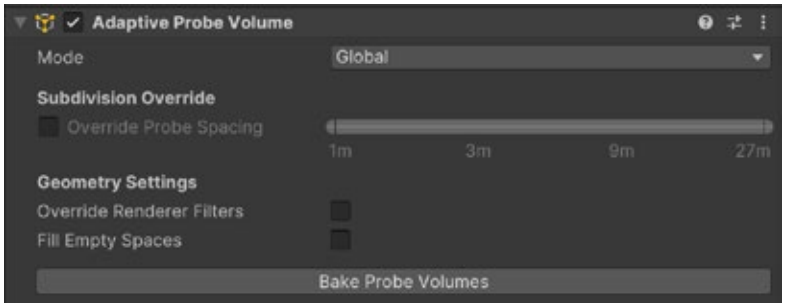
1. First make sure the active URP Asset has the **Light Probe System** option set to **Adaptive Probe Volumes**.



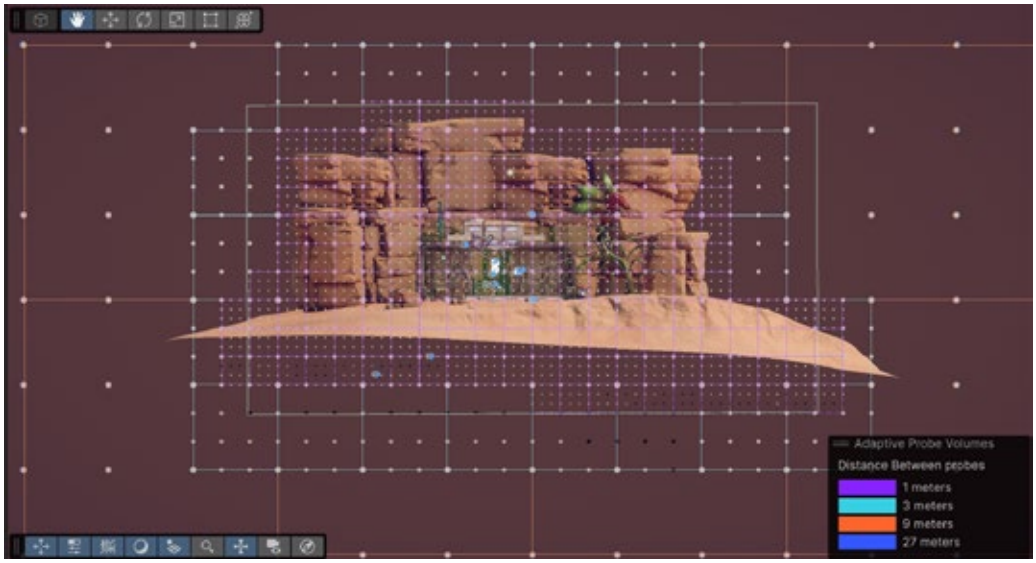
2. In the Hierarchy window right-click and select **GameObject > Light > Adaptive Probe Volume** (APV).



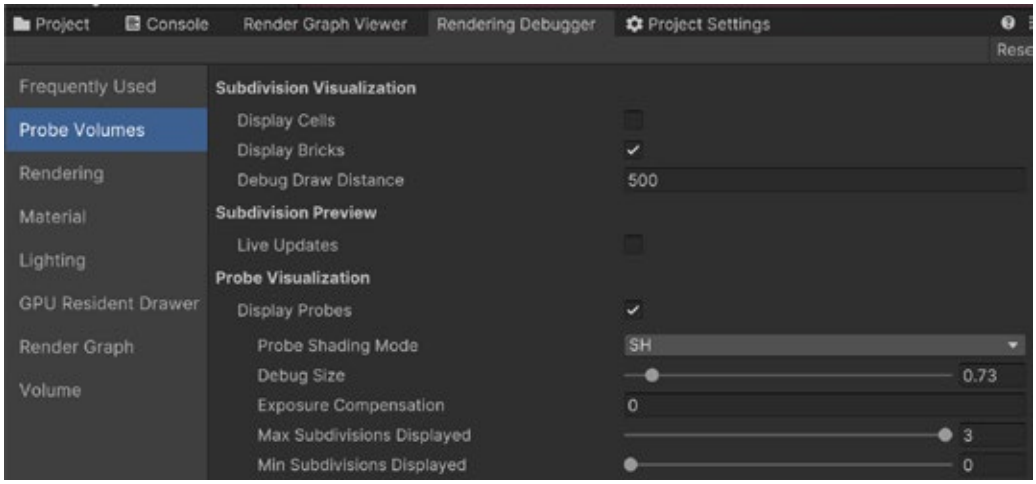
3. Set the Mode to **Global** and accept the default settings – Subdivisions of 1, 3, 9 and 27 meters.



4. Bake the volume by pressing **Bake Probe Volumes**. The current scene is scanned and the probes are placed based on the geometry in the scene. Probes are at their densest where there is the most geometry.



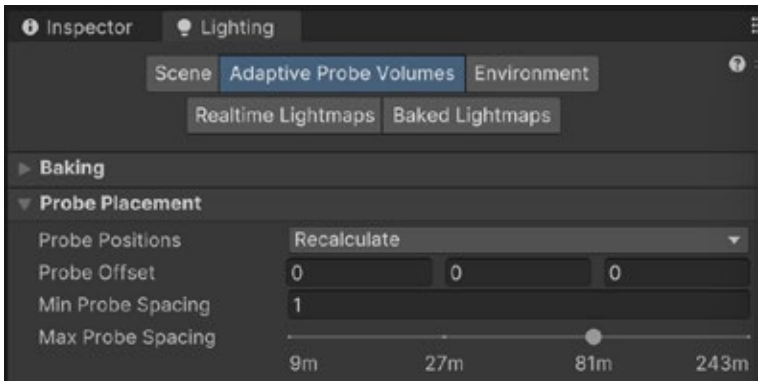
5. To view the result of the bake open **Analysis > Rendering Debugger**. Select **Probe Volumes** and select **Display Probes**. To view the different resolutions choose **Display Bricks**.



For many scenes that would complete the job, and you can head off for a coffee break. But APVs provide much more fidelity. You can add multiple volumes with different subdivisions to have precise control over the placement and density of probes.

Take the oasis environment in the URP 3D Sample as an example. Imagine most of the action in the scene is around the tent and therefore, you want to place most of the probes around it. To achieve this you would:

1. Open **Rendering > Lighting > Adaptive Probe Volumes** and change **Max Probe Spacing** to 81m.



2. Add an **Adaptive Probe Volume** set as **Global** and set the **Override Probe Spacing** to 27m>81m.

3. Add an Adaptive Probe Volume set as **Local** and set the **Override Probe Spacing** to 1m>9m. Set the Volume to be a bit bigger than the tent.

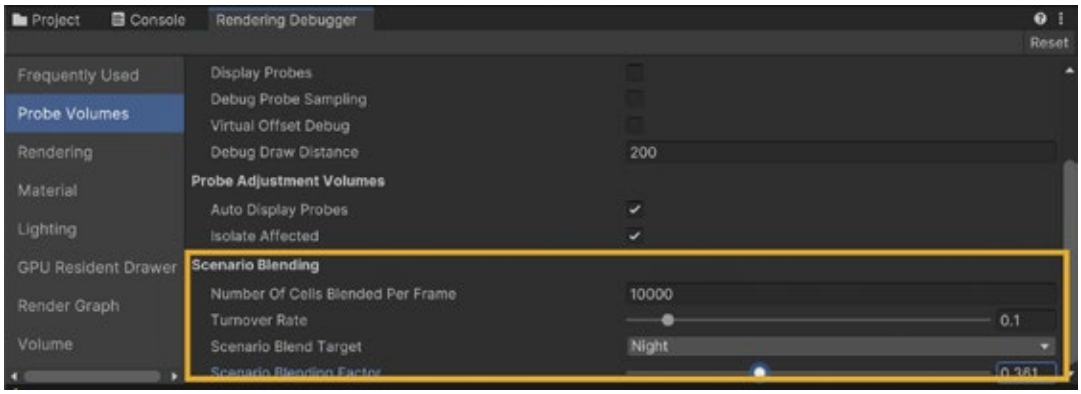
4. Bake the Probe Volumes.

As you can see from the image below, most probes are around the tent.

Probe placement

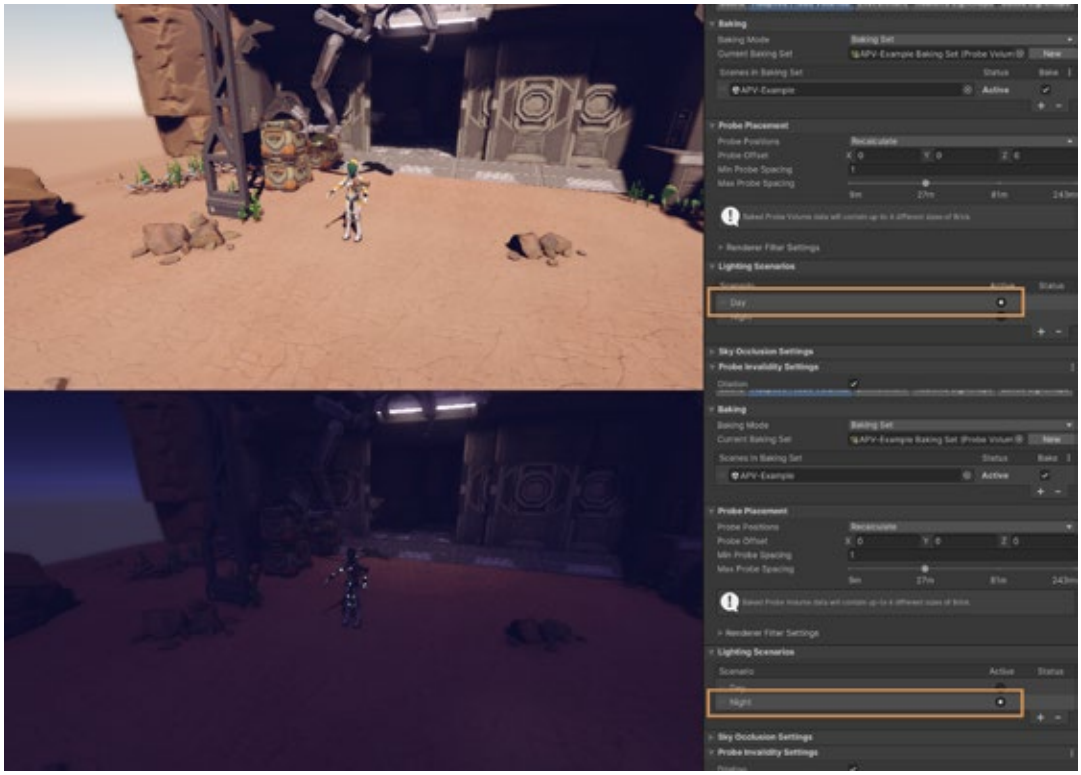
Lighting Scenario asset

Another feature of Adaptive Probe Volumes is the ability to switch between indirect lighting data. A **Lighting Scenario** asset contains the baked lighting data for a scene or **Baking Set**. You can bake different lighting setups into different Lighting Scenarios, and change which one URP uses at runtime or at design time using the Rendering Debugger.



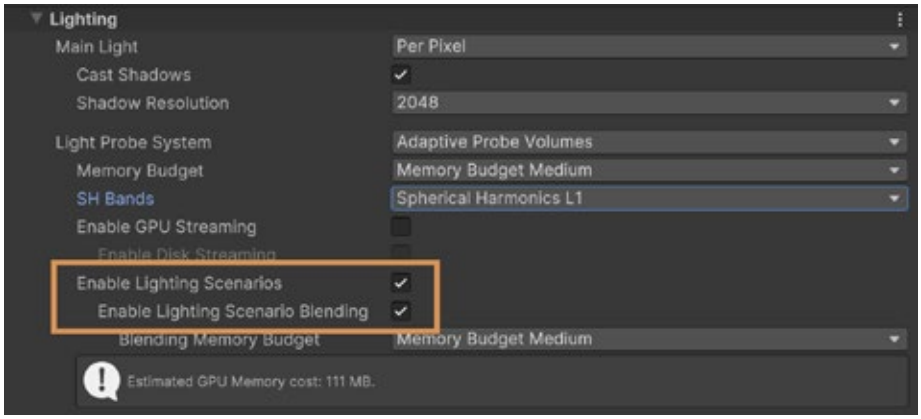
Scenario Blending using the Rendering Debugger

For example, you can create one Lighting Scenario for day, and another one for night. At runtime, you can switch or blend between the two.



Day/night Lighting Scenarios

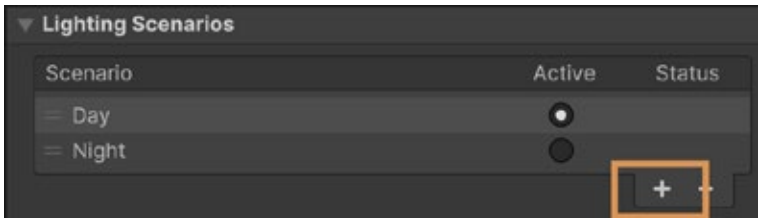
1. To use a Lighting Scenario asset, go to the active URP Asset and enable **Lighting > Light Probe Lighting > Lighting Scenarios**.



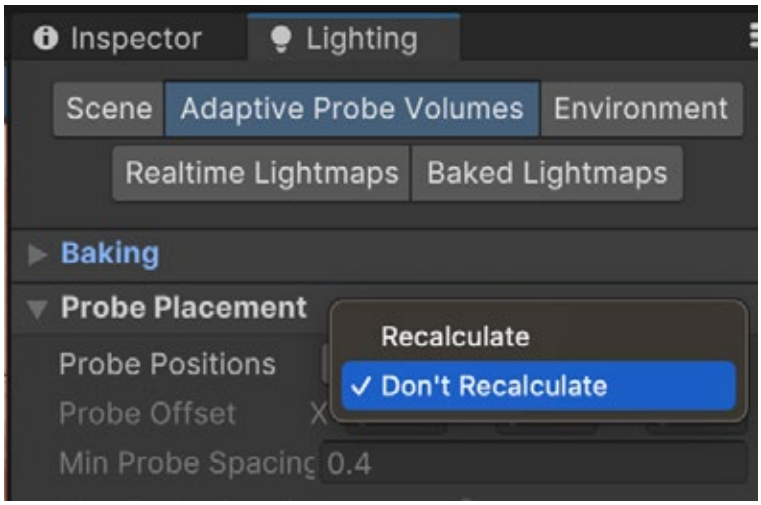
2. To create a new Lighting Scenario asset so you can store baking results inside, do the following:

    a. Open the **Adaptive Probe Volumes** panel in the **Lighting** window.

    b. In the **Lighting Scenarios** section, select the **Add** (+) button to add a Lighting Scenario asset.



3. In the **Lighting** window, under the **Adaptive Probe Volume** tab, make sure the **Probe Positions** are set to **Don't Recalculate**. This ensures that Unity will only rebake lighting without changing the probe positions, which could otherwise invalidate previously baked scenarios.

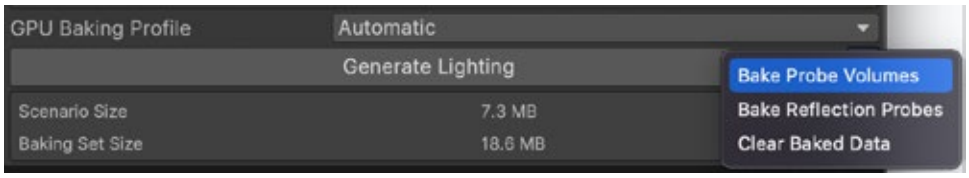


4. To bake into a Lighting Scenario, follow these steps:

    a. In the Lighting Scenarios section, select a Lighting Scenario to make it active.

    b. Select **Generate Lighting**. URP stores the baking results in the active Lighting Scenario.

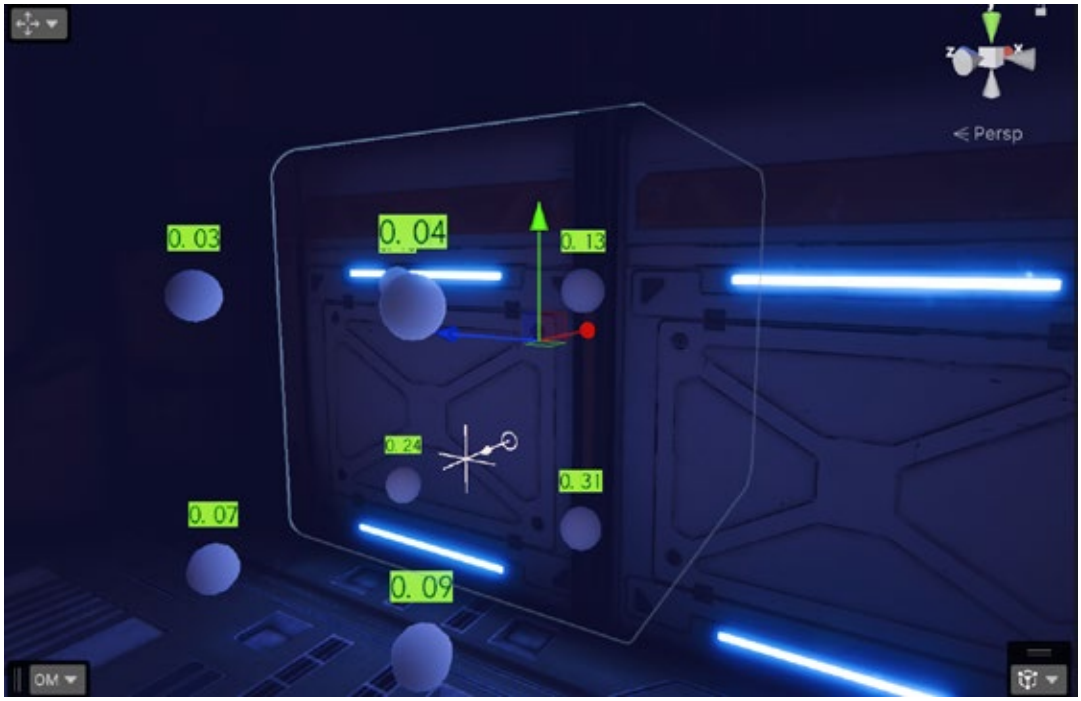
    c. Use the dropdown button next to **Generate Lighting** to only focus on the probes if you're not using lightmaps.



You can set which Lighting Scenario URP uses at runtime using the ProbeReferenceVolume API.

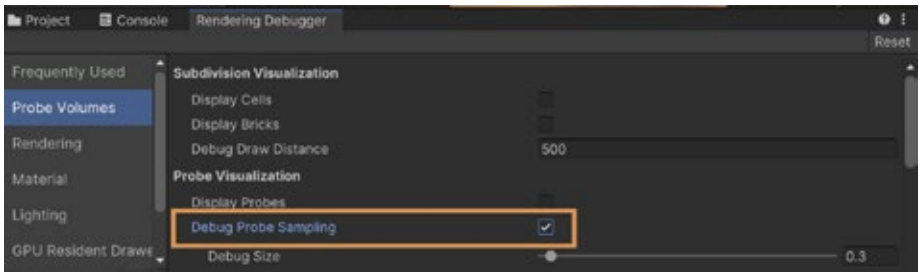
Note:
If you change the active Lighting Scenarios at runtime, URP changes only the indirect lighting data in the light probes. You might still need to use scripts to move geometry, modify lights or change direct lighting.

Fixing issues with Adaptive Probe Volumes



Debug Probe Sampling

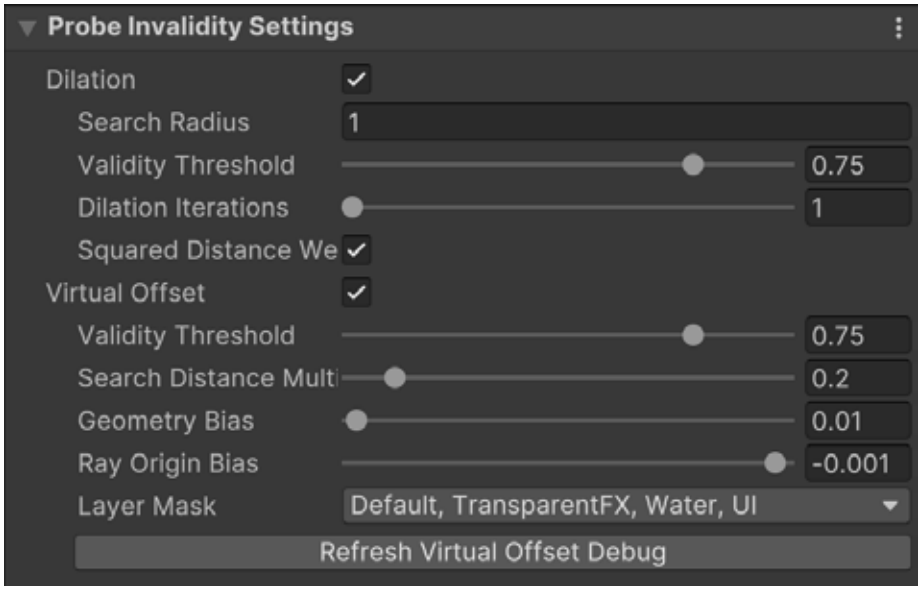
To fix issues such as APV artifacts, use **Window > Analysis > Rendering Debugger > Probe Volumes > Debug Probe Sampling** to inspect probes and how they are sampled for a given pixel.



Visualizing Probe Sampling per pixel

Since light probes are added in a grid, placement can sometimes cause rendering errors such as dark areas where it should be light and vice versa. The Editor provides several tools to let a technical artist quickly fix these issues.

Light probes inside geometry are called invalid probes. URP marks a probe as invalid when it fires sampling rays to capture surrounding light data, but the rays hit the unlit backfaces inside geometry. The APV system has several tools to fix these issues.



The Probe Invalidity Settings available in the Adaptive Probe Volumes panel

Virtual Offset tries to make invalid light probes valid, by moving their capture points so they're outside any colliders. And **Dilation** detects light probes that remain invalid after Virtual Offset, and gives them data from valid probes nearby.

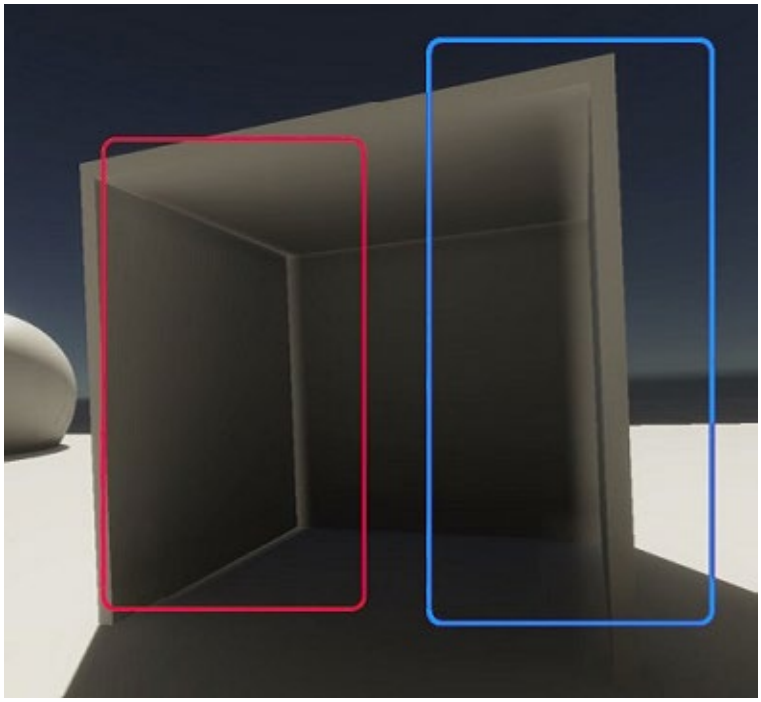
You can check which light probes are invalid using the **Rendering Debugger.**

In the left-side scene in the image above, Virtual Offset isn't active and dark bands are visible. In the scene on the right side, Virtual Offset is active.

In the left-side scene in the image above, Dilation isn't active and some areas are too dark. In the scene on the right, Dilation is active.

Light leaks

Light leaks are areas that are too light or dark, often in the corners of a wall or ceiling.



A light leak

Light leaks often occur when geometry receives light from a light probe that isn't visible to the geometry, for example due to the light probe being on the other side of a wall. APVs use regular grids of light probes, so light probes might not follow walls or be at the boundary between different lighting areas.

Try the following techniques to fix light leaks:

— Create thicker walls.

— Add an Adaptive Probe Volumes Options override to your scene:

- Add a Volume, then an **Adaptive Probe Volumes Options** override to the Volume. This adjusts the position that GameObjects use to sample the light probes.
- Enable Rendering Layers:
    - In the Lighting window, configure the **Rendering Layer Masks** in the Adaptive Probe Volumes panel to allow the APV to assign a Rendering Layer Mask to each light probe.
- Adjust Baking Set properties:
    - If adding a Volume doesn't work, use the Adaptive Probe Volumes panel in the Lighting window to adjust Virtual Offset and Dilation settings.
- Use a Probe Adjustment Volume component:
    - Use this component to make light probes invalid in a small area. This triggers Dilation during baking, and improves the results of **Leak Reduction Mode** at runtime.

Rendering Layers

When switching the URP 3D Sample oasis environment from using light probes/lightmaps to using APV only, an issue arises with light leaks, which you can see on the bright roof and wall in the image below.

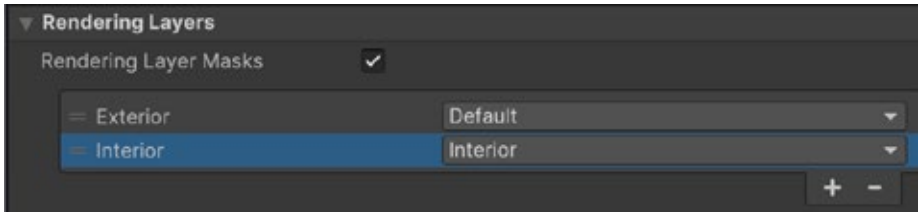
Light leaking in the tent in the oasis environment from the URP 3D Sample

This is because some pixels are blending between probes on the inside and outside of the tent. By using **Window > Analysis > Rendering Debugger > Probe Volumes > Debug Probe Sampling**, you can spot which probes are used when interpolating the value for a pixel.

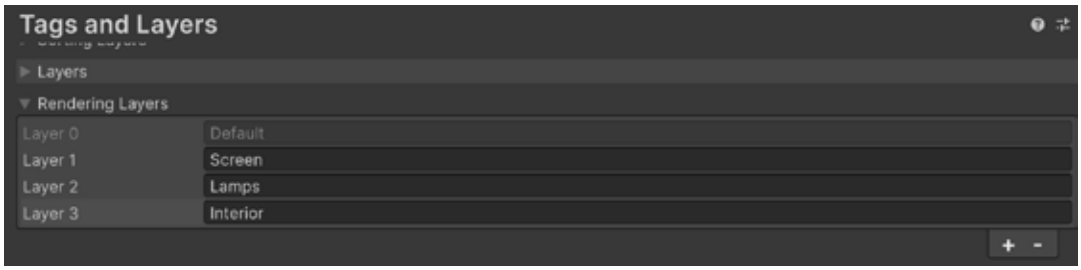
Viewing the interpolated probes for a pixel

One option to fix this is to use a **Volume** to modify how APV is sampled at runtime using the **Adaptive Probe Volume Options** override. Use the **NormalBias** and **ViewBias** settings to adjust the sampling position:: NormalBias pushes it along the normal (away from walls), while ViewBias pushes it towards the camera (keeping it on the same side of the wall as the camera). When you change these properties in the Volume, you can see the updates in real-time in both the lighting results and the **Debug Probe Sampling View**, where the sampling position and weights are updated accordingly. But a better option is to use Rendering Layers.

APV supports Rendering Layers, allowing you to create up to four different masks and restrict sampling to those specific masks for certain objects. This can be useful to prevent interior objects from sampling exterior probes, or vice versa. Activate and add them using **Window > Rendering > Lighting > Adaptive Probe Volumes > Rendering Layers**.



You'll also need to add a layer via **Project Settings > Tags and Layers > Rendering Layers**:



To implement this, edit the meshes themselves to ensure they are divided between the different areas you want to create. In this project, for example, the meshes are edited to separate the interior and exterior into multiple meshes. Once the meshes are split, assign the correct Rendering Layers to them, and specify which ones APV should use in the **Adaptive Probe Volume Tab**.

You don't need to assign layers to every object in the tent, only to those susceptible to leaking, like the walls or objects near the walls.

When generating lighting, the system will automatically assign layers to the probes during the bake process based on the nearby objects, eliminating the need to manually assign layers per probe. To facilitate this automatic probe assignment, you need to assign layers to larger objects. In the oasis environment tent example, the interior layer is assigned to the walls and ceiling of the tent to ensure that most of the interior probes hit them during baking and are automatically assigned to the interior mask. Probes are assigned to the layer they encounter most frequently.

Once this is done, click **Generate Lighting** and observe that leaking is eliminated for the tent, thanks to the separate interior and exterior masks.

Light leaks without and with rendering layers

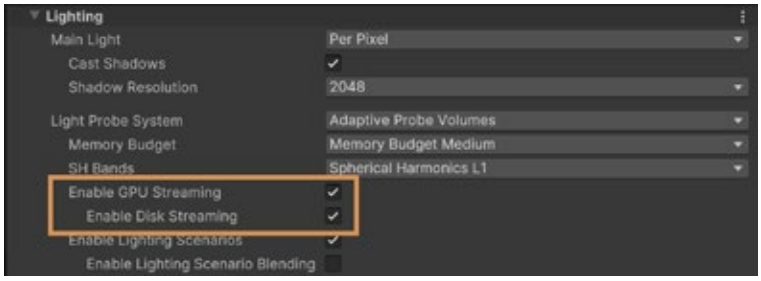
Get more information here about fixing issues with APVs.

Streaming APVs

APV streaming enables you to use APV-based lighting in large worlds. APV streaming bakes APV data that's larger than the available CPU or GPU memory, and loads it at runtime when it's needed. At runtime, as the camera moves, URP loads only APV data from cells within the camera's view frustum.

You can enable and disable streaming for different URP quality levels. Enable streaming with the following steps:

1. Select **Edit > Project Settings > Quality** from the main menu.
2. Select a Quality Level.
3. Double-click the Render Pipeline Asset to open it in the Inspector.
4. Expand the Lighting tab.
5. You can now enable two types of streaming:
    a. Enable Disk Streaming to stream from disk to CPU memory.
    b. Enable GPU Streaming to stream from CPU memory to GPU memory. You must enable Enable Disk Streaming first.

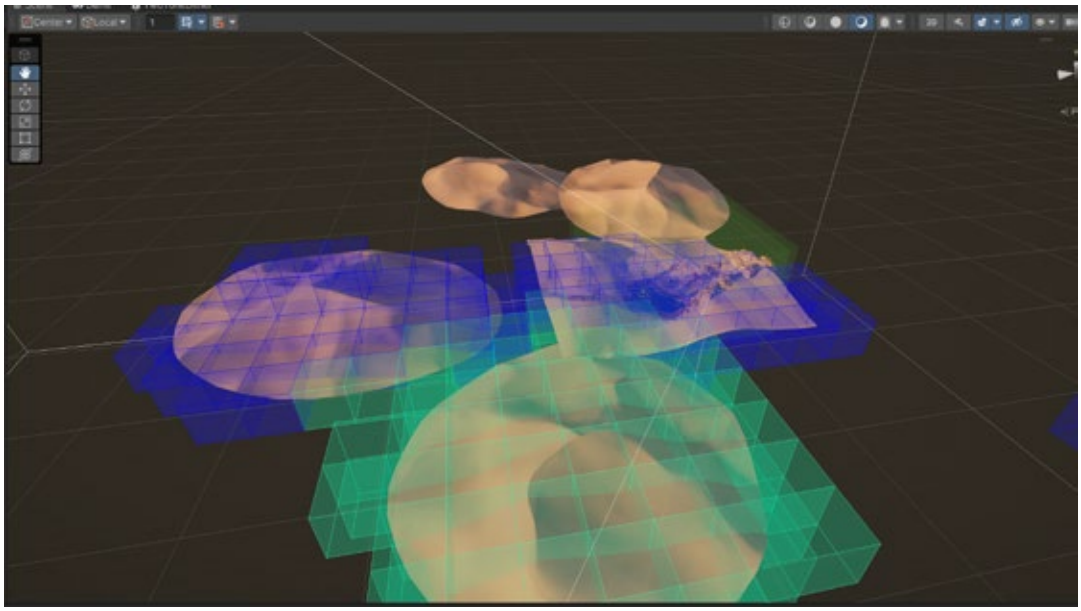


You can configure streaming settings in the same window. Refer to the URP Asset for more information.

Debug streaming

The smallest section URP loads and uses is a cell, which is the same size as the largest brick in an APV. You can influence the size of cells in an APV by adjusting the density of light probes

Use the Rendering Debugger to view the cells in an APV or debug streaming.



APV Streaming

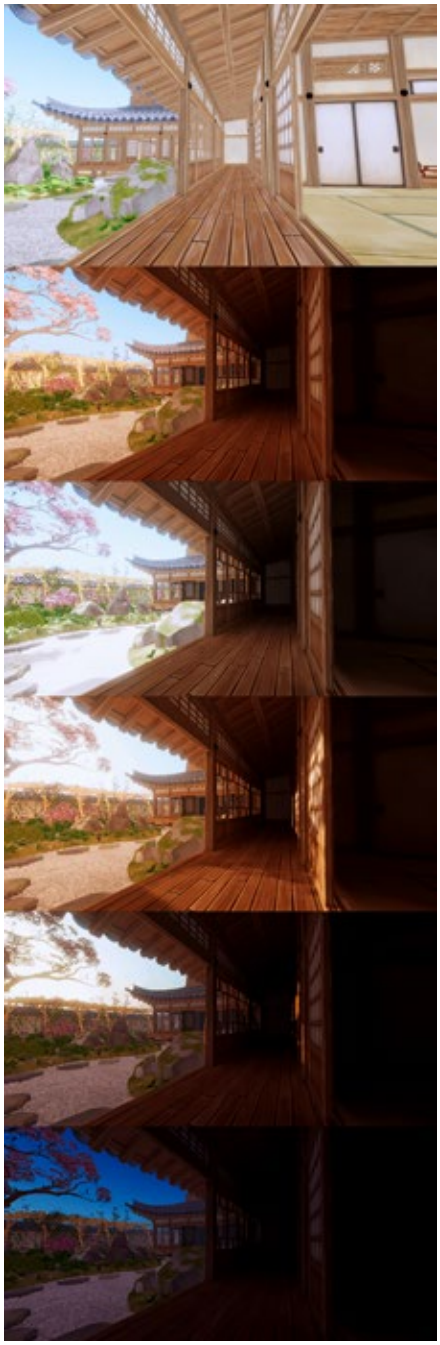
Sky occlusion

Sky occlusion is the process whereby if a GameObject samples a color from the sky, Unity will dim the color if the light can't reach the GameObject. Sky occlusion in Unity uses the sky color from the ambient probe, which updates at runtime. This means you can dynamically light GameObjects as the sky color changes. For example, you can change the sky color from light to dark to simulate the effect of a day-night cycle.

Note:
If you enable sky occlusion, APVs might take longer to bake, and Unity might use more memory at runtime.

When you enable sky occlusion, Unity bakes an additional static sky occlusion value into each probe in an APV. The sky occlusion value is the amount of indirect light the probe receives from the sky, including light that bounced off static GamesObjects.

The main benefit of using sky occlusion is you can modify the sky lighting at runtime.



Let's look at the series of images to the left to illustrate this:

a. The top image shows the problem that occurs when you can't bake the sky lighting because you need it to change at runtime. In this image only an ambient probe is used with no baking resulting in a poor result.

b. In the second to fifth images the ambient probe is used together with sky occlusion. You could also light this image with a regular APV bake, with sky occlusion disabled but then the lighting would not change at runtime.

An example of the results of using sky occlusion in a scene. The images are from the Unity Asset Store package Azure[Sky] Dynamic Skybox by 7stars.

Follow these steps to enable sky occlusion:

1. Enable the **Progressive GPU Lightmapper**. Unity doesn't support sky occlusion if you use Progressive CPU. Go to **Window > Rendering > Lighting**.
2. Go to the Scene panel.
3. Set Lightmapper to Progressive GPU.

4. Open the Adaptive Probe Volumes panel.
5. Enable Sky Occlusion.

To update the lighting data, you must also bake the APV after you enable or disable sky occlusion. Once the sky occlusion is baked, the scene lighting will respond to the ambient probe updates. In URP, the ambient probe is updated in real-time only when using the Color or Gradient Mode, not the Skybox mode. This means you'll probably have to manually animate a color to match the animated sky visuals.

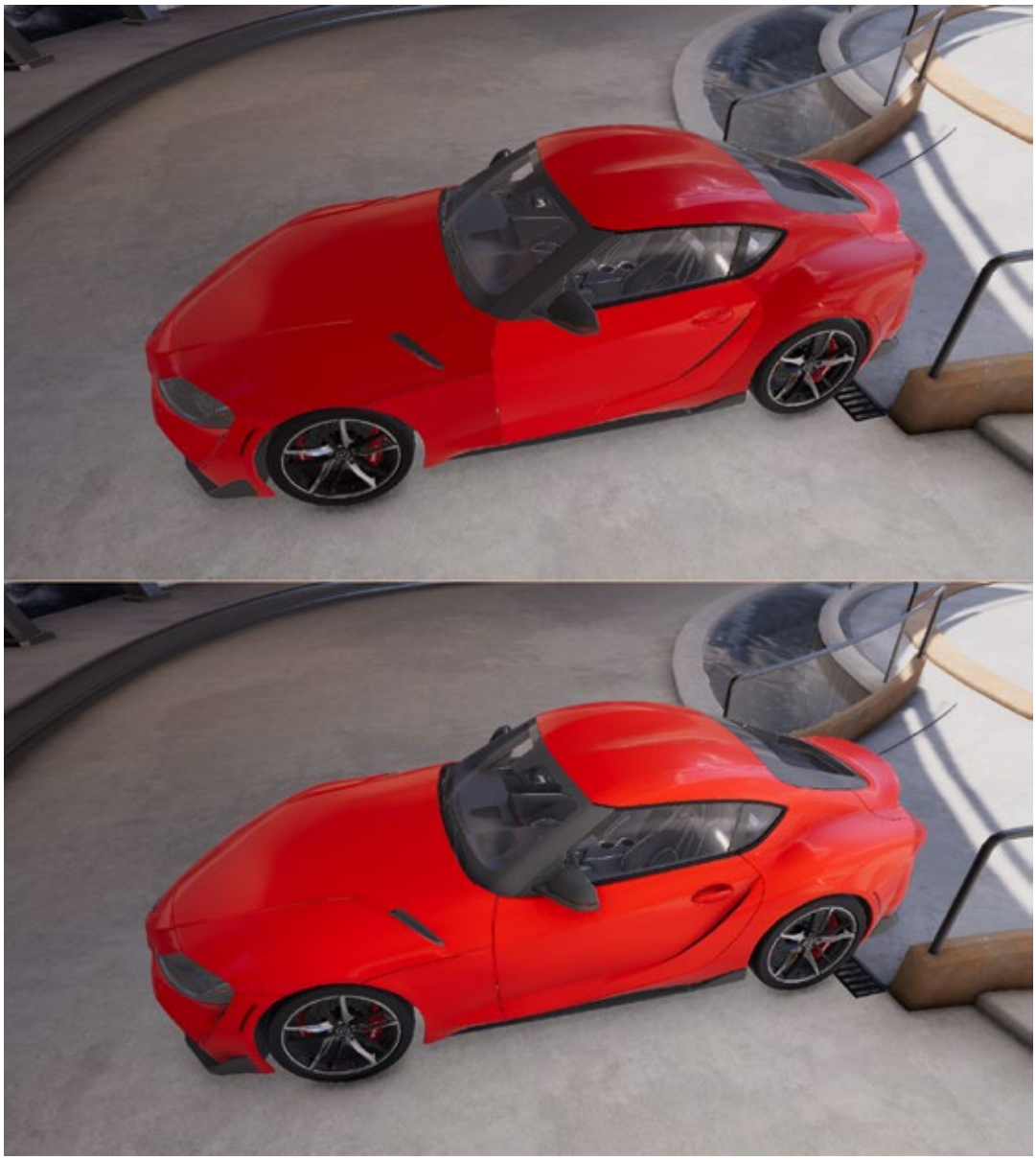
Note:
URP now supports per-vertex quality sampling for probes. This is especially useful to boost performance on lower-end devices. To set the sampling mode use the **URP Asset** in the Lighting section. **Advanced Properties** must be active to view the option; press the ellipsis at the top right of the Lighting panel to activate it. With Advanced Properties active, the **SH Evaluation Mode** dropdown will appear.

More Information

— Adaptive Probe Volumes documentation.

— GDC 2023 session: Efficient and impactful lighting with Adaptive Probe Volumes

Light probes vs APVs



Light Probe Groups in use in the top image, and APVs in the bottom image; images are from the Unity Asset Store package ArchVizPRO Photostudio URP by ArchVizPro

The bottom image (shown above) shows how smoothly a transition from dark to light works with APV. In the top image, the Light Probe Group results in a bright light on the car door because a single interpolated probe is used per object. This is because the door is a separate GameObject to the rest of the door and uses a different probe, resulting in a rendering error.

The table below compares the features of light probes and APVs.

Light Probe Groups	Adaptive Probe Volumes
Time-consuming to place probes and move them if geometry changes	Fast to place and easy to update as geometry changes
A single interpolated probe is used for lighting objects: — Objects cannot transition well from darkness to light and stand out. — It can cause problems for big objects.	Each pixel is individually lit: — This ensures smooth transitions. — Volumetric effects work well using APV because the APV grid is easy to sample at any location.
Static objects are usually lit using light maps. Only dynamic objects use probes.	No need for lightmaps or lightmap UVs: — Use a single lighting solution for all objects in a scene. — Light large worlds with a constrained memory budget.
Probes can be freely placed and moved at runtime.	Probes are placed in a grid structure and cannot be moved at run time.
Switch GI is not supported.	The Lighting Scenario asset allows for switching between different lighting, e.g., from day to night, turning a light on or off, and so on.

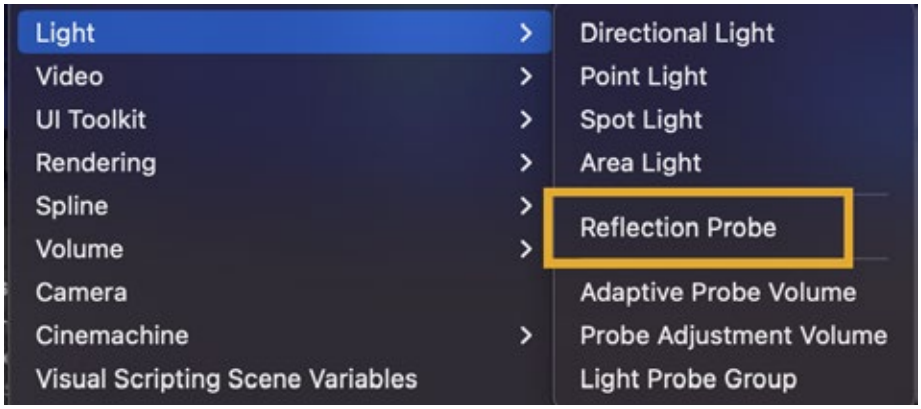
Reflection probes

A ray-tracing tool, such as Maya or Blender, can take the time to accurately calculate the values for each frame pixel of a reflective surface. This process takes far too long for a real-time renderer, which is why shortcuts are often used.

Reflections in a real-time renderer use environment maps (pre-rendered cubemaps). Unity supplies a default map using the SkyManager. Having a single map as the source of reflections from all locations in a scene can lead to unconvincing reflections. Take the example of the robot shown in this section. If the metal parts of this character always reflect the sky, then it will look very strange when inside the hangar where the sky is not visible. This is where reflection probes are helpful.

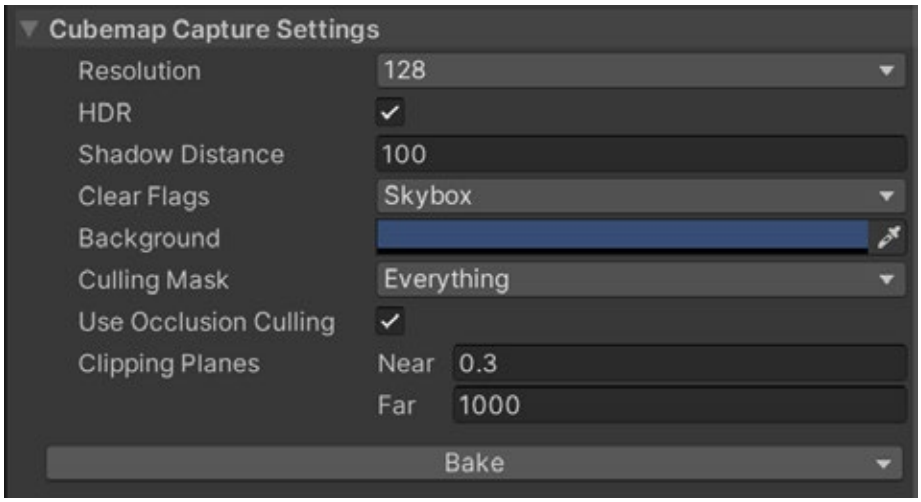
A Reflection Probe component is a pre-rendered cubemap placed at a key position in the scene. You can use several reflection probes in a single scene. As a dynamic object moves through the scene, it can select the nearest reflection probe and use that as the basis of its reflections. You can also set up the scene to blend between probes.

To add a Reflection Probe component, right-click the **Hierarchy** window and select **Light > Reflection Probe**.



Adding a Reflection Probe component

Then position the probe and adjust its settings. Once the probe is placed correctly and the settings are adjusted, click **Bake** to generate a cubemap.



Settings for the Reflection Probe component

The following image shows the two reflection probes used in FPS Sample: The Inspection, one inside the hangar and one outside.

Each reflection probe captures an image of its surroundings in a cubemap texture.

Reflection probe blending

Blending is a great feature of reflection probes. You can enable blending via the **Renderer Asset Settings** panel. Blending is always on when the Forward+ path is chosen, regardless of the Renderer Asset setting.

Blending gradually fades out one probe's cubemap, while fading in the other as the reflective object passes from one zone to the other. This gradual transition prevents a moving object from suddenly acquiring completely different reflections when crossing the boundary between two reflection probes.

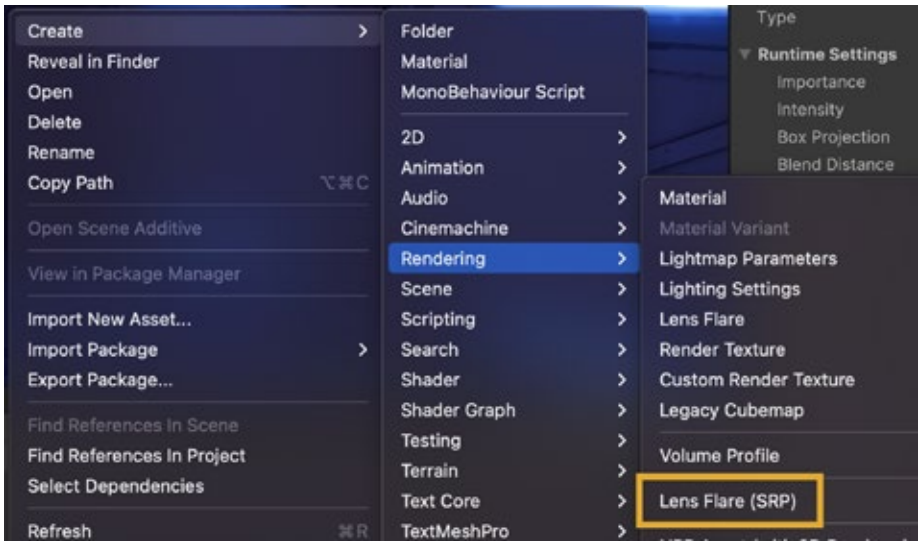
Box Projection

Normally, the reflection cubemap is assumed to be at an infinite distance from any given object. Different angles of the cubemap will be visible as the object turns, but it's not possible for the object to move closer or further away from the reflected surroundings. While this works well for outdoor scenes, its limitations show in an indoor scene. The interior walls of a room are clearly not an infinite distance away, and the reflection of a wall should get larger as the object nears it.

The Box Projection option enables you to create a reflection cubemap at a finite distance from the probe, allowing objects to show reflections of different sizes according to their distance from the cubemap's walls. The size of the surrounding cubemap is determined by the probe's zone of effect, depending on its Box Size property. For example, with a probe that reflects the interior of a room, you should set the size to match the dimensions of the room.

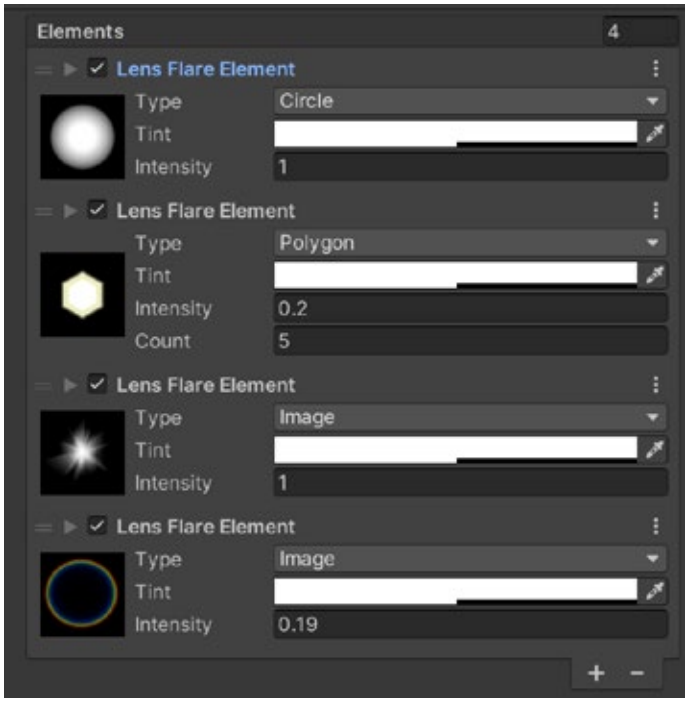
Lens flares

If you're coming to URP from using the Built-In Render Pipeline the workflow for creating a lens flare has been updated for URP. The first step in configuring it is to create a Lens Flare (SRP) Data asset. Right-click in the **Project** window, in a suitable Assets folder, and select **Create > Rendering > Lens Flare (SRP)**.



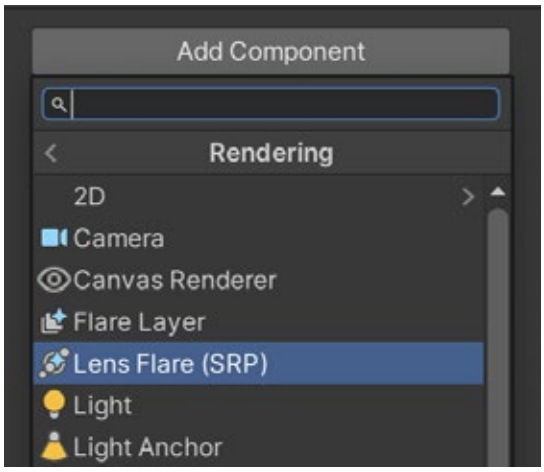
Creating a Lens Flare (SRP) Data asset

Use this asset to configure the shape of your flare by setting **Type** as Circle, Polygon, or Image assets and adjusting the Tint and Intensity settings.



Adding and configuring Lens Flare elements

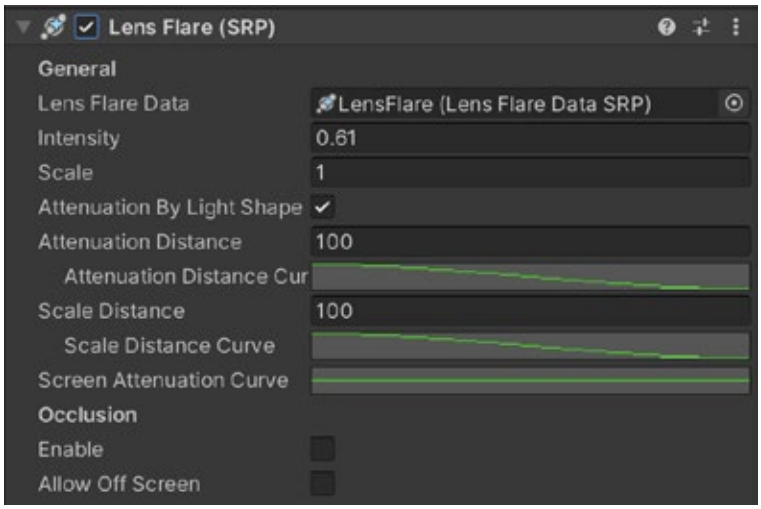
To render a lens flare, choose the light source that will cause the flare and then select **Add Component > Rendering > Lens Flare (SRP)**.



Setting up rendering for a lens flare

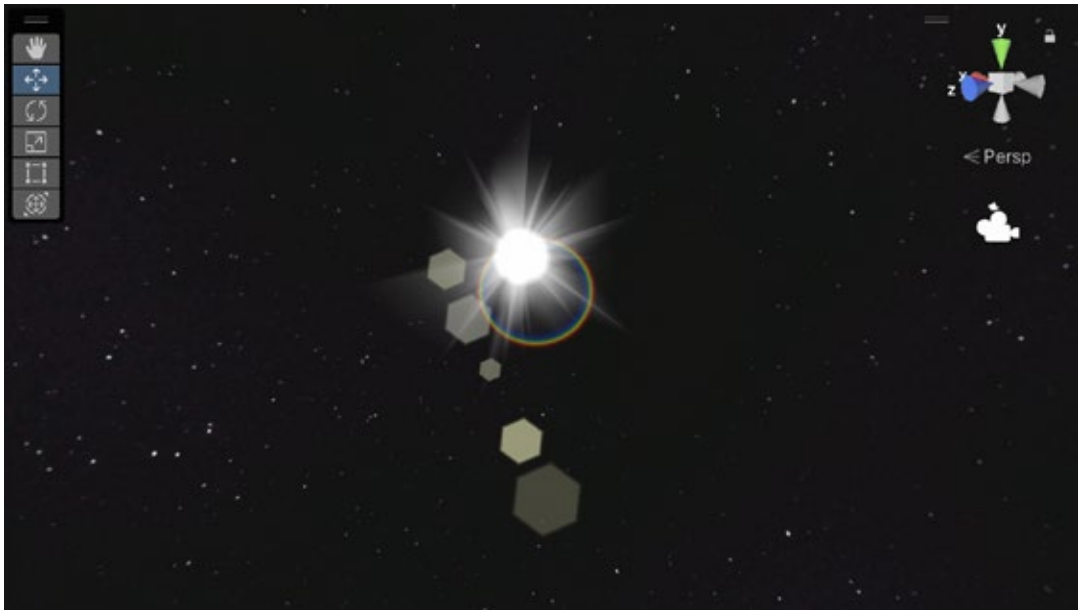
Select the Lens Flare Data Asset.

In the **Settings** panel for this component, assign the **Lens Flare Data asset** you created to the **Lens Flare Data property**.



Settings for the Lens Flare (SRP) component

If you use lens flares you'll find that the workflows for adding and adjusting them are very flexible.



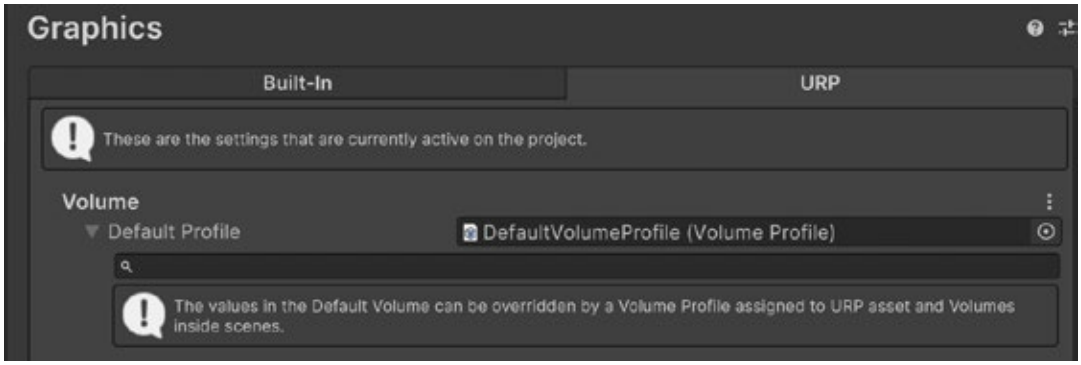
An example of a lens flare

Screen space lens flare

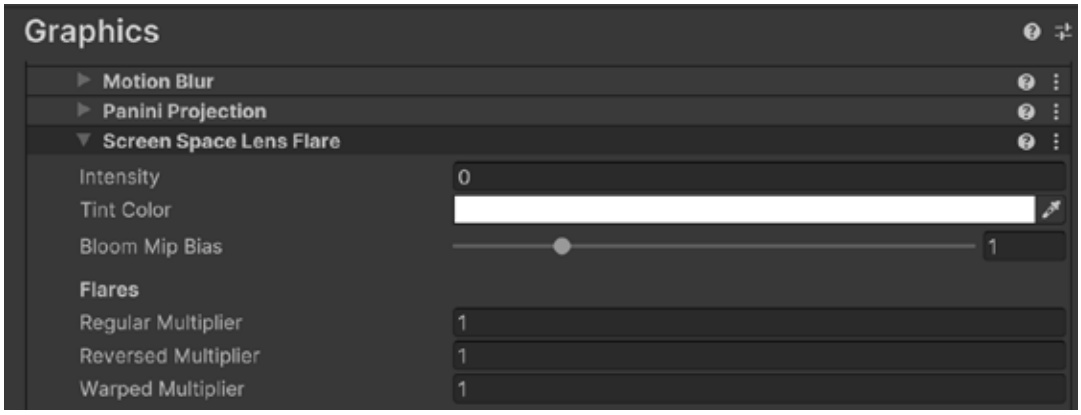
Setting up lens flares for multiple lights can be time consuming. Unity 6 introduces a new post-processing technique, the Screen Space Lens Flare override (SSLF). This technique can generate flares from any bright surface, such as a bright specular highlight or an emissive mesh. In contrast, the lens flare (SRP) effect is limited to generating flares specifically from lights. Screen space lens flare uses a post-production technique.

Follow these steps to use SSLF:

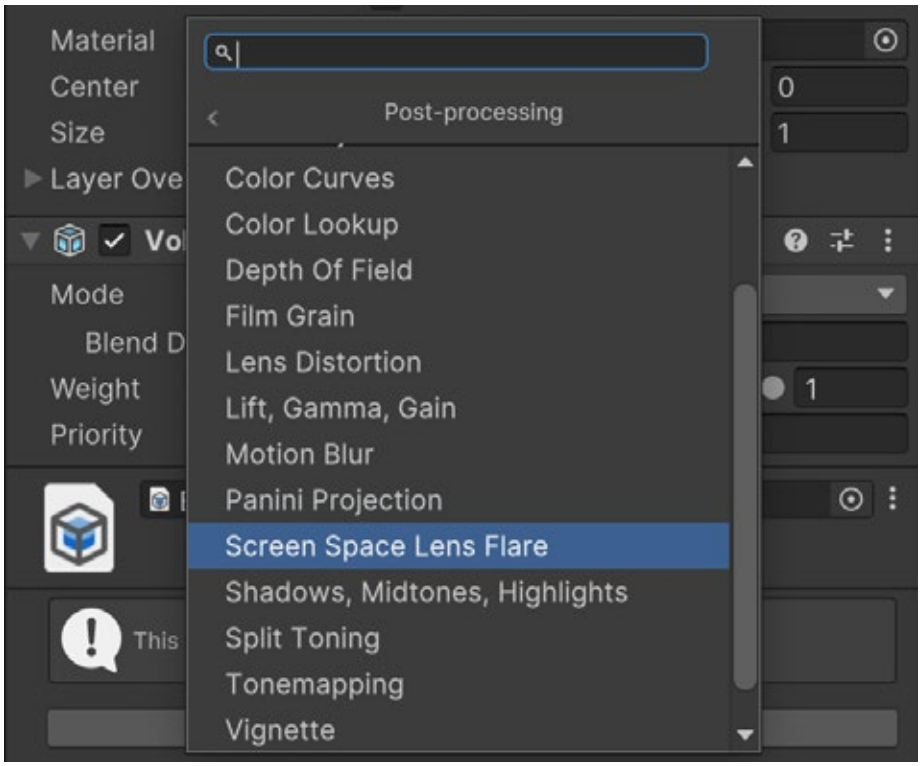
1. Because SSLF is a post-processing filter you use a Volume component to apply it. Either add a Volume component to your scene or use the new Default Volume in Unity 6. Settings for the Default Volume are adjusted using **Edit > Project Settings > Graphics**.



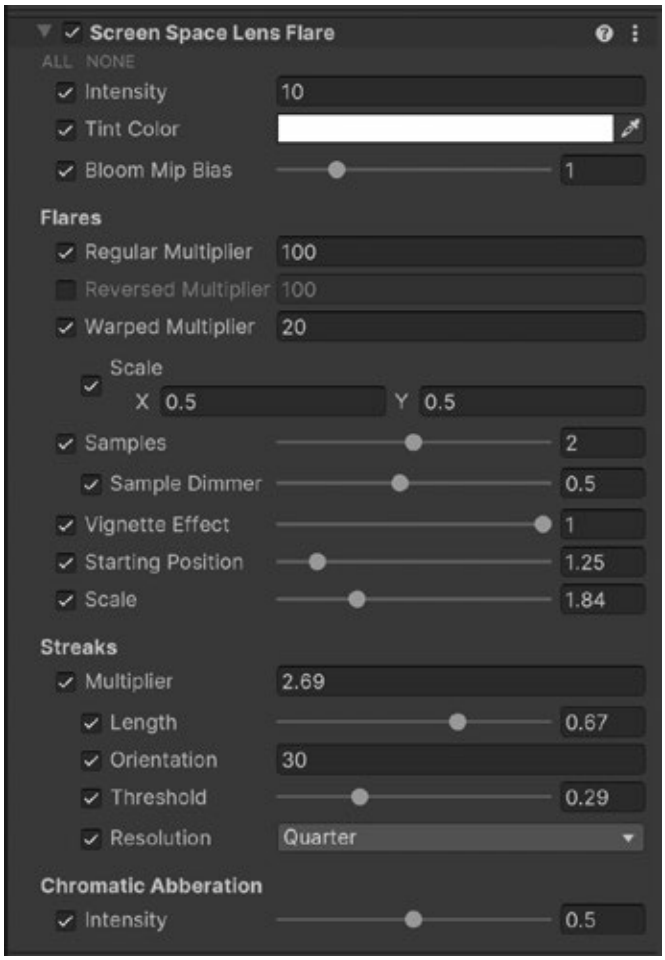
2. If using the Default Volume look for the Screen Space Lens Flare override in the settings panel.



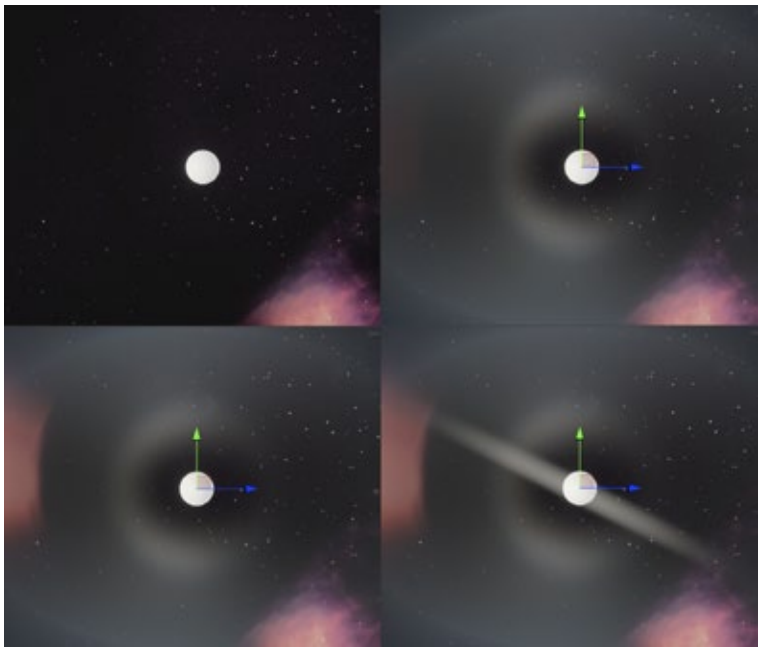
3. If using a scene Volume create a Volume Profile so you can add overrides. Then add the override via **Post-processing > Screen Space Lens Flare**.



4. Now you can experiment with the settings to achieve the desired style for your scene. Keep in mind that intensity needs to be more than 0.



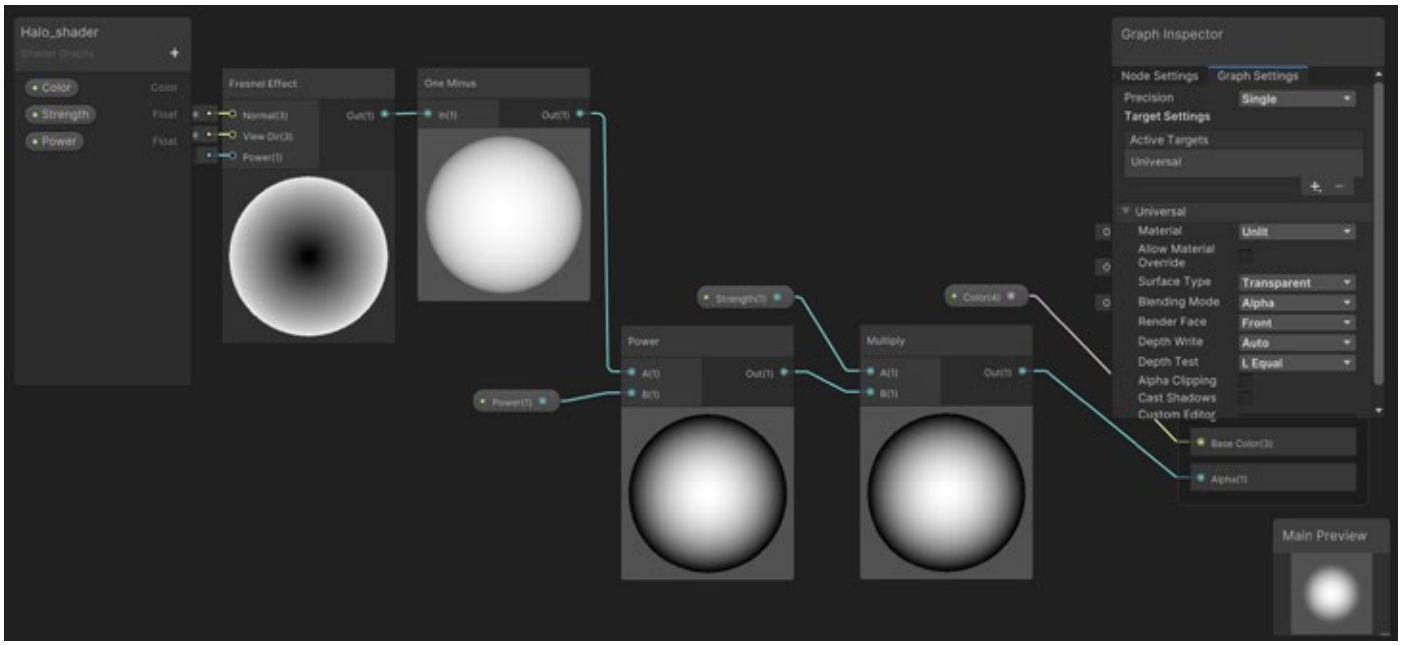
You can combine SSLF with a Lens Flare (SRP) component for more control.



Clockwise from top left: No SSLF; flares added; flares, warped flares, and streaks; flares and warped flares

Light halos

The **Draw Halo** property is not available for lights in URP, but it's easily mimicked with a billboard. Another option is to set the alpha transparency of a sphere. The first image below shows the Shader Graph for such a shader, and the second image depicts the result. For more information on using Shader Graph to create this shader, see the Additional tools chapter.

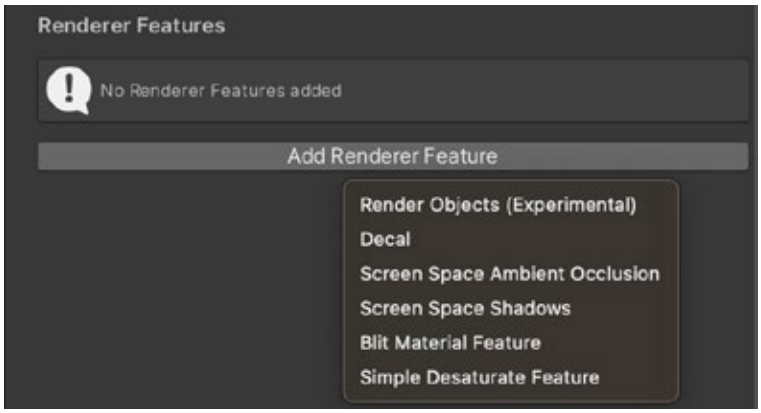


Fresnel transparency using Shader Graph

A halo effect that uses a sphere with a material using the Shader Graph shader from above

Screen Space Ambient Occlusion

Since ambient light does not consider geometry by default, high levels of ambient light can lead to unconvincing renders. In the real world, a narrow gap between two objects is likely to be darker than a much wider gap. Ambient occlusion can help deal with this issue in your Unity project. To use it with URP, select the Renderer that the URP Asset is using. Go to **Add Renderer Feature** and choose **Screen Space Ambient Occlusion** (SSAO).



Choosing SSAO from the Add Renderer Feature

Either use the default SSAO settings or adjust as needed:

The SSAO settings

Let's look at the SSAO properties.

— **Method**: This property defines the type of noise the SSAO effect uses.

— **Intensity**: This property defines the intensity of the darkening effect.

— **Radius**: When Unity calculates the ambient occlusion value, the SSAO effect takes samples of the normal texture within this radius from the current pixel. A lower Radius value improves performance because the SSAO Renderer Feature samples pixels closer to the source pixel.

- **Falloff Distance:** SSAO does not apply to objects farther than this distance from the Camera. A lower value increases performance in scenes that contain many distant objects.
- **Direct Lighting Strength:** This property defines how visible the effect is in areas exposed to direct lighting.
- **Quality**: For details about these quality settings, check the documentation
  - Source
  - Downsample
  - After Opaque
  - Blur Quality
  - Samples

A scene with only an ambient occlusion texture demonstrating a varying falloff distance

SSAO adds shading to narrow gaps. Let's look at the three images to the left:

The top image has no SSAO. The middle image shows the calculated SSAO, while the bottom image shows the result of SSAO. Notice that the grinder and scales have a stronger edge where they meet the desk.

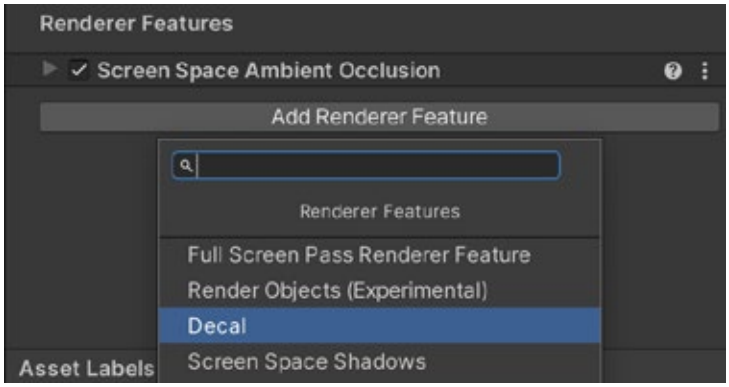
SSAO is a post-processing technique the details of which are covered later in this guide.

The haunted room in three versions: At the top, with no SSAO, in the middle, with SSAO applied, and at the bottom, rendered with SSAO

Decals

A Decal Projector

The Decal Projector component provides you with a great way of adding detail to a mesh. Use them for elements such as bullet holes, footsteps, signage, cracks, and more. Because they use a projection framework, they conform to an uneven or curved surface. To use a Decal Projector with URP, you need to locate your Renderer Data asset and add the **Decal Renderer Feature**.

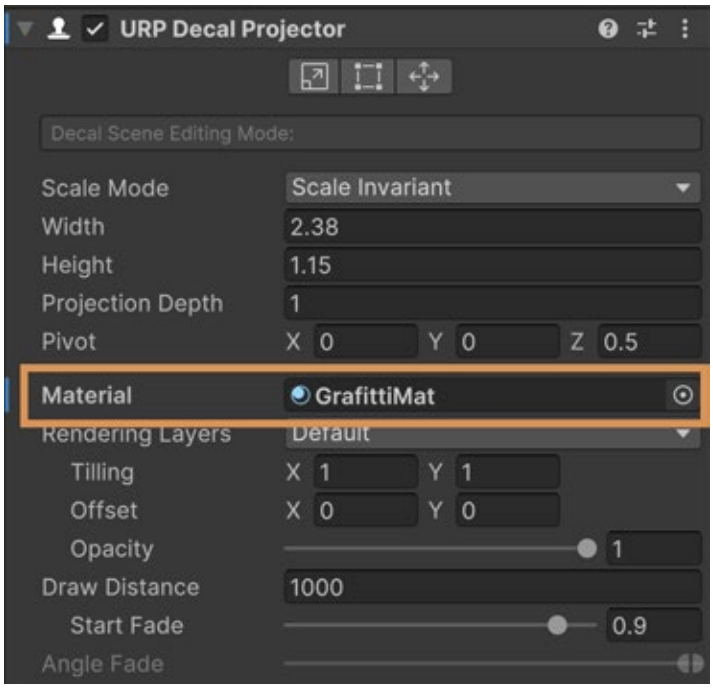


Adding the Decal Renderer Feature

For most purposes, you can accept the default settings.

Now your scene is ready for decals. Create a decal by right-clicking in the Hierarchy view and selecting **Rendering > URP Decal Projector.** By default, the projector uses the material Decal, which will project a white square onto a surface. Use the usual tools to position and orientate the projector. Adjust the **Width**, **Height**, and **Projection Depth** in the Inspector.

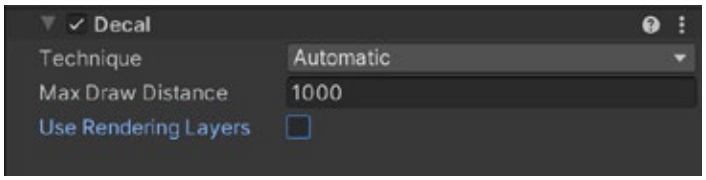
To customize the decal, create a material using the **Shader Graph > Decal** shader. Then assign it to the URP Decal Projector.



Decal Projector component settings

The Inspector for a Decal Projector includes three **Editing Mode** buttons: Scale, Crop, and Pivot/UV, which you can read about here.

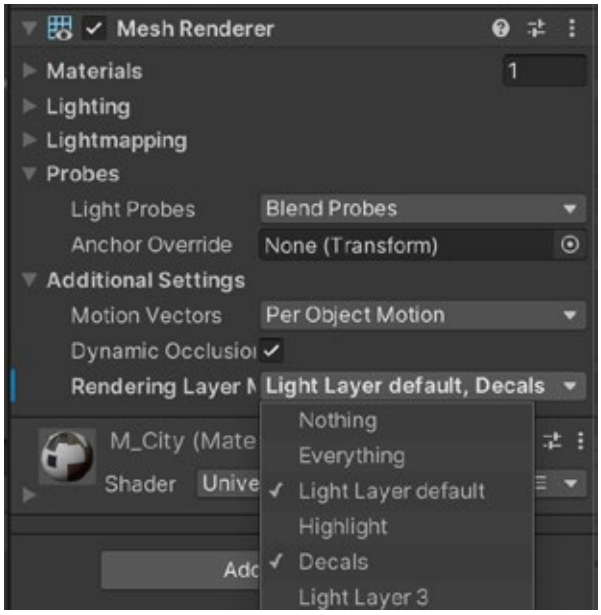
By default, the projector will affect any surface within its frustum. The Decal Renderer Feature includes the setting **Use Rendering Layers**. Enable this to facilitate targeting specific meshes.



Decal Renderer Feature settings

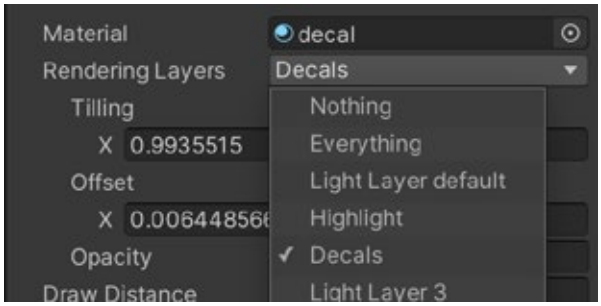
Refer back to the Rendering Layers section to learn about setting up and using this rendering option. Here are the steps to set up a decal:

1. Use **Edit > Project Settings ... > Tags and Layers > Rendering Layers** to name a Rendering Layer.
2. Select the mesh/meshes that you want to receive the projector. In the Inspector, find **Mesh Renderer > Additional Settings > Rendering Layer Mask**, and add the named Rendering Layer to the mask.



Adding Rendering Layer to the Mesh Renderer Rendering Layer Mask

3. Select the URP Decal Projector and in the Inspector, select the named Rendering Layer for the Rendering Layers property.



The image below shows the scene with and without a decal, and with a wall projection limited by using Rendering Layers.

From left to right: No decal in the image, the decal hitting all objects, and the decal applied to the wall only using Rendering Layers

Shaders

This section is for users who want to convert an existing custom shader to work with URP and/or want to write a custom shader in code without using Shader Graph. It provides the information required to port both basic and advanced shaders to URP from the Built-In Render Pipeline. The tables included show helpful samples of available HLSL shader functions, macros, and so on. In each case, a link is provided to the relevant include containing many other useful functions.

For those who already have experience coding shaders, the includes provide you with a clear idea of what's available in HLSL to write compact and efficient shaders. After considering the information here, hopefully porting your shaders to URP won't seem so daunting.

Another approach is to use Shader Graph to create versions of your custom shaders. An introduction to Shader Graph is provided in the Additional tools section.

Comparing URP and Built-In Render Pipeline shaders

URP shaders use the ShaderLab structure, as seen in the code snippet below. As such, Property, SubShader, Tags, and Pass will all be familiar to shader coders.

```
SubShader {
  Tags {“RenderPipeline” = “UniversalPipeline” }
   Pass {
      HLSLPROGRAM
      ...
      ENDHLSL
   }
}
```

The basic structure of a SubShader block

The first thing to notice is that a URP shader uses the key-value pair `“RenderPipeline” = “UniversalPipeline”` in the SubShader tag.

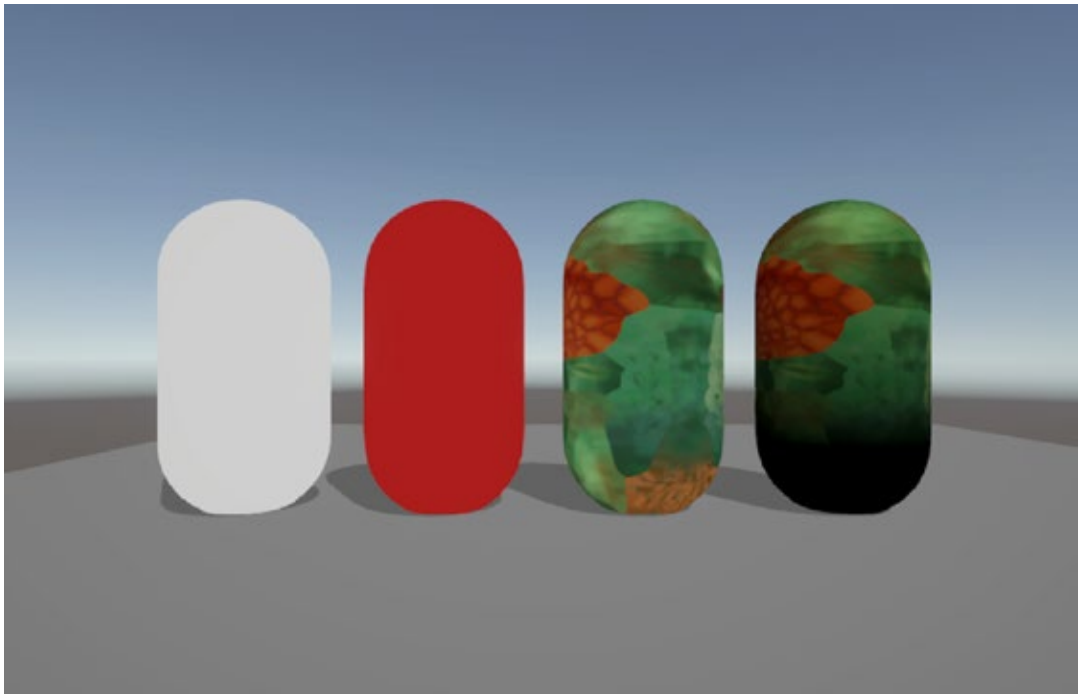
A SubShader tag with the name `RenderPipeline` tells Unity which render pipelines to use this SubShader with. The value of `UniversalPipeline` indicates that Unity should use this SubShader with URP.

Looking at the render pass code, you’ll see the shader code contained between the `HLSLPROGRAM / ENDHLSL` macros. For URP, the shader code inside those passes is written in HLSL.

Unity will use the first SubShader block that is supported on the GPU. If the first SubShader block doesn’t have a `“RenderPipeline” = “UniversalPipeline”` tag, it won’t run in the URP. Instead, Unity will try to run the next SubShader, if any. If none of the SubShaders are supported, Unity will render the well-known magenta error shader.

Custom shaders

If you start creating a custom shader by using **Create > Shader > Unlit Shader** you’ll get a template intended for the Built-In Render Pipeline. It will use code that makes it incompatible with the SRP Batcher. Why does this happen? For most purposes developers will find using Shader Graph a more convenient route for custom shaders for the URP. However, many developers will have shaders that they have created over many years using Unity and will want to know how best to use these with the URP. This section will point you in the right direction using five examples. If you want to view the scene in the Editor it is available via **Shaders > Shaders** in the examples repo mentioned earlier. For more information checkout the documentation.



Shaders in URP, from the left: Unlit hard coded white; unlit using property to set color; unlit using a texture; simple Lambert lighting using the Main Light - floor; for more information on how to access and use shadows, see the “Shadows” section further down

Unlit

Let’s unpack the simplest of shaders, a basic unlit example:

- Every visible pixel using this shader will be set to the same color.
- **Properties** are empty because the color is hard set.
- In **Tags** the **RenderType** is set to **Opaque** and **RenderPipeline** is set to **UniversalPipeline**. The #include to use is **Core.hlsl** which contains a large number of useful functions and macros.
    - If you’re familiar with Built-In shaders then this serves a similar purpose to UnityCG.cginc. The function `TransformObjectToHClip` is found in the Core.hlsl include. The purpose of this function is to convert Object Space to Homogenous Space.
- The vertex shader vert simply sets the positionHCS value of the **Varyings** struct that is passed to the fragment shader `frag`.
- HLSL uses semantics for all values passed between shader stages. A semantic is a string attached to a shader input or output that conveys information about the intended use of a parameter.
    - For example, with **Attributes** `positionOS`, the semantic is `POSITION`. When compiling `POSITION` in a vertex shader is the position in Object Space for a vertex.

The fragment shader simply returns white resulting in the white capsule on the left in the image above.

```
Shader “CustomURP/Unlit”
{
  Properties
  { }
  SubShader
  {
      Tags { “RenderType” = “Opaque” “RenderPipeline” = “UniversalPipeline” }
      Pass
      {
          HLSLPROGRAM

          #pragma vertex vert
          #pragma fragment frag
          #include “Packages/com.unity.render-pipelines.universal/ShaderLibrary/Core.hlsl”
          struct Attributes
          {
              float4 positionOS   : POSITION;
          };
          struct Varyings
          {
              float4 positionHCS  : SV_POSITION;
          };
          Varyings vert(Attributes IN)
          {
              Varyings OUT;
              OUT.positionHCS = TransformObjectToHClip(IN.positionOS.xyz);
              return OUT;
          }
          half4 frag() : SV_Target
          {
              half4 customColor = half4(1, 1, 1, 1);
              return customColor;
          }

          ENDHLSL
      }
  }
}
```

Unlit Color

— For the second shader example, unlit color, you'll need to include a property to set the color.Use an attribute, `[MainColor]`; this is optional but helps inform Unity how to use the property. The name of the property is `_BaseColor`, the name in the Inspector is **Base Color** and the type is a `Color`.

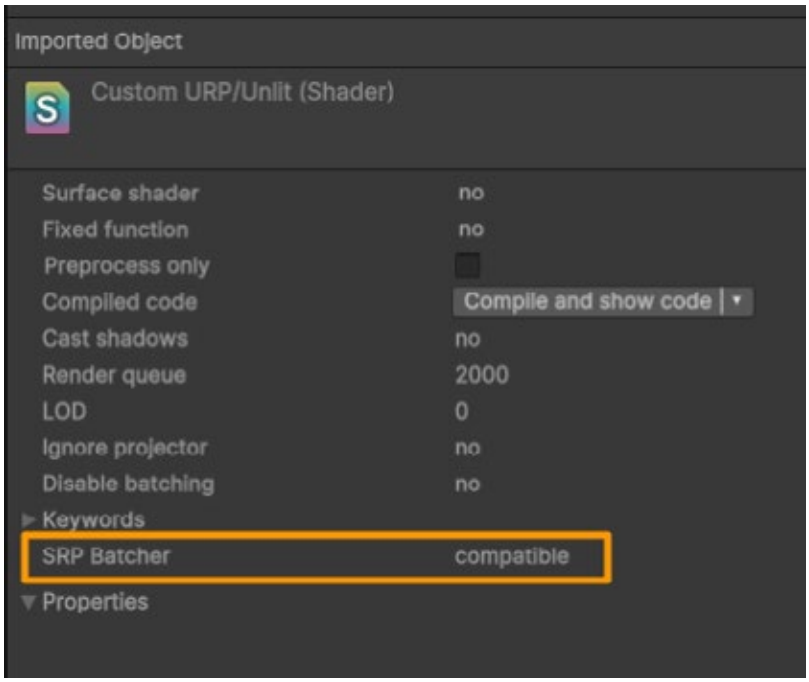
— Shader variables with URP must be compatible with SRP Batcher. In this example compatibility is achieved by declaring them inside two macros `CBUFFER_START(UnityPerMaterial)` and `CBUFFER_END` (described as a `CBUFFER` block).

— Now the fragment shader returns the value of `_BaseColor`.

```
Shader "CustomURP/UnlitColor"
{
    Properties
    {
        [MainColor] _BaseColor("Base Color", Color) = (1, 1, 1, 1)
    }
    SubShader
    {
        Tags { "RenderType" = "Opaque" "RenderPipeline" = "UniversalPipeline" }
        Pass
        {
            HLSLPROGRAM
            #pragma vertex vert
            #pragma fragment frag
            #include "Packages/com.unity.render-pipelines.universal/ShaderLibrary/Core.hlsl"
            struct Attributes
            {
                float4 positionOS   : POSITION;
            };
            struct Varyings
            {
                float4 positionHCS  : SV_POSITION;
            };
            CBUFFER_START(UnityPerMaterial)
                half4 _BaseColor;
            CBUFFER_END
            Varyings vert(Attributes IN)
            {
                Varyings OUT;
                OUT.positionHCS = TransformObjectToHClip (IN.positionOS.xyz);
                return OUT;
            }
```

```
            half4 frag() : SV_Target
            {
                return _BaseColor;
            }
            ENDHLSL
        }
    }
}
```

To confirm if the shader is SRP Batcher compatible, select the shader and check the Inspector which will indicate if the shader is SRP Batcher compatible.



The shader's Inspector will indicate if it's compatible with the SRP Batcher.

Unlit Textured

The third example in the image uses a texture.

— The shader has a property named `_BaseMap`, (in the Inspector it's called **Base Map**) that uses the attribute `[MainTexture]`and the type 2D.

— To use a texture you need interpolated UV values passing from the vertex to the fragment shader. You add a `float2, uv`, with semantic `TEXCOORD0`, to both the `Attributes` and the `Varyings` structs.

— Just before the `CBUFFER` block, add two macros: `TEXTURE2D` which takes the property `_BaseMap`, and `SAMPLER(sampler_BaseMap)`.

— For tiling and offset to work you need a `float4` defining that uses the name of the 2D property with the suffix _ST. This is essential when using the macro `TRANSFORM_TEX`, which is used by the vertex shader. The macro takes the vertex UV value, in this example `IN.uv`, and a 2D property that has been declared using the `TEXTURE2D` macro. It ensures tiling and offsets are supported.

— The fragment shader uses the macro `SAMPLE_TEXTURE2D`. This takes three parameters – a Texture2D, a sampler, and the UV value, and returns a color value. This value is returned in the `frag` method.

```
Shader “CustomURP/UnlitTexture”
{
   Properties
   {
       [MainColor] _BaseColor(“Base Color”, Color) = (1, 1, 1, 1)
       [MainTexture] _BaseMap(“Base Map”, 2D) = “white” {}
   }
   SubShader
   {
       Tags { “RenderType” = “Opaque” “RenderPipeline” = “UniversalPipeline” }
       Pass
       {
           HLSLPROGRAM
           #pragma vertex vert
           #pragma fragment frag
           #include “Packages/com.unity.render-pipelines.universal/ShaderLibrary/Core.hlsl”
           struct Attributes
           {
               float4 positionOS   : POSITION;
               float2 uv           : TEXCOORD0;
           };
           struct Varyings
           {
               float4 positionHCS  : SV_POSITION;
               float2 uv           : TEXCOORD0;
           };
           TEXTURE2D(_BaseMap);
           SAMPLER(sampler_BaseMap);
           CBUFFER_START(UnityPerMaterial)
               half4 _BaseColor;
               float4 _BaseMap_ST;
           CBUFFER_END
           Varyings vert(Attributes IN)
           {
```

```
            Varyings OUT;
            OUT.positionHCS = TransformObjectToHClip (IN.positionOS.xyz);
            OUT.uv = TRANSFORM_TEX(IN.uv, _BaseMap);
            return OUT;
        }
        half4 frag(Varyings IN) : SV_Target
        {
            half4 color = SAMPLE_TEXTURE2D(_BaseMap, sampler_Base Map, IN.uv);
            return color;
        }
        ENDHLSL
    }
  }
}
```

Lit Simple

— To use lighting in a URP shader add the include **Lighting.hlsl**, which is in the same folder as **Core.hlsl**.

— This example shader uses the main light – the directional light with the greatest intensity. It also uses the Lambert technique, calculating at the vertex level and using the interpolated value in the fragment shader. Therefore, you need to update the `Varyings` struct adding a `half3 lightAmount` with semantic `TEXCOORD2`.

— The vertex shader has a `VertexNormalInputs` using the function `GetVertexNormalInputs`. This function takes a normal in object space and converts it to world space.

  — For a centered object you can use the object space position as a proxy to the normal. `VertexNormalInputs` is a struct containing a `float4` value, `normalWS`.

— You get details of the main light using the function `GetMainLight`. This returns a `Light` struct containing, amongst other data, the light color and direction.

— Finally, in the `vert` function, you use the function `LightingLambert` to return the lighting at the current vertex. The `LightingLambert` function takes three parameters – light color, light direction, and a world space normal. At this point you have all the necessary data to call the function. It returns a `half3`.

— The fragment shader uses the macro `SAMPLE_TEXTURE2D`. This takes three parameters – a Texture2D, a sampler, and a float2 value, uv. You multiply this by the `lightAmount` after bouncing this up to a `half4` by adding an additional `w` value set to 1.

```
Shader “CustomURP/LitSimple”
{
   Properties
   {
       [MainColor] _BaseColor(“Base Color”, Color) = (1, 1, 1, 1)
       [MainTexture] _BaseMap(“Base Map”, 2D) = “white” {}
   }
   SubShader
   {
       Tags { “RenderType” = “Opaque” “RenderPipeline” = “UniversalPipeline” }
       Pass
       {
           HLSLPROGRAM
           #pragma vertex vert
           #pragma fragment frag
           #include “Packages/com.unity.render-pipelines.universal/ShaderLibrary/Core.hlsl”
           #include “Packages/com.unity.render-pipelines.universal/ShaderLibrary/Lighting.hlsl”
           struct Attributes
           {
               float4 positionOS   : POSITION;
               float2 uv           : TEXCOORD0;
           };
           struct Varyings
           {
               float4 positionHCS  : SV_POSITION;
               float2 uv           : TEXCOORD0;
               half3 lightAmount   : TEXCOORD2;
           };
           TEXTURE2D(_BaseMap);
           SAMPLER(sampler_BaseMap);
           CBUFFER_START(UnityPerMaterial)
               half4 _BaseColor;
               float4 _BaseMap_ST;
           CBUFFER_END
           Varyings vert(Attributes IN)
           {
               Varyings OUT;
               OUT.positionHCS = TransformObjectToHClip(IN.positionOS.xyz);
               OUT.uv = TRANSFORM_TEX(IN.uv, _BaseMap);
               VertexNormalInputs positions =
               GetVertexNormalInputs(IN.positionOS);
               Light light = GetMainLight();
```

```
                OUT.lightAmount = LightingLambert(light.color, light.direction, positions.normalWS.xyz);
                return OUT;
            }
            half4 frag(Varyings IN) : SV_Target
            {
                half4 color = SAMPLE_TEXTURE2D(_BaseMap, sampler_BaseMap, IN.uv) * half4(IN.lightAmount, 1);
                return color;
            }
            ENDHLSL
        }
    }
}
```

Shadows

— To control the strength of the shadow add a property `_ShadowStrength`, which is called **Shadow Strength** in the Inspector. It is a `Float` value initialized to 0.5. Add this value to the `CBUFFER` block.

  — To use shadows you need the `pragma, multi_compile`, adding: `_MAIN_LIGHT_SHADOWS`

  — `MAIN_LIGHT_SHADOWS_CASCADE`

  — `_MAIN_LIGHT_SHADOWS_SCREEN`

— The `Varyings` struct has a `float4` value `shadowCoords` using the semantic `TEXCOORD3`.

— In the `vert` function you use the function `GetVertexPositionInputs`, to convert object space to world space. Now you can convert the vertex position to a position on the shadow map using the function `GetShadowCoord`. Save this as the `Varyings` value, `shadowCoords`.

— In the `frag` function the `shadowAmount` uses the function `MainLightRealtimeShadow` passing the interpolated `shadowCoord`. `Strength,` is set to one minus `_ShadowStrength`. The `color` value is the `_BaseColor` modulated by the maximum of `strength` and `shadowAmount`.

```
Shader “CustomURP/SimpleShadows”
{
   Properties
   {
       [MainColor] _BaseColor(“Base Color”, Color) = (1, 1, 1, 1)
       _ShadowStrength(“Shadow Strength”, Float) = 0.5
   }
   SubShader
   {
       Tags { “RenderType” = “AlphaTest” “RenderPipeline” =  “UniversalPipeline” }
       Pass
       {
           HLSLPROGRAM
           #pragma vertex vert
           #pragma fragment frag
           #pragma multi_compile _ _MAIN_LIGHT_SHADOWS _MAIN_LIGHT_
           SHADOWS_CASCADE _MAIN_LIGHT_SHADOWS_SCREEN
           #include “Packages/com.unity.render-pipelines.universal/
           ShaderLibrary/Lighting.hlsl”
           struct Attributes
           {
               float4 positionOS  : POSITION;
           };
           struct Varyings
           {
               float4 positionCS  : SV_POSITION;
               float4 shadowCoords : TEXCOORD3;
           };
           CBUFFER_START(UnityPerMaterial)
               half4 _BaseColor;
               float _ShadowStrength;
           CBUFFER_END
           Varyings vert(Attributes IN)
           {
               Varyings OUT;
               OUT.positionCS = TransformObjectToHClip(IN.positionOS.xyz);
               VertexPositionInputs positions =
               GetVertexPositionInputs(IN.positionOS.xyz);
               // Convert the vertex position to a position on the shadow map
               float4 shadowCoordinates = GetShadowCoord(positions);
               OUT.shadowCoords = shadowCoordinates;
               return OUT;
           }
           half4 frag(Varyings IN) : SV_Target
           {
```

```
                // Get the value from the shadow map at the shadow coordinates
                half shadowAmount = MainLightRealtimeShadow(IN.shadowCoords);
                half strength = 1.0 - _ShadowStrength;
                half4 color = _BaseColor * max(strength, shadowAmount);

                return color;
            }

            ENDHLSL
        }
    }
}
```

Custom shaders require some work when upgrading to URP. These tables of functions will be helpful.

— Transform positions in a custom URP shader

— Use the camera in a custom URP shader

— Use lighting in a custom URP shader

— Use shadows in a custom URP shader

See this step-by-step video tutorial that uses a Unity project to show how to convert a custom unlit Built-In shader to URP.

See the tutorial

Note: A great resource for users planning to write shaders for URP is this tutorial by Cyanilux.

Pipeline callbacks

A great feature of SRPs is that you can add code at just about any stage of the rendering process using a C# script. Scripts can be injected at stages such as:

— Rendering shadows

— Rendering prepasses

— Rendering G-buffer

— Rendering deferred lights

— Rendering opaques

— Rendering Skybox

— Rendering transparents

— Rendering post-processing

You can inject scripts in the rendering process via the **Add Renderer Feature** option in the Inspector for the **Universal Renderer Data Asset**. Remember, when using URP, there is a Universal Renderer Data object and a URP Asset. The URP Asset has a Renderer List with at least one Universal Renderer Data object assigned. It is the asset you assign in **Project Settings > Graphics > Scriptable Render Pipeline Settings**.

If you are experimenting with multiple setting assets for different scenes, then attaching the following script to your Main Camera can be useful. Set the **Pipeline Asset** in the Inspector. Then it will switch the asset when the new scene is loaded.

```
using UnityEngine;
using UnityEngine.Rendering;
using UnityEngine.Rendering.Universal;
[ExecuteAlways]
public class AutoLoadPipelineAsset : MonoBehaviour
{
       public UniversalRenderPipelineAsset pipelineAsset;
       // Start is called before the first frame update
       void OnEnable()
       {
           if (pipelineAsset)
           {
                GraphicsSettings.defaultRenderPipeline = pipelineAsset;
             QualitySettings.renderPipeline = pipelineAsset;
           }
       }
}
```

Script to switch Universal Render Pipeline Asset on scene load

The next section covers two different types of Renderer Features, one for artists and the other for experienced programmers.

Render Objects

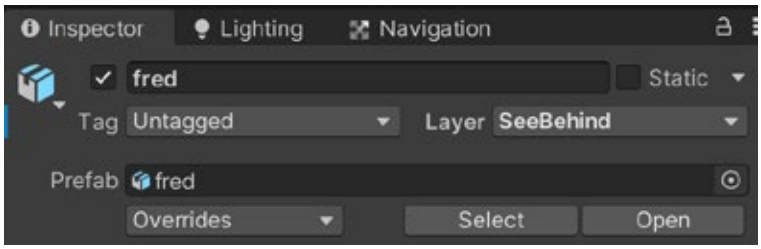
A common problem in games is losing sight of the player character as they disappear behind environment objects. You could attempt to move the Camera so that the character is always in view, or adjust the environment to be as open as possible. But such options are not always available. A good trick is to show a silhouette of the character when an environment model appears between the character and the Camera, as shown in the image below.

Showing a silhouette when an environment model masks the character

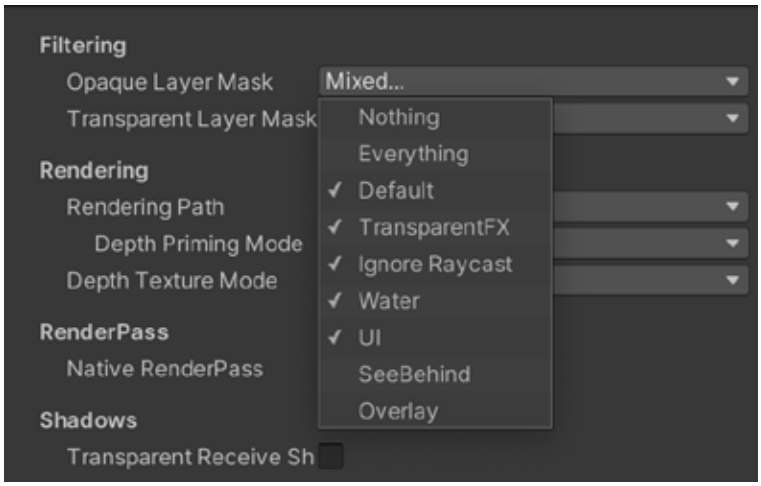
Here's how you can you create this silhouette:

1. First, you need a material to use when the character is masked. Create a material and set the shader to **Universal Render Pipeline > Lit or Unlit** (the previous image shows the Lit option). Set the **Surface Inputs > Base Map** color. In this example, the material is called Character.

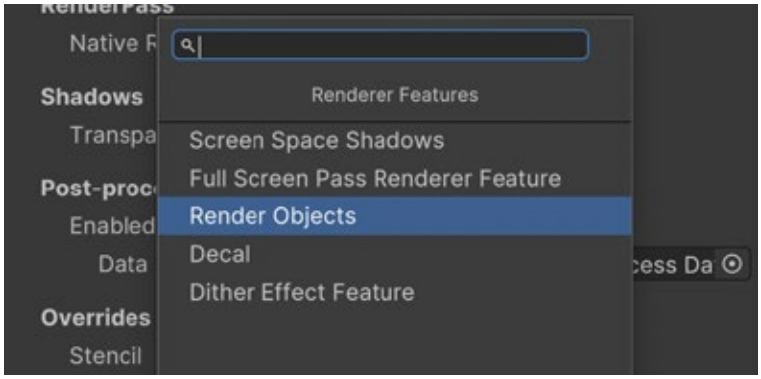
2. To avoid rendering the character more times than necessary, let's place it on a special layer. Select the character, add a **SeeBehind** layer to the Layers list and select it for the character.



3. Select the **Renderer Data** object used by the URP Asset. Go to the **Opaque Layer Mask** and exclude the SeeBehind layer. The character will then disappear.

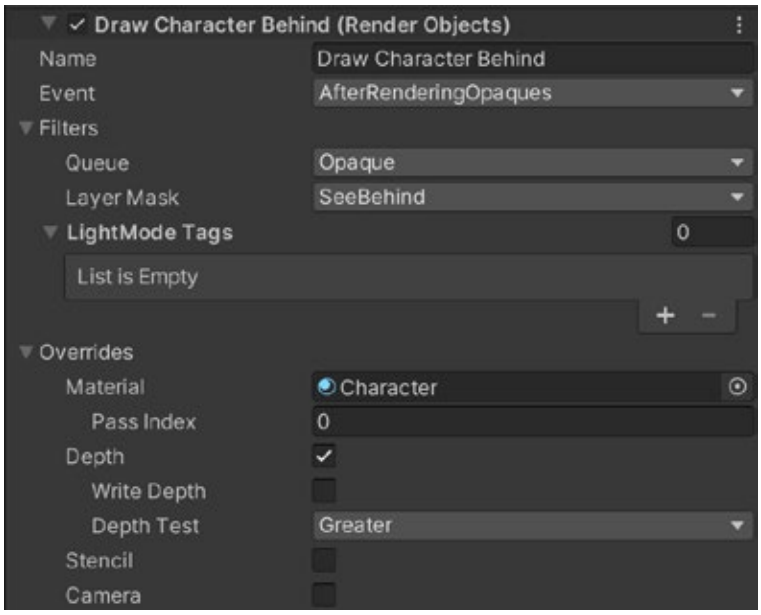


4. Click **Add Renderer Feature** and select **Render Objects**.

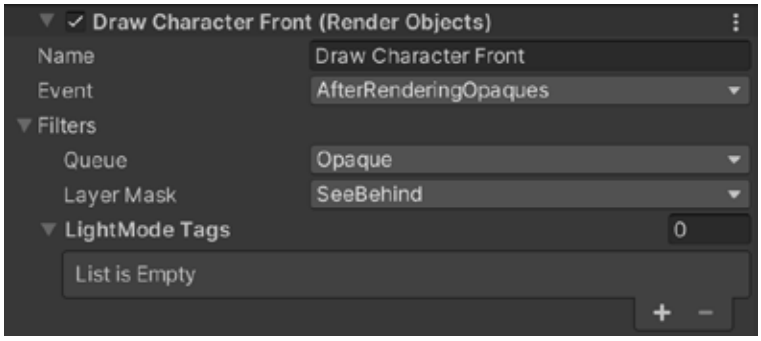


5. Fill out the settings for this Render Object's **Pass**. Give it a name and choose when the render should be triggered. In this example, it's called AfterRenderingOpaques.

   Set the **Layer Mask** to the **SeeBehind** layer, which was the layer chosen for the character. Expand the **Overrides** and set the **Override Mode** to **Material**. Select the material created in step 1. You'll want to use **Depth** when rendering, without having to update the depth buffer by writing to it. Set the **Depth Test** to **Greater** so that this Pass only renders when the distance to the rendered pixel is further from the Camera than the distance currently stored in the depth buffer.



6. At this stage, you only see the silhouette of the character when it's behind another object. You don't see the character at all when it's in full view. To fix this, add another **Render Objects** feature. This time you don't need to update the Overrides panel. This Pass will draw the character when not masked by another object.



The silhouette trick is a good example of the benefits of using the SRP workflow to facilitate easy injection in the render pipeline.

The render graph system

The render graph system allows you to author a custom SRP in a maintainable and modular way. You can use the RenderGraph API to create a render graph, a high-level representation of the custom SRP's render passes, which explicitly states how the render pipeline uses its resources across render passes. It is not a graphical system.

Describing render passes in this way has two benefits: It simplifies render pipeline configuration, and it allows the render graph system to efficiently manage parts of the render pipeline, which can improve runtime performance.

To use the render graph system, you need to write your code in a different way to that required for a regular custom SRP.

Main principles

Before you write render passes with the **RenderGraph** API, know the following foundational principles:

- You no longer handle resources directly; instead, you use render graph system-specific handles. All **RenderGraph** APIs use these handles to manipulate resources. The resource types a render graph manages are **RTHandles, ComputeBuffers**, and **RendererLists**.
- Actual resource references are only accessible within the execution code of a render pass.
- The framework requires an explicit declaration of render passes. Each render pass must state which resources it reads from and/or writes to.
- There is no persistence between each execution of a render graph. This means that the resources you create inside one execution of the render graph don't carry over to the next execution.
- For resources that need persistence (e.g., from one frame to another), you can create them outside of a render graph, like regular resources, and import them. They behave like any other render graph resource in terms of dependency tracking, but the graph does not handle their lifetime.
- A render graph mostly uses RTHandles for texture resources. This has a number of implications on how to write shader code and how to set them up.

Resource management

The render graph system calculates the lifetime of each resource with the high-level representation of the whole frame. This means that when you create a resource via the RenderGraph API, the render graph system does not create the resource at that time. Instead, the API returns a handle that represents the resource, which you then use with all RenderGraph APIs. The render graph only creates the resource just before the first pass that needs to write it. In this case, "creating" does not necessarily mean that the render

graph system allocates resources. Rather, it means that it provides the necessary memory to represent the resource so that it can use the resource during a render pass. In the same manner, it also releases the resource memory after the last pass that needs to read it. This way, the render graph system can reuse memory in the most efficient manner based on what you declare in your passes. If the render graph system does not execute a pass that requires a specific resource, then the system does not allocate the memory for the resource.

Render graph execution overview

Render graph execution is a three-step process that the render graph system completes, from scratch, every frame. This is because a graph can change dynamically from frame to frame, for example, depending on the actions of the user.

— **Setup:** The first step is to set up all the render passes. This is where you declare all the render passes to execute and the resources each render pass uses.

— **Compilation:** The second step is to compile the graph. During this step, the render graph system culls render passes if no other render pass uses their outputs. This allows for less organized setups because you can reduce specific logic when you set up the graph. This step also calculates the lifetime of resources. This allows the render graph system to create and release resources in an efficient way as well as compute the proper synchronization points when it executes passes on the asynchronous compute pipeline.

— **Execution:** Finally, execute the graph. The render graph system executes all render passes that it did not cull, in declaration order. Before each render pass, the render graph system creates the proper resources and releases them after the render pass if later render passes do not use them.

Let's look at a practical example. The final code for this example is here.

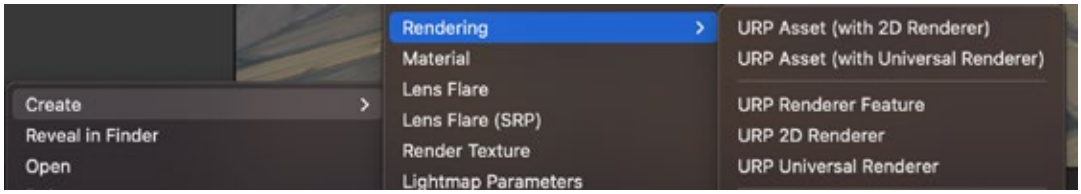
Learn how to use the render graph system to create a Renderer Feature that is injected into the render pipeline. In this tutorial we create a performant post-processing pass using the latest methods to reduce bandwidth, making it suitable on mobile platforms.

Watch the tutorial

Renderer Feature

A Renderer Feature can be used at any stage in URP to affect the final render. This example is of a post-processing technique using a material to process each pixel in the image, creating a tint effect.

1. Start by finding a suitable folder in the Project Assets folder. Right-click and choose **Create > Rendering > URP Renderer Feature**. Name it **TintFeature**.



2. Double-click the default **TintFeature** file. This is a C# script containing boilerplate for a Renderer Feature.

```
using UnityEngine;
using UnityEngine.Rendering;
using UnityEngine.Rendering.Universal;
using UnityEngine.Rendering.RenderGraphModule;

0 references
public class TintRendererFeature : ScriptableRendererFeature
{
    2 references
    class CustomRenderPass : ScriptableRenderPass
    {
        // This class stores the data needed by the RenderGraph pass.
        // It is passed as a parameter to the delegate function that executes the RenderGraph pass.
        3 references
        private class PassData
        {
        }

        // This static method is passed as the RenderFunc delegate to the RenderGraph render pass.
        // It is used to execute draw commands.
        1 reference
        static void ExecutePass(PassData data, RasterGraphContext context)
        {
        }

        // RecordRenderGraph is where the RenderGraph handle can be accessed, through which render passes can be added to t
        // FrameData is a context container through which URP resources can be accessed and managed.
        0 references
        public override void RecordRenderGraph(RenderGraph renderGraph, ContextContainer frameData)
        {
            const string passName = "Custom Render Pass";

            // This adds a raster render pass to the graph, specifying the name and the data type that will be passed to th
            using (var builder = renderGraph.AddRasterRenderPass<PassData>(passName, out var passData))
            {
                // Use this scope to set the required inputs and outputs of the pass and to
                // setup the passData with the required properties needed at pass execution time.

                // Make use of frameData to access resources and camera data through the dedicated containers.
                // Eg:
                // UniversalCameraData cameraData = frameData.Get<UniversalCameraData>();
                UniversalResourceData resourceData = frameData.Get<UniversalResourceData>();
```

Default code for a Renderer Feature

3. Add these properties to the TintRendererFeature:

    — **RenderPassEvent** allows the user to set the injection point in the Inspector.

    — **Material** is the one to use when copying.

    — Requirements are set to **Color**.

    — Initialize a ProfilingSampler. You'll get two ID values allowing access to `_BlitTexture` and `_BlitScaleBias`.

    — Lastly, define a **MaterialPropertyBlock**.

```
public RenderPassEvent injectionPoint = RenderPassEvent.AfterRendering;
public Material passMaterial;
public ScriptableRenderPassInput requirements =
                              ScriptableRenderPassInput.Color;
private ProfilingSampler m_Sampler;
private static readonly int m_BlitScaleBiasID =
                              Shader.PropertyToID("_BlitScaleBias");
private static MaterialPropertyBlock s_SharedPropertyBlock = null;
```

4. Rename **CustomRenderPass** to **TintPass** and add these properties to the **TintPass** class. The Material will contain the shader you apply to the current state of the rendered image. The PassData defines the data used when you declare the pass. This is where you set the data that the rendering code can access.

```
private Material m_Material;
private string m_PassName;
private ProfilingSampler m_Sampler;
private class PassData
{
    internal Material material;
    internal TextureHandle source;
}
```

4. Add a constructor to the TintPass to initialize the material, and set the position of this pass in the render pipeline.

```
public TintPass(Material mat, string name)
       {
           m_PassName = name;
           m_Material = mat;
           m_Sampler ??= new ProfilingSampler(GetType().Name + "_" + name);
        }
```

5. Delete the functions `ExecutePass`, `OnCameraSetup`, `Execute` and `OnCameraCleanup`.

6. Add the code below to the RecordRenderGraph function:

    — Get a `resourceData` instance, this is used to get a texture descriptor from the active color texture after post-processing.

    — Change the name and request a new texture. Render Graph will allocate it when needed.

    — The first blit copies the current color buffer to an intermediary texture so it can be used as an input to the next pass. A pass is created using `AddRasterRenderPass`. In the first pass you set the source of the `passData` instance to the `activeColorTexture` of the `resourceData` instance.

    — Set the builder input texture using the method `UseTexture` and the output using `SetRenderAttachment`.

    — Finally, set the render function that the builder uses. It uses a function, `ExecuteCopyColorPass`, which is created in the steps below.

    — The second blit uses a material when copying. It is similar to the first blit except it assigns a material to the `passData` instance and uses the function `ExecuteMainPass` in the `SetRenderFunc` assignment.

```
public override void RecordRenderGraph(RenderGraph renderGraph, ContextContainer frameData)
{
  UniversalResourceData resourceData = frameData.Get<UniversalResourceData>();
  var colCopyDesc =
          renderGraph.GetTextureDesc(resourceData.afterPostProcessColor);
  colCopyDesc.name = "_TempColorCopy";
  TextureHandle copiedColorTexture = renderGraph.CreateTexture(colCopyDesc);
  using (var builder = renderGraph.AddRasterRenderPass<PassData>(m_PassName +
                "_CopyPass", out var passData, m_Sampler))
  {
      passData.source = resourceData.activeColorTexture;
      builder.UseTexture(resourceData.activeColorTexture, AccessFlags.Read);
      builder.SetRenderAttachment(copiedColorTexture, 0, AccessFlags.Write);
      builder.SetRenderFunc(
         (PassData data, RasterGraphContext rgContext) =>
         {
             ExecuteCopyColorPass(rgContext.cmd, data.source);
         });
  }
  using (var builder = renderGraph.AddRasterRenderPass<PassData>(m_PassName +
                "_FullScreenPass", out var passData, m_Sampler))
  {
      passData.source = resourceData.activeColorTexture;
```

```
      passData.material = m_Material;
      builder.UseTexture(copiedColorTexture, AccessFlags.Read);
      builder.SetRenderAttachment(resourceData.activeColorTexture, 0,
                AccessFlags.Write);
      builder.SetRenderFunc(
         (PassData data, RasterGraphContext rgContext) =>
         {
             ExecuteMainPass(rgContext.cmd, data.material, data.source);
         });
   }
}
```

7. You'll need to provide the `ExecuteCopyColorPass`. It simply uses the Blitter method `BlitTexture`. This function is provided with a variety of parameters. This example uses this version.

```
public static void BlitTexture(CommandBuffer cmd,
RTHandle source, Vector4 scaleBias, float mipLevel, bool
bilinear)
```

This function should be placed before the `RecordRenderGraph` function.

```
private static void ExecuteCopyColorPass(RasterCommandBuffer cmd, RTHandle sourceTexture)
       {
           Blitter.BlitTexture(cmd, sourceTexture, new Vector4(1, 1, 0, 0), 0.0f, false);
       }
```

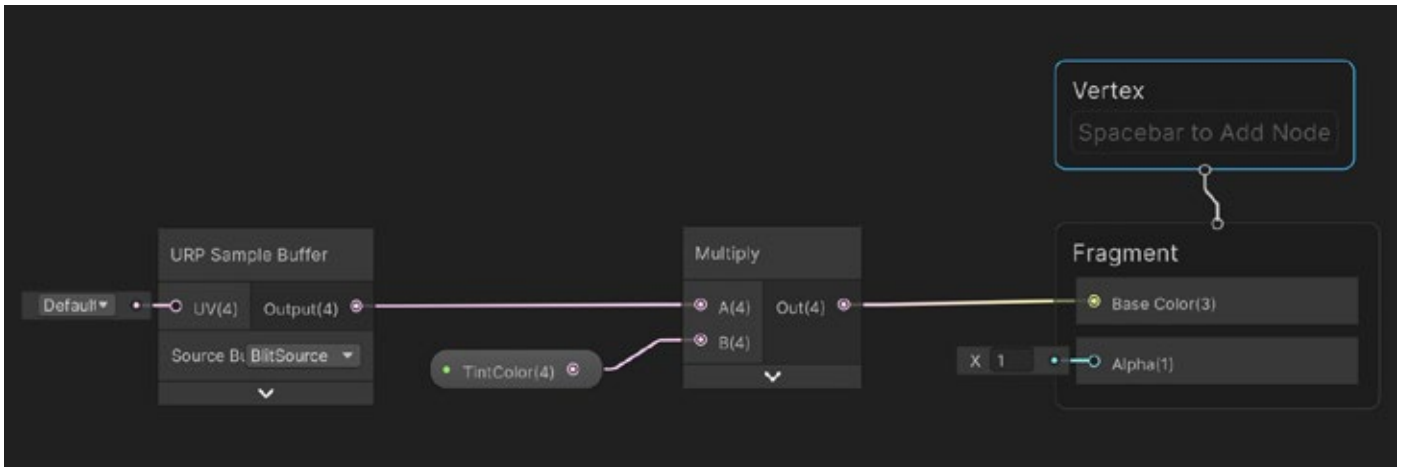
8. Now you define the `ExecuteMainPass` function. You need to set the `_BlitScaleBias` uniform for user material with shaders replying on core `Blit.hlsl` to work.

```
private static void ExecuteMainPass(RasterCommandBuffer cmd, Material material,
     RTHandle copiedColor)
{
   s_SharedPropertyBlock.Clear();
    s_SharedPropertyBlock.SetVector(m_BlitScaleBiasID, new Vector4(1, 1, 0, 0));
    cmd.DrawProcedural(Matrix4x4.identity, material, 0, MeshTopology.Triangles,
                       3, 1, s_SharedPropertyBlock);
}
```

9. Rename `CustomRenderPass` to TintPass, and change m_ScriptablePass to `m_pass`.
10. Delete the existing code in the `Create` method. Create a new TintPass using the custom constructor. Define the `renderPassEvent` and configure the input.

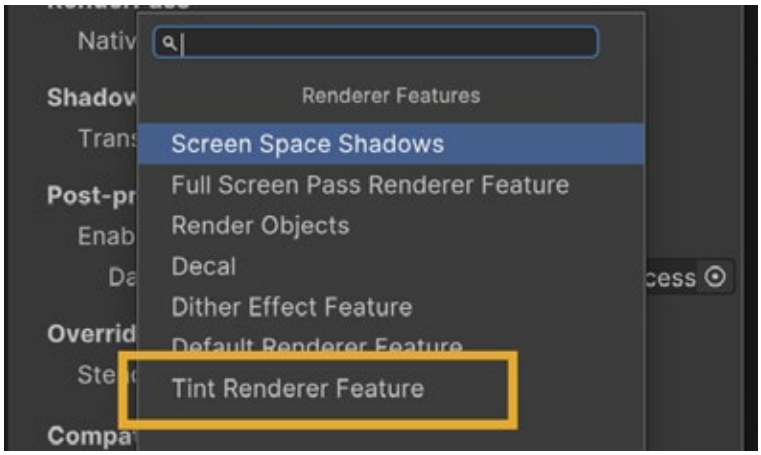
```
public override void Create()
    {
        m_pass = new TintPass(passMaterial, name);
        m_pass.renderPassEvent = injectionPoint;
        m_pass.ConfigureInput(requirements);
    }
```

These next steps complete this example of a Renderer Feature, which is designed to work with a Shader Graph shader. It's a simple example consisting of a **TintColor** property, a **URP Sample Buffer** node using the BlitSource and a **Multiply** node that modulates the existing BlitSource with the TintColor. Let's look at the steps below.

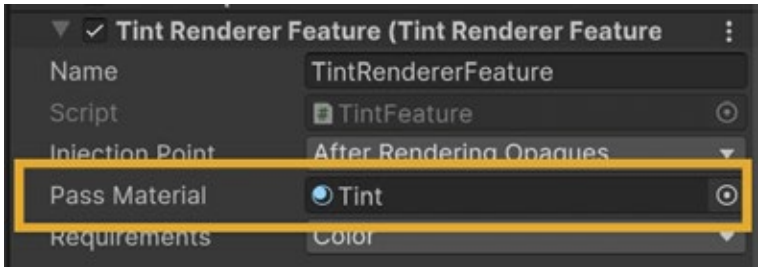


Tint Shader Graph

1. To see the effect in action, select the **Renderer Data** object and click **Add Renderer Feature**. TintFeature will appear in the list.



2. Create a material using the Tint Shader Graph.
3. Assign the Tint material to the Renderer Feature and set the materials color.



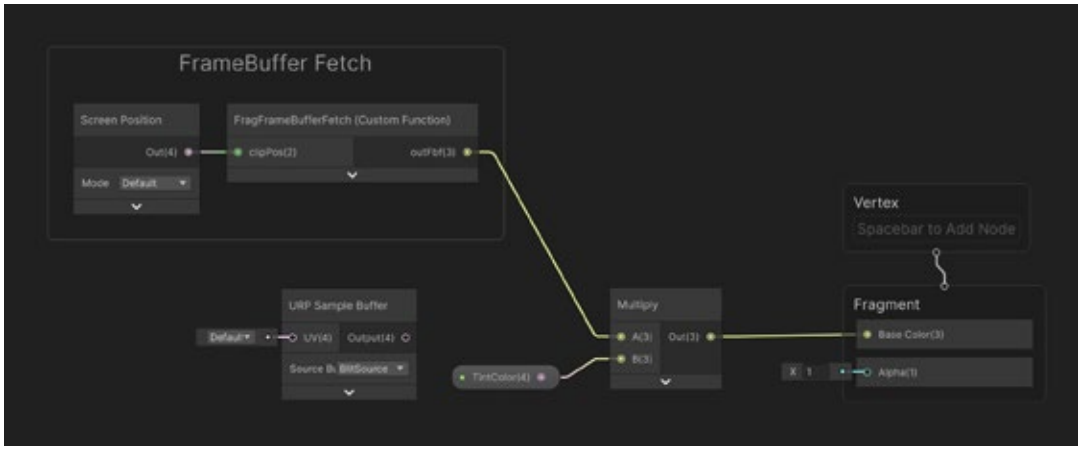
Effect of TintFeature: Unprocessed to the left, tinted on the right

Unity 6 comes with a Render Graph Viewer window that you can open via **Window > Analysis > Render Graph Viewer.** This viewer allows you to study what is happening in the pipeline.

The Render Graph Viewer window

Notice that **Draw Objects Pass**, **TintRendererFeature_CopyPass**, and **TintRendererFeature_FullScreen Pass** are all separate passes. It would be better to combine them into a single pass. But separate passes are necessary because of the way textures are used. If you click on the pass name, with the Pass List expanded, you'll see details about the pass. If you click on Draw Objects Pass you'll notice the message "Failed to merge"; this occurs because the next pass reads data output by this pass as a regular texture. TintRendererFeature_CopyPass has the same issue. Let's fix this.

You'll need a new material. The project includes a material in the Resources folder called **FrameBufferFetch**. This uses the shader of the same name (FrameBufferFetch) which has two passes. You're interested in the second pass that samples the current active frame buffer. Using this approach you'll need to adapt the Tint Shader Graph. Instead of using the URP Sample Buffer node, you're going to use a custom function node. It uses the HLSL in the **FrameBufferFetch.hlsl** file. Essentially it just uses the macro `LOAD_FRAMEBUFFER_X_INPUT`.



The Tint Shader Graph using custom node FrameBufferFetch

Let's go back to the TintFeature. In the TintPass you need to add a new private static property.

```
private static Material s_FrameBufferFetchMaterial;
```

You can assign it in the custom constructor by using the Load method.

```
s_FrameBufferFetchMaterial ??= UnityEngine.Resources.
Load("FrameBufferFetch") as Material;
```

In the ExecuteCopyColorPass you need to remove the Blit and use a DrawProcedural instead. Using the identity matrix again, you'll use the material s_FrameBufferFetchMaterial for the second pass. The first pass is index 0 and the second pass is index 1. You're using topology triangles again, so you'll use indexCount 3 and instanceCount 1.

```
cmd.DrawProcedural(Matrix4x4.identity, s_FrameBufferFetchMaterial, 1,
MeshTopology.Triangles, 3, 1, null);
```

Next you'll use the `RecordRenderGraph` method. For the first pass replace `UseTexture` with `SetInputAttachment`. This method uses FrameBufferFetch to access the previous pass.

```
builder.SetInputAttachment(resourceData.activeColorTexture, 0 )
```

The same steps are down for the second pass.

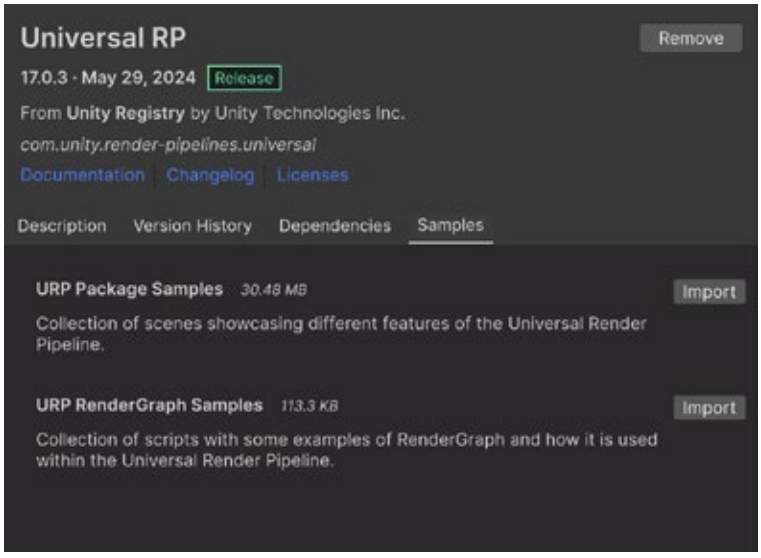
```
builder.SetInputAttachment( copiedColorTexture, 0 )
```

Look at the Render Graph Viewer and refresh if necessary. You will see that the three passes, Draw Objects Pass and the two TintRendererFeature passes, are combined into a single pass, which improves performance. In the Viewer window, the **F** means the input is accessed via FrameBufferFetch.

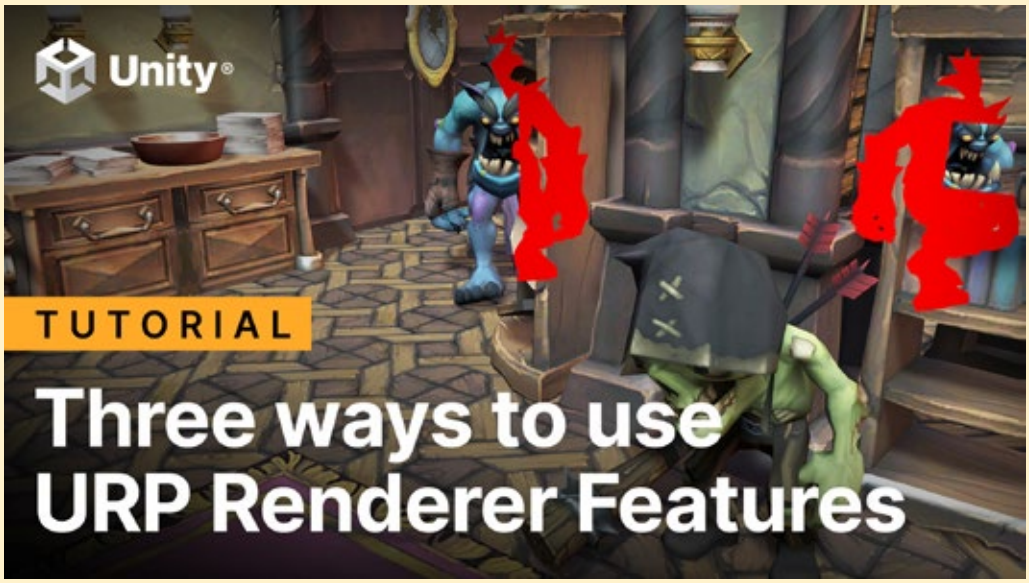
The three passes are merged

FramebufferFetch support is available on mobile platforms targeting Vulkan, Metal, and DirectX 12. On other platforms the engine falls back on texture sampling. Using FrameBufferFetch reduces bandwidth usage, which can improve performance if bandwidth bound, and generally reduce battery usage.

For more examples of using the render graph system, download the package samples via the Package Manager. Search for Universal RP, and click the Samples tab. URP RenderGraph Samples are available to import there.



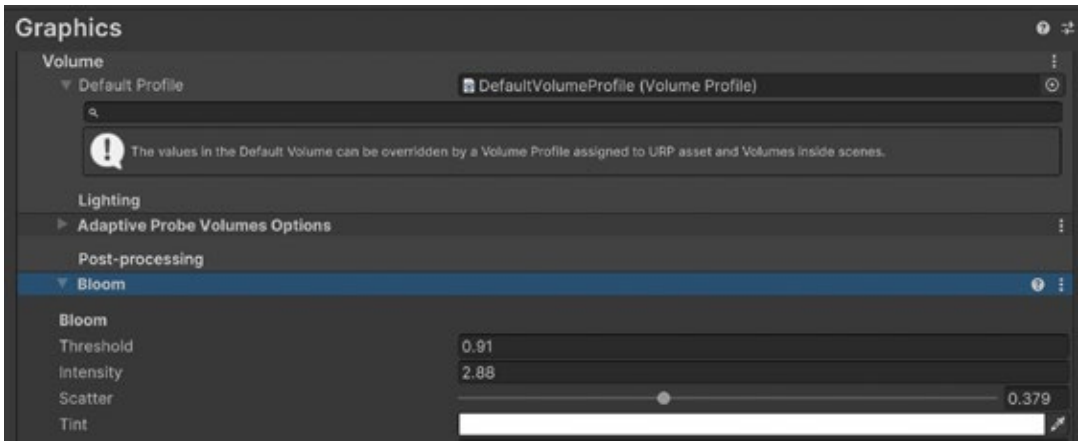
Importing the URP RenderGraph Samples via the Universal RP package and Package Manager



In this video tutorial, we show you three practical exercises using Renderer Features: How to create a custom post-processing effect, stencil effect, and occlude characters by their environment.

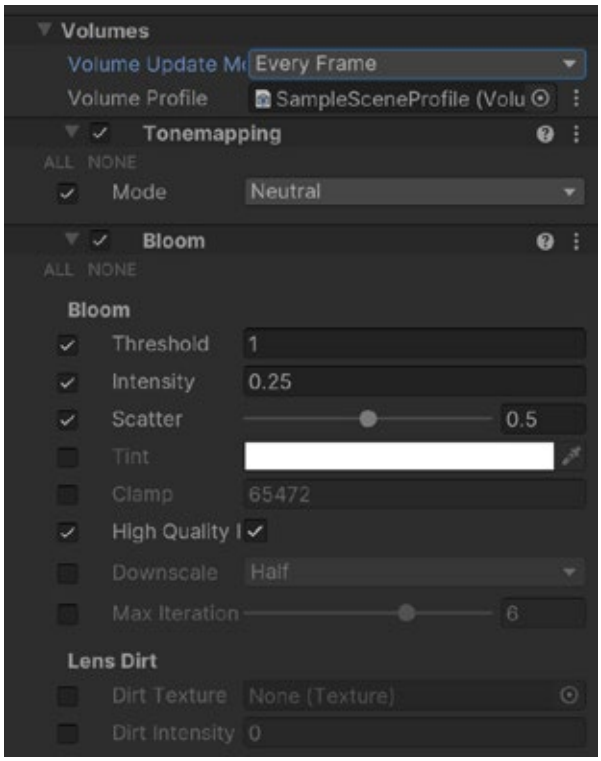
Post-processing

URP uses a Volume framework when adding post-processing effects. Unity 6 includes a **Default Volume**. It can be found at **Project Settings > Graphics > Volume.** Any settings applied here affect the entire project but can be overridden by volumes added to a scene.



The Default Volume option

Another feature that's new to Unity 6 is a volume for the active URP Asset, which can also be overridden by volumes added to a scene.



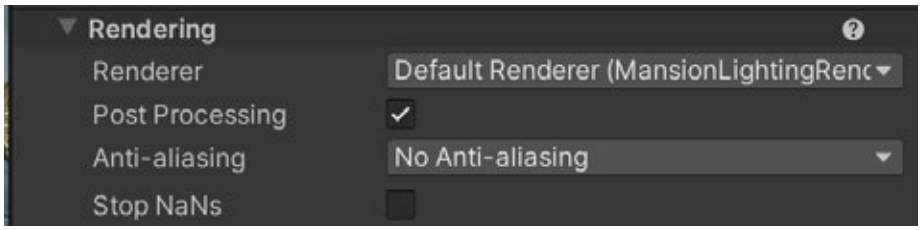
URP Asset > Volumes

When you add volumes to a scene, you can choose which post-processing effects apply to them. A volume can be Global or Local. If Global, the volume affects the Camera everywhere in the scene. With the Mode set to Local, volumes affect the Camera if it's within the bounds of the Collider.

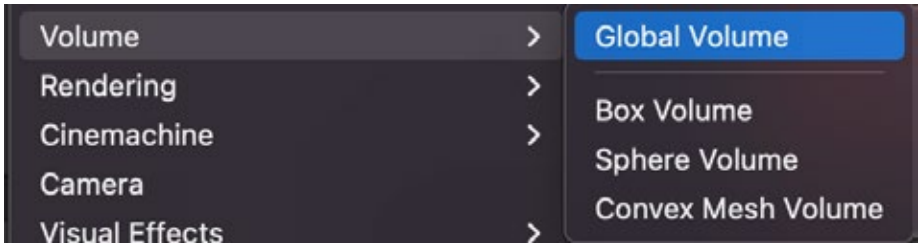
Applying post-processing effects: The top-left image has no effects applied, the top-right image has Bloom applied, the bottom-left has Vignette applied, and the bottom-right has Color Adjustment added.

Using the URP post-processing framework

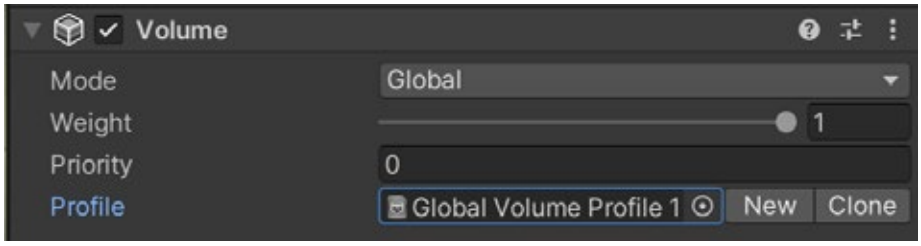
1. The first step is to make sure your Main Camera has post-processing enabled. Select the **Main Camera** in the **Hierarchy** window, go to the **Inspector**, and expand the **Rendering** panel. Check the **Post Processing** option.



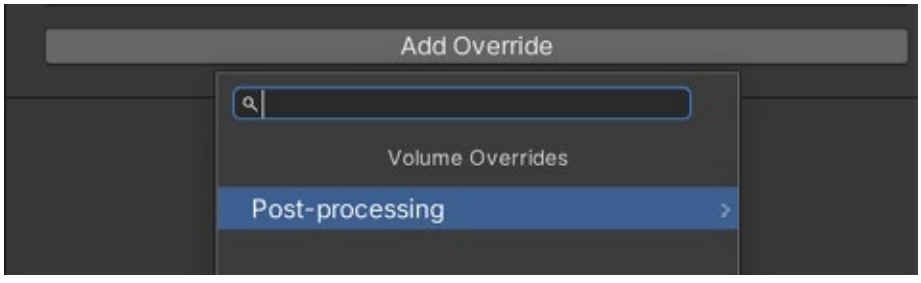
2. Right-click the **Hierarchy** window and select **Create > Volume > Global Volume** to create a Global Volume.

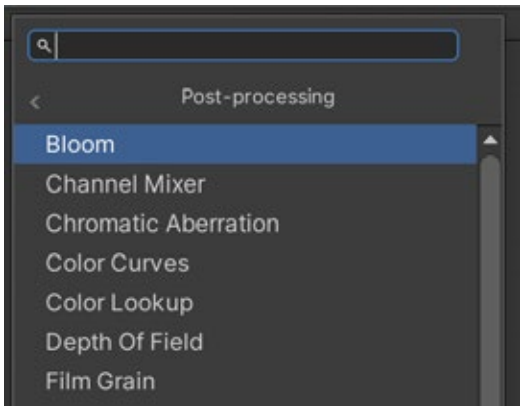


3. With the Global Volume selected in the Hierarchy window, find the **Volume** panel in the Inspector and create a new **Profile** by clicking on **New**.



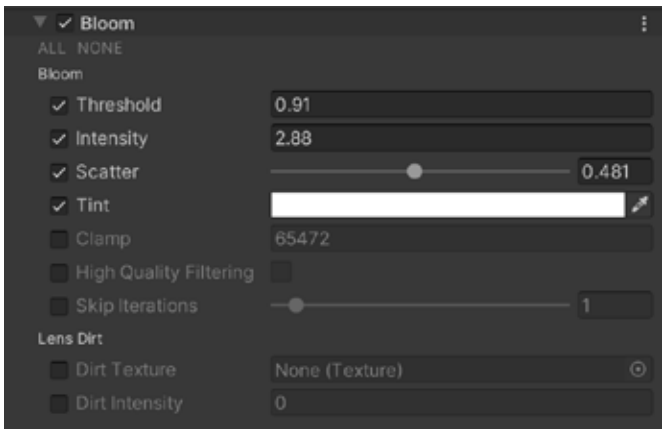
4. Start adding post-processing effects. See the table further down that lists available effects. Click **Add Override** and select **Post-processing**. In this example, the Bloom effect is chosen.



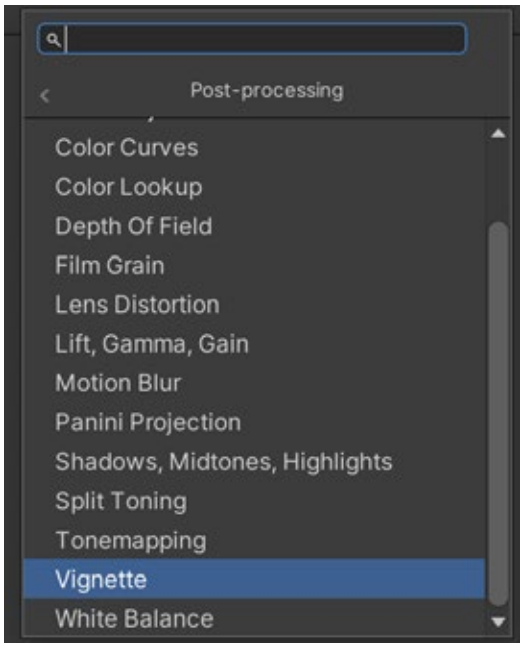


Selecting the Bloom effect

5. Each effect has a dedicated Settings panel. The image here shows the settings for Bloom.



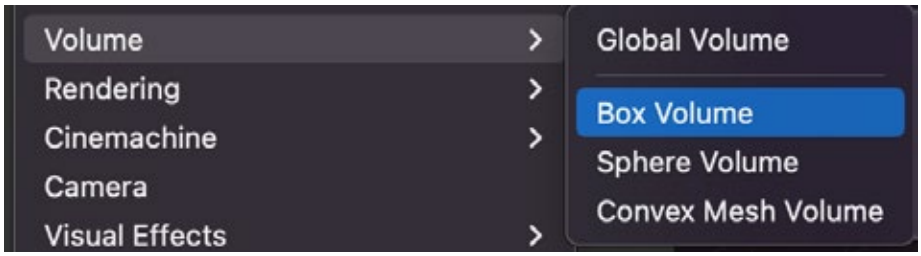
6. You can easily add multiple effects (such as Vignette in this example) and configure each one using their Settings panel.



Adding a Local Volume component

With the Volume framework, you can configure the scene so that as a Camera moves around it, different post-processing profiles are triggered. This is achieved by adding a Local Volume component. Let's go through the steps for setting this up.

1. In the **Hierarchy** window, right-click and choose **Create > Volume > Box Volume**. Alternatively, choose **Sphere Volume** if this shape is more suited to your purpose, or **Convex Mesh Volume** for a tighter control over the shape of the Collider component that defines the volume region.

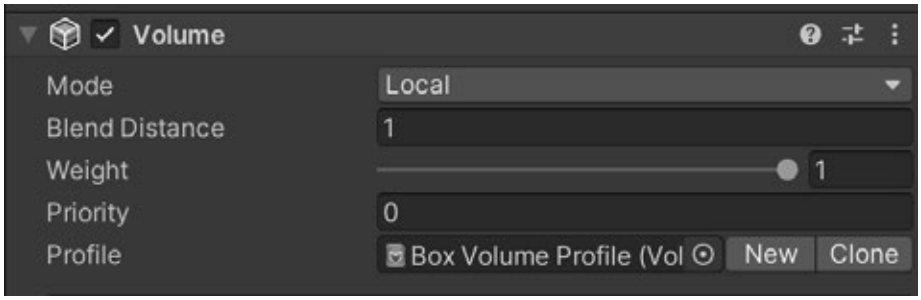


2. From the **Volume** panel in the **Inspector**, create a new **Profile** to store this volume data. The panel can also be used to set:

    a. **Blend Distance:** This is the furthest distance from the Volume's Collider that URP starts blending from, and the distance in Collider dimensions where this profile fades in. At the edge of the Collider, the post-processing effects will fade out and the Blend Distance from the edge of the Collider will fully fade in.

    b. **Weight:** Weight defines the maximum strength of the post-processing effects. If Weight is set to 1, then the effect will reach full strength. A setting of 0 means there is no effect, while 0.5 sets the strength of the effect at a maximum of 50%.

    c. **Priority:** Use this value to determine which Volume URP is used when multiple Volumes have an equal amount of influence on the scene. The higher the number, the higher the Priority. If you are merging Global and Local, then keep Global at the default 0 setting and set the Local Volume(s) to 1 or more.



Settings for a Local Volume

4. Position the **Volume** and control its dimensions using the **Box Collider** component, as shown in the image below.

Positioning and sizing a Box Volume using the attached Box Collider component

Post-processing can weigh heavily on your processor, so carefully consider the effects on low-end hardware and mobile devices. If your project must use it, then test on the target hardware. Some filters are less processor intensive than others. This document outlines the mobile-friendly effects.

These are the available post-processing effects in URP.

Effect	Description
Bloom	Adds a glow around pixels above a defined brightness level
Channel Mixer	Modifies the influence of each input color channel on the overall mix
Chromatic Aberration	Creates fringes of color along boundaries that separate dark and light parts of the image

Color Adjustments	Tweaks the overall tone, brightness, and contrast of the final rendered image
Color Curves	An advanced way to adjust specific ranges in hue, saturation, or luminosity
Color Lookup	Maps the colors of each pixel to a new value using a Lookup Texture
Depth of Field	Simulates the focus properties of a camera lens
Film Grain	Simulates the random optical texture of photographic film
Lens Distortion	Distorts the final rendered picture to simulate the shape of a real-world camera lens
Lift Gamma Gain	Uses different trackballs to affect different ranges within the image; adjust the slider under the trackball to offset the color lightness of that range
Motion Blur	Simulates the blur that occurs in an image when a real-world camera films objects moving faster than the camera's exposure time
Panini Projection	Helps you render perspective views in scenes with a very large field of view
Screen Space Lens Flare	Adds a lens flare that applies to the entire scene not just a single light
Shadows Midtones Highlights	Separately controls the shadows, midtones, and highlights of the render
Split Toning	Adds different color tones to the shadows and highlights in your scene
Tonemapping	Remaps the HDR values of an image to a new range of values
Vignette	Comprises darkening toward the edges of an image compared to the center
White Balance	Removes unrealistic color casts, so items that would appear white in real life render as white in your final image

Motion Blur

The top image shows Motion Blur off and the bottom image shows Motion Blur on.

The Motion Blur post-processing effect simulates the blur that occurs in an image when a real-world camera films objects moving faster than the camera's exposure time. This is usually due to rapidly moving objects, or a long exposure time.

Using Motion Blur

As with all post-processing effects using URP, Motion Blur uses the Volume system, so to enable and modify Motion Blur properties, you must add a Motion Blur override to a Volume in your scene.

Property	Description
Mode	Select the motion blur technique. Options: — **Camera Only**: Use only the motion of the camera to blur the objects. This technique does not use the motion vectors and has better performance than Camera and Objects. — **Camera and Objects**: Use the motion of both the camera and the GameObjects. GameObject motion vectors overwrite the camera motion vectors.
Quality	Set the quality of the effect. Lower presets give better performance, but at a lower visual quality.
Intensity	Set the strength of the motion blur filter to a value from 0 to 1. Higher values give a stronger blur effect, but can cause lower performance, depending on the Clamp parameter.
Clamp	Set the maximum length that the velocity resulting from camera rotation can have. This limits the blur at high velocity, to avoid excessive performance costs. The value is measured as a fraction of the screen's full resolution. The value range is 0 to 0.2. The default value is 0.05.

Troubleshooting performance issues

To decrease the performance impact of Motion Blur, you can:

— **Reduce the Quality**: A lower quality setting gives higher performance but may exhibit more visual artifacts.

— **Change the Mode property from Camera and Objects to Camera Only:** This technique has better performance than Camera and Objects.

— **Decrease the Clamp:** Do this to reduce the maximum velocity that Unity takes into account. Lower values give higher performance.

Controlling post-processing with code

You can also dynamically adjust your post-processing profile using a C# script. The following code example shows how to adjust the intensity of the Bloom effect. If a Vignette is applied, you can control the vignetting color via code. For example, if the player character takes damage, you can temporarily tint it red.

```
using UnityEngine;
using UnityEngine.Rendering;
using UnityEngine.Rendering.Universal;
public class PPController : MonoBehaviour
{
       // Start is called before the first frame update
       void Start()
       {
       Volume volume = GetComponent<Volume>();
       Bloom bloom;
       if (volume.profile.TryGet<Bloom>(out bloom))
       {
              bloom.intensity.value = 0;
       }
   }
}
```

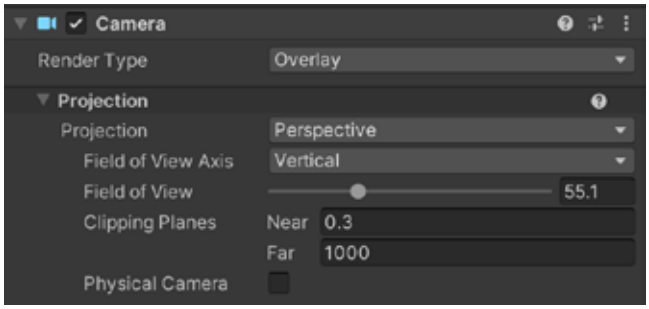
Camera Stacking

A common requirement in games is the ability to combine geometry viewed from different cameras in a single render. The image below shows a shelf in the foreground acting as an inventory within the game. Collected items are added to the shelf and can be selected at key points by the player. Notice that it has a different field of view, as well as different lighting and post-processing. This has been set up using the Camera Stacking feature in URP.

An example of using Camera Stacking

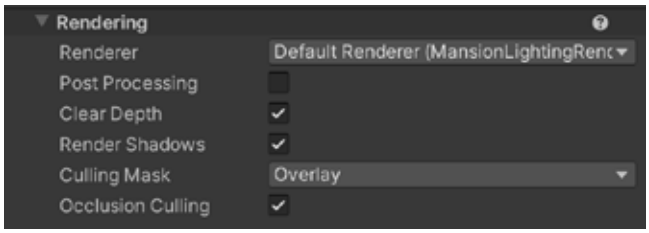
Let's look at how to set this feature up.

1. Create a Camera by right-clicking the **Hierarchy** view and choosing **Camera**. Remove the audio listener component.
2. Use the **Inspector > Camera Settings** panel to set this Camera as **Render Type Overlay**.



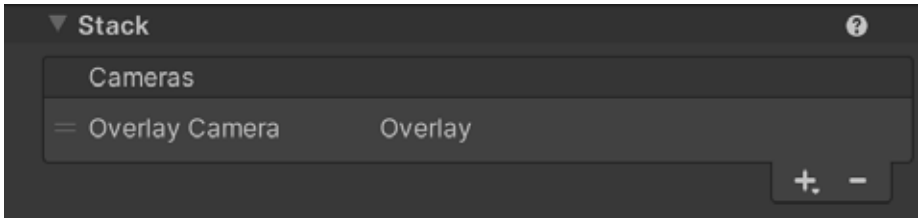
3. Create a new **Layer** for the Camera and the GameObjects it renders.

4. Update the **Rendering > Culling Mask** for the Camera using the Inspector.



5. Move the Camera to a suitable place in the scene, then add and position **GameObjects** by placing them in **Layer Overlay**.

6. Make sure the **Main Camera** does not render Overlay by updating its **Rendering > Culling Mask**.



7. In the **Stack** panel, use the "**+**" button to add the **Overlay Camera**.

Controlling a stack with code

As with post-processing, you can control the stack from code, and add or remove cameras dynamically during runtime. See this code example:

```
using UnityEngine;
using UnityEngine.Rendering.Universal;
public class StackController : MonoBehaviour
{
      public Camera overlayCamera;
      // Start is called before the first frame update
      void Start()
      {
      Camera camera = GetComponent<Camera>();
      var cameraData = camera.GetUniversalAdditionalCamera
      Data();
      cameraData.cameraStack.Remove(overlayCamera);
      }
}
```

Post-processing and Camera Stacking, both easily configured using URP, are powerful tools for creating rich, atmospheric effects in your games.

The SubmitRenderRequest API

Sometimes you might want to render your game to a different destination than the user's screen. The **SubmitRenderRequest** API is designed with this purpose in mind. Let's look at a possible use case.

Coding a screengrab

The script below will render the game to an off-screen **RenderTexture** when the user presses the onscreen GUI. The script should be attached to the Main Camera. A **RenderTexture** is created in the **Start** callback. It is 1920 × 1080 pixels with a bit depth of 24. When the user presses the "Render Request" button, the RenderRequest method is called.

In the RenderRequest method, there's a reference to the Camera component. Create a RenderPipeline.StandardRequest instance, then check whether the current pipeline supports the RenderRequest framework. If it does, you set the RenderTexture that was initialized in the Start callback as the destination of this request object and initialize the render using RenderPipeline.SubmitRenderRequest. This method takes a camera instance and a request object.

At this point, Texture2D contains a render of the current scene. To save this to a file, you first need to convert the RenderTexture to a Texture2D instance. The method **ToTexture2D** shows one possible route. Once you have a Texture2D you can use the **EncodeToPNG** method of a Texture2D instance to get a byte array. You can then use the System.IO.File method **WriteAllBytes** to save the byte array to a file.

If you use the script directly, the screengrab will be saved in a newly created folder called **RenderOutput** in the **Assets** folder of your game. The file name is R_ followed by a randomly chosen integer between 0 and 100,000.

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.Rendering;
[RequireComponent(typeof(Camera))]
public class StandardRenderRequest : MonoBehaviour
{
   [SerializeField]
   RenderTexture texture2D;
   private void Start()
   {
       texture2D = new RenderTexture(1920, 1080, 24);
   }
   // When user clicks on GUI button,
   // Render Requests are sent with various output textures to render
   given frame
   private void OnGUI()
   {
       GUILayout.BeginVertical();
       if (GUILayout.Button("Render Request"))
       {
           RenderRequest();
       }
       GUILayout.EndVertical();
   }
   void RenderRequest()
   {
       Camera cam = GetComponent<Camera>();
       RenderPipeline.StandardRequest request = new RenderPipeline.StandardRequest();
       if (RenderPipeline.SupportsRenderRequest(cam, request))
       {
           // 2D Texture
           request.destination = texture2D;
           RenderPipeline.SubmitRenderRequest(cam, request);
           SaveTexture(ToTexture2D(texture2D));
       }
   }
   void SaveTexture(Texture2D texture)
   {
```

```
        byte[] bytes = texture.EncodeToPNG();
        var dirPath = Application.dataPath + "/RenderOutput";
        if (!System.IO.Directory.Exists(dirPath))
        {
            System.IO.Directory.CreateDirectory(dirPath);
        }
        System.IO.File.WriteAllBytes(dirPath + "/R_" + Random.Range(0,
        100000) + ".png", bytes);
        Debug.Log(bytes.Length / 1024 + "Kb was saved as: " + dirPath);
        #if UNITY_EDITOR
                UnityEditor.AssetDatabase.Refresh();
        #endif
    }
    Texture2D ToTexture2D(RenderTexture rTex)
    {
        Texture2D tex = new Texture2D(rTex.width, rTex.height,
        TextureFormat.RGB24, false);
        RenderTexture.active = rTex;
        tex.ReadPixels(new Rect(0, 0, rTex.width, rTex.height), 0, 0);
        tex.Apply();
        Destroy(tex);//prevents memory leak
        return tex;
    }
}
```

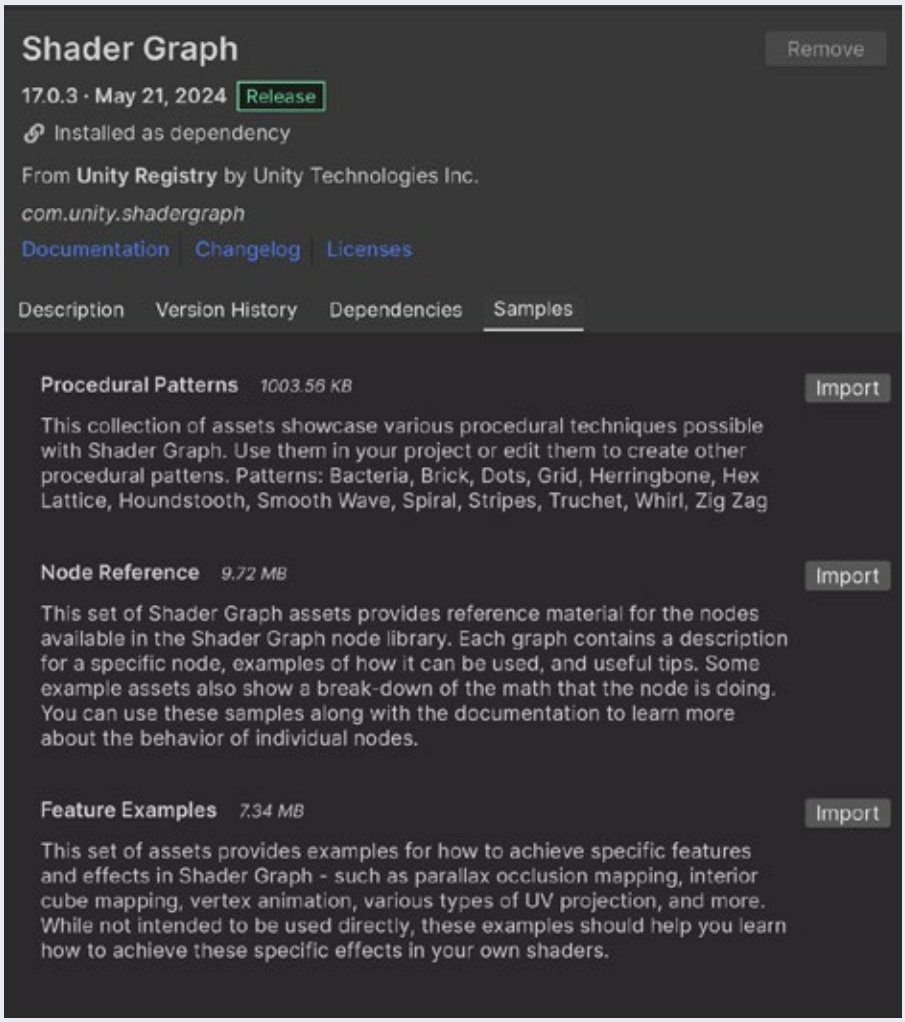
Additional tools compatible with URP

Another benefit of using URP is its compatibility with Unity's authoring tools that bring complex creation tasks into the reach of technical artists. This chapter provides an introduction to Shader Graph and VFX Graph.

Shader Graph

Shader Graph brings custom shaders to an artist's workflow. The Shader Graph tool is included when you start a project using the URP template or import the URP package.

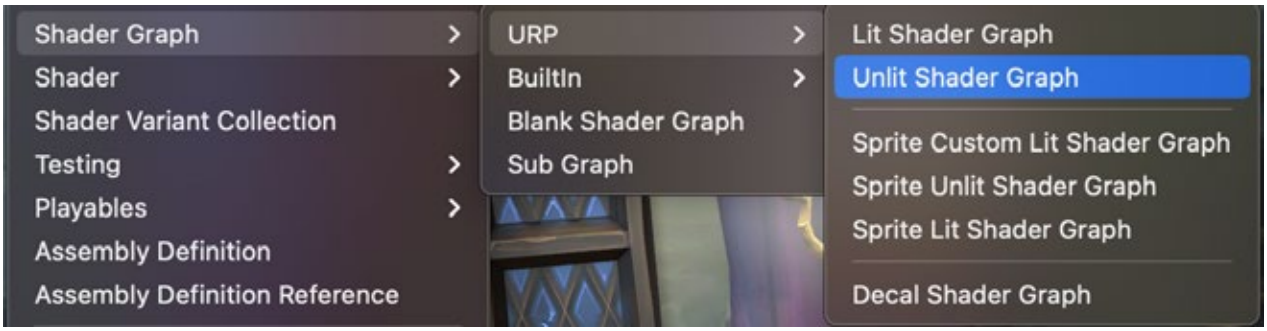
Note:



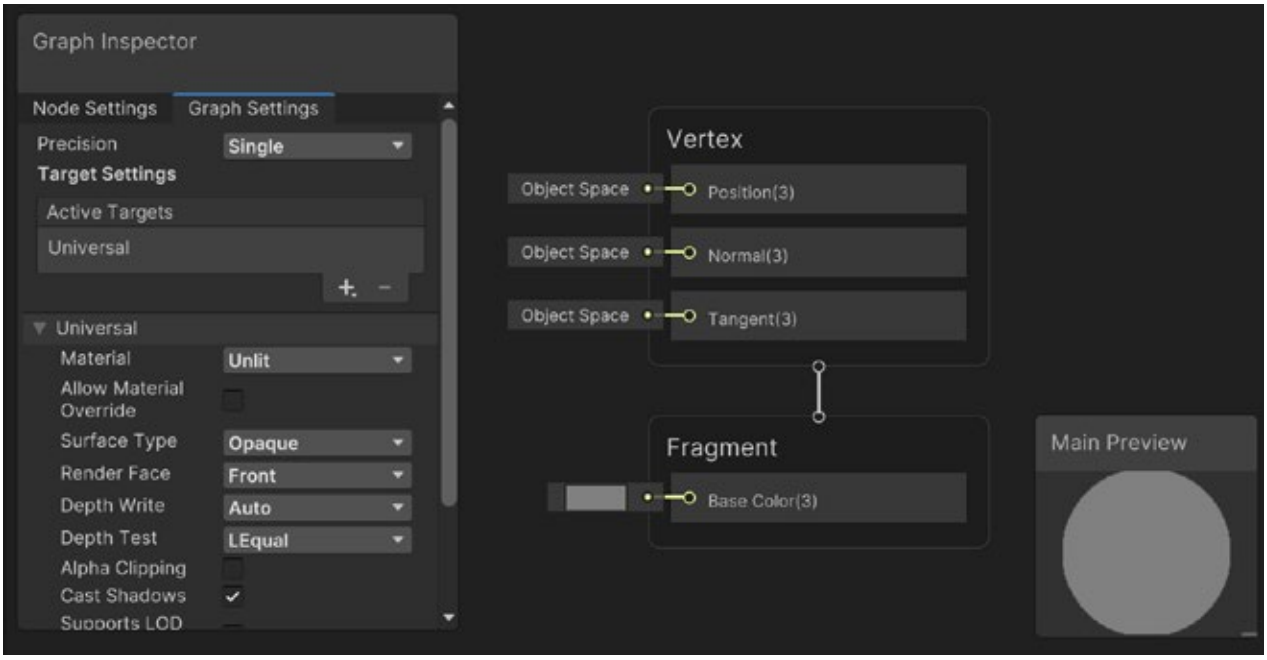
You can find the Shader Graph node examples libraries in the Shader Graph package in the Package Manager window. Read about the new Shader Graph production ready shaders in Unity 6 in this blog post.

Covering Shader Graph warrants a separate guide, but let's go over some basic yet crucial steps by creating the Light Halo shader from the Lighting chapter.

1. Right-click in the **Project** window, find a suitable folder, and choose **Create > Shader Graph > URP > Unlit Shader Graph**. For this example, choose Unlit. Name the new asset FresnelAlpha.

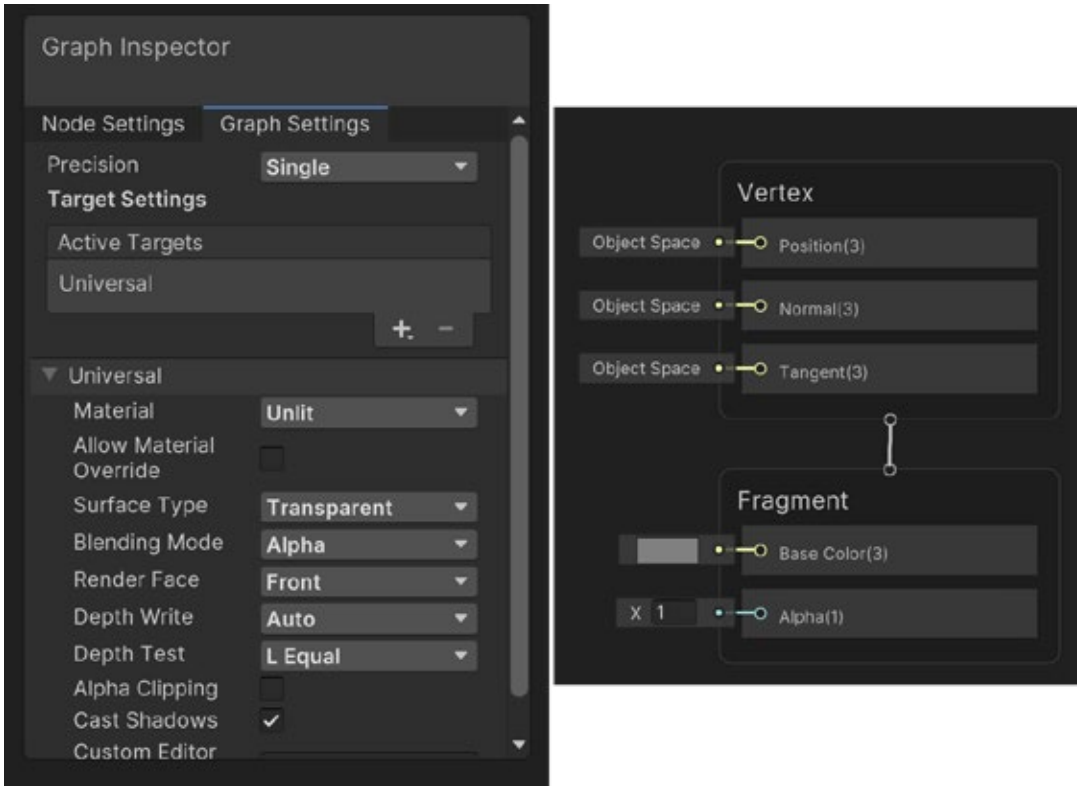


2. Double-click the new **Shader Graph Asset** to launch the Shader Graph editor.

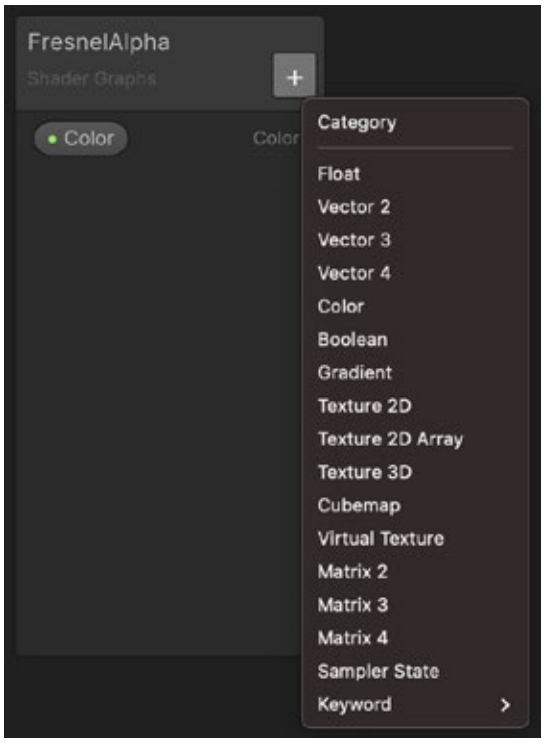


If you're familiar with shaders, then you'll recognize the Vertex and Fragment nodes. By default, this shader will ensure any model with a material using it that it is correctly placed in the Camera view using the Vertex node, and that each pixel is set to a grey color using the Fragment node.

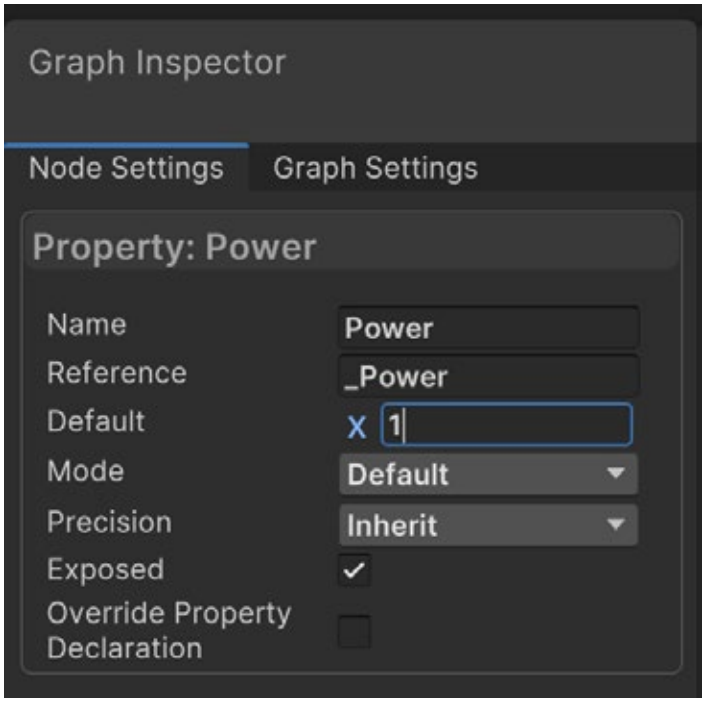
3. This shader is going to set the alpha transparency of the object. It therefore needs to apply to the Transparent queue. Change the **Graph Inspector > Graph Settings > Surface Type** to **Transparent**. You'll see that the Fragment node now has an Alpha input as well as Base Color.



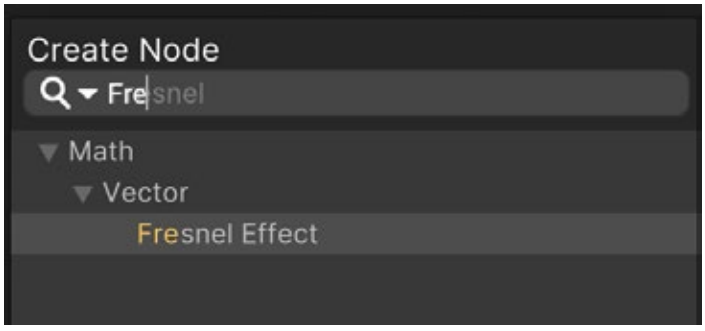
4. Add properties to the shader. For instance, add Color as a Color, and Power and Strength as Float values.



5. Set the default values using **Graph Inspector > Node Settings > Default**. Set Color to white, Power to 4, and Strength to 1.



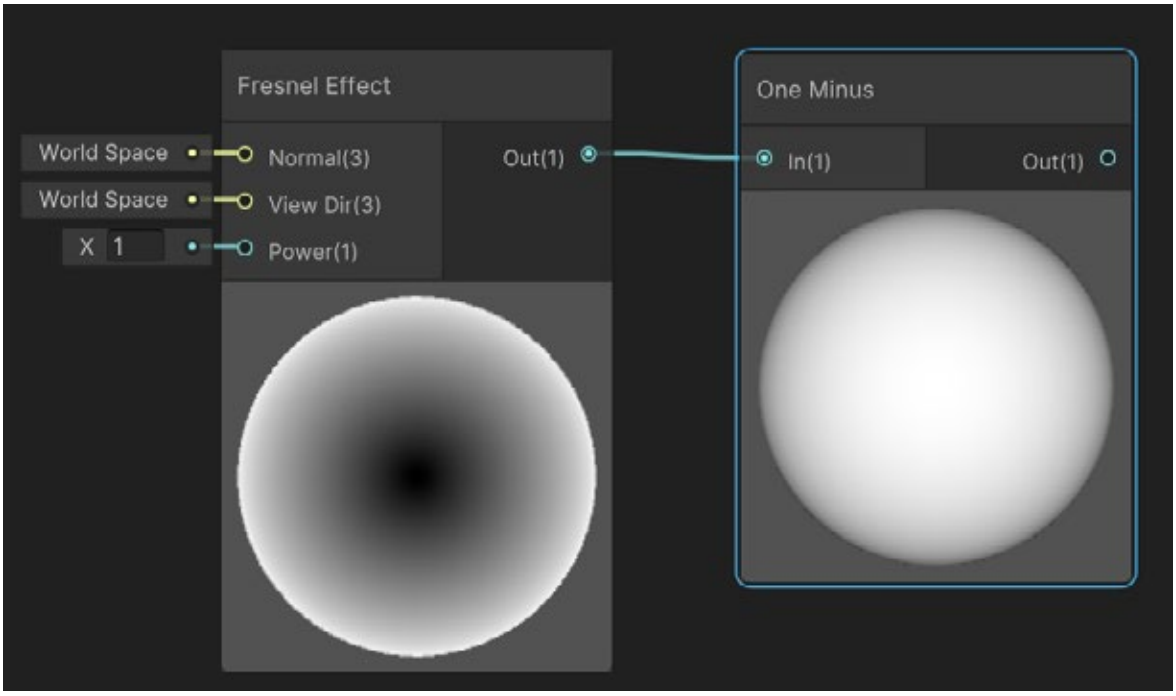
6. Shader Graph functions by joining nodes together. A node will have one or more inputs and an output. To add a node, right-click and choose **Create Node** in the **Search** panel at the top, then enter **Fre**. The results will show a **Fresnel Effect** node.



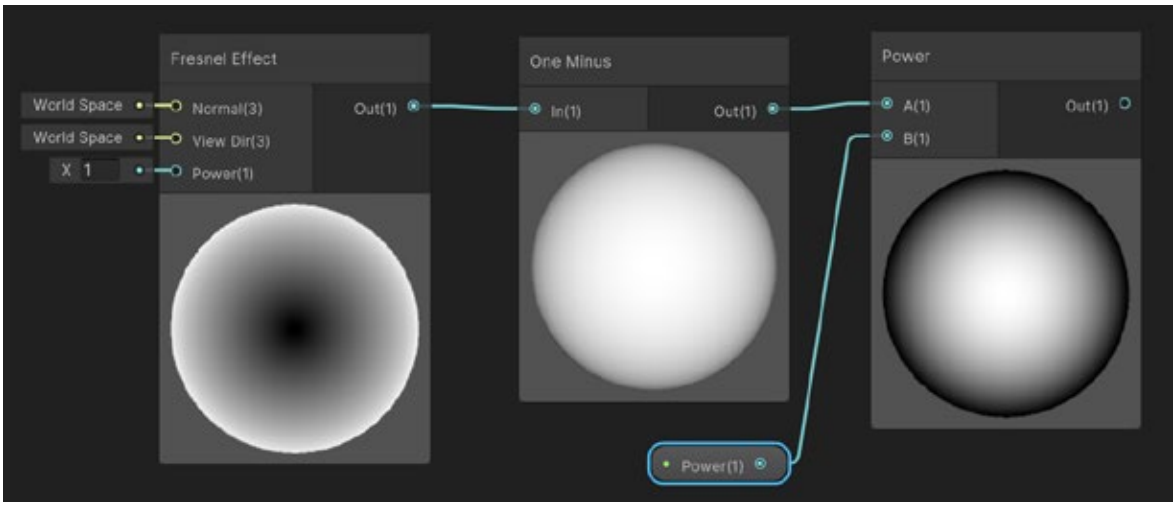
7. A node shows a preview of its effect. Notice that the Fresnel Effect is bright toward the edge. The value is the difference between the View direction and the Normal direction – and for a sphere, this is greatest at the edge.

   The alpha value should be lowest at the edge. You can flip the result using a One Minus node. To do this, click **Create Node** and enter **One**. Select the **One Minus** node. Now drag from Out(1) on the Fresnel Effect node to In(1) on the One Minus node. The 1 means

that the value type is a single float. If it was 3, then it would be a vector with three components. The nodes should be joined like this:

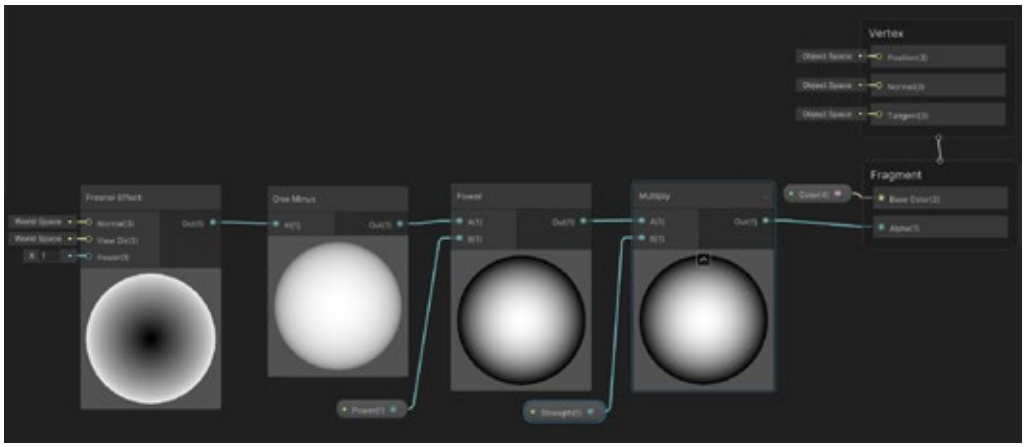


8. Let's look at how to control the size of gradient and the overall transparency. Use a **Power** node for sizing the gradient. Create a Power node and connect One Minus Out(1) to Power A(1). Drag the Power property to the graph and join it to Power B(1). The graph should now look like this:

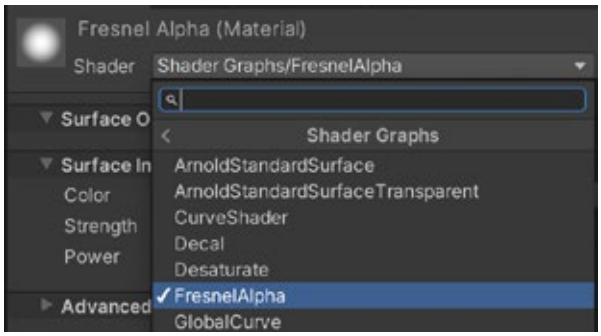


9. Control the overall transparency using a **Multiply** node. Create it and connect Power Out(1) to Multiply A(1). Drag the Strength property to the graph and join it to Multiply B(1). Then join the Multiply Out(1) to Fragment Alpha(1) and drag the Color(4) property to the graph and join it to Fragment Base Color(3).

Notice here that the property Color comprises a four-component vector, while Base Color is a three-component vector. Shader Graph will map the first three components of Color to the Base Color vector.



10. Save the asset and create a new material. Assign this shader to the new material, which is located in **Shader Graphs/FresnelAlpha**.

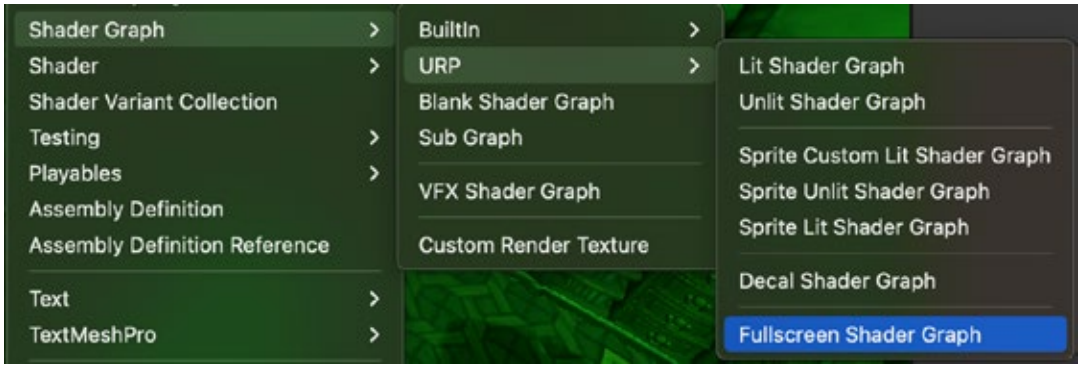


11. Now you can apply the material to an object, controlling its visibility at the edges.

A shader is applied to a sphere-shaped Point light to provide a halo effect around it.

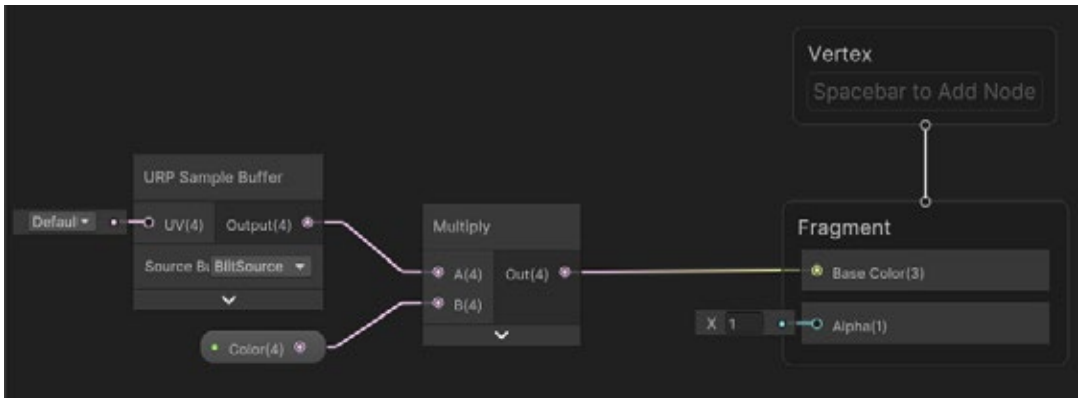
Fullscreen Shader Graph

The Fullscreen Shader Graph allows you to create custom post-processing passes. Right-click in the Project pane and select **Create > Shader Graph > URP > Fullscreen Shader Graph**.



Creating a Fullscreen Shader Graph

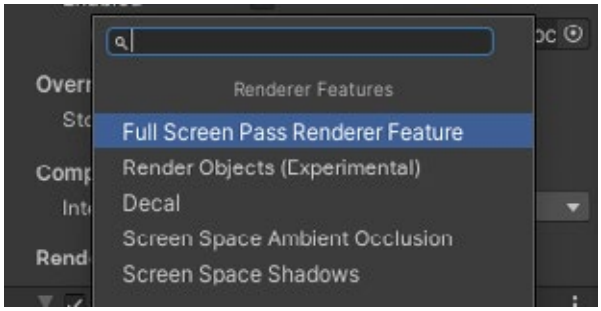
You can access a pixel's color for the fragment shader using a URP Sample Buffer node that itself uses the BlitSource option. The graph below shows a simple tint example. The URP Sample Buffer also gives access to world normals and motion vectors that are useful for edge detection and motion trails.



A simple tinting example

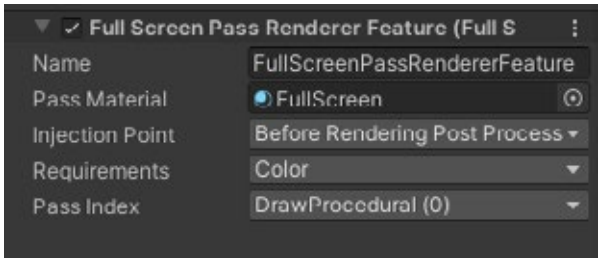
To use this example, you need a way to Blit the result of the current camera render texture using a material that uses this shader.

With the active Renderer Data asset selected, use the Inspector to add a Renderer Feature. Select **Full Screen Pass Renderer Feature**.



Adding the Full Screen Pass Renderer Feature

It just remains to update the settings for this Renderer Feature. Set the material you created that uses the Fullscreen Shader Graph, then select the position in the render pipeline.



The Renderer Feature settings

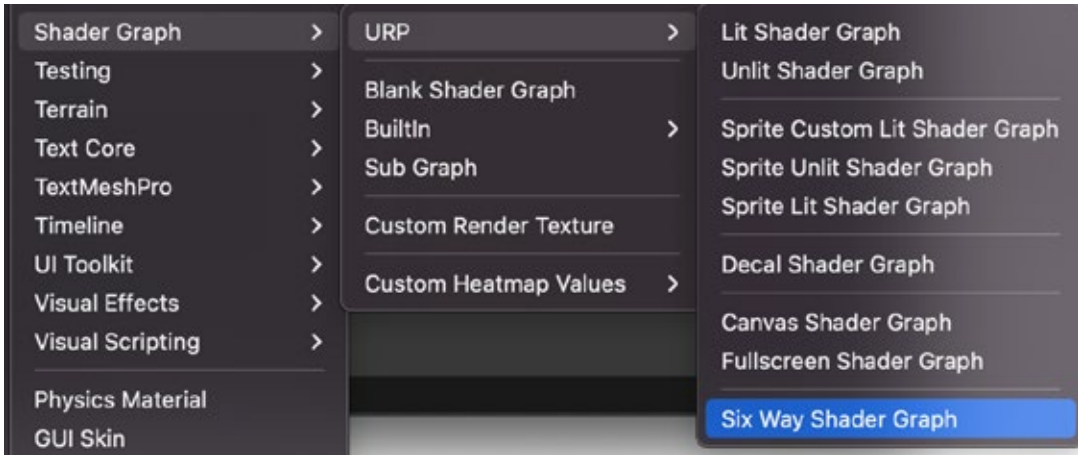
The image below shows the tint effect on the left. The Fullscreen Shader Graph is a useful way to create custom post-processing effects.

The tint effect

Six Way Shader Graph

Here are four versions of the same smoke effect under different lighting conditions. From the top left: Directional light and ambient; top right, ambient, probe volumes and directional light; bottom left, ambient and probes, and bottom right, spot light and probes

The Six Way Shader Graph is a feature in Unity 6 that lets you dynamically relight smoke effects for more realism, using six-way lightmaps that can be baked in DCC tools like Houdini, Blender, or Embergen.



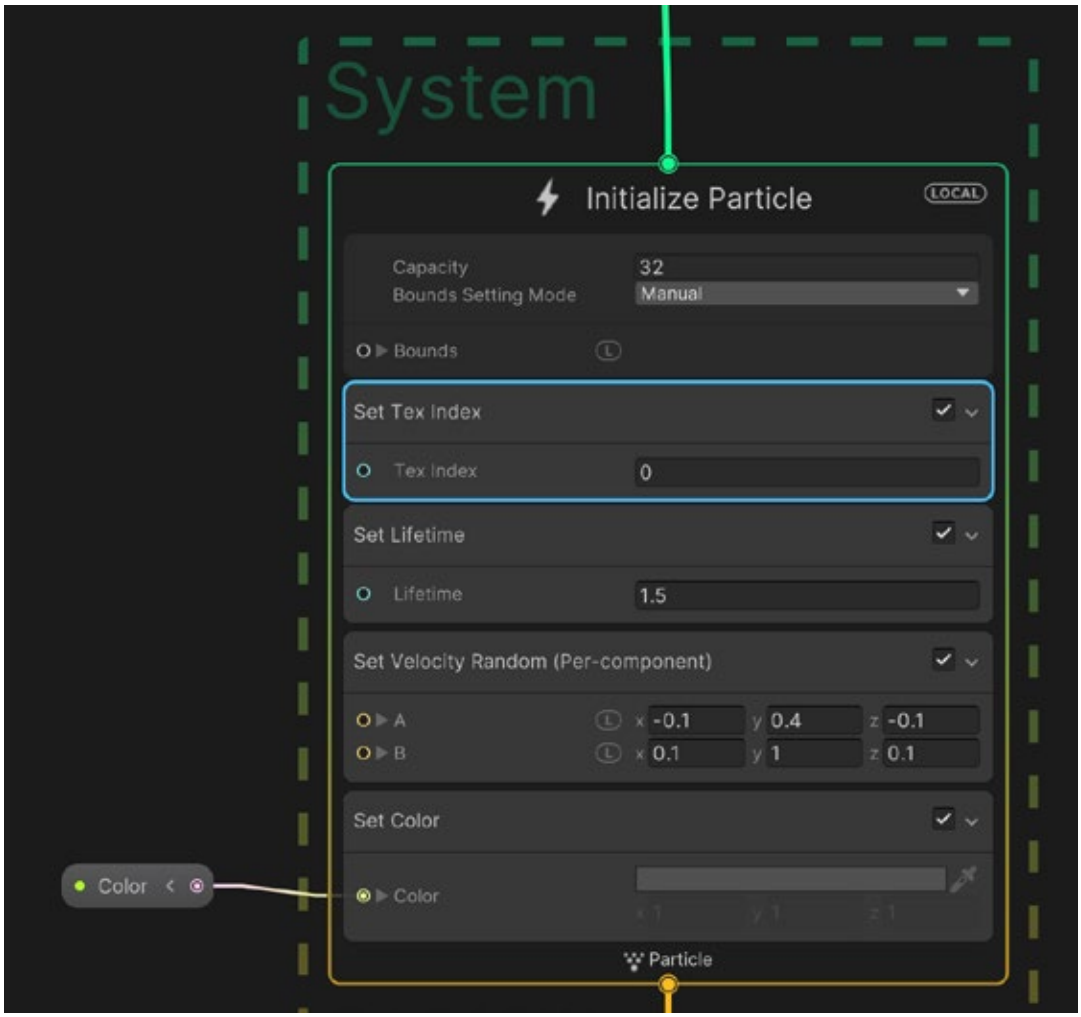
Create a Six Way Shader Graph

To know more about six-way lighting see the blog post Realistic smoke lighting with 6-way lighting in VFX Graph. And see this blog post that goes through the Shader Graph process with an example project and some advanced suggestions.

VFX Graph

Almost any kind of visual effect is possible in Unity, whether you plan on your characters shooting fireballs from their fingertips or traveling through a wormhole. Visual effects (VFX) in a game enhance the atmosphere, help tell the story, and add details that can truly captivate your players.

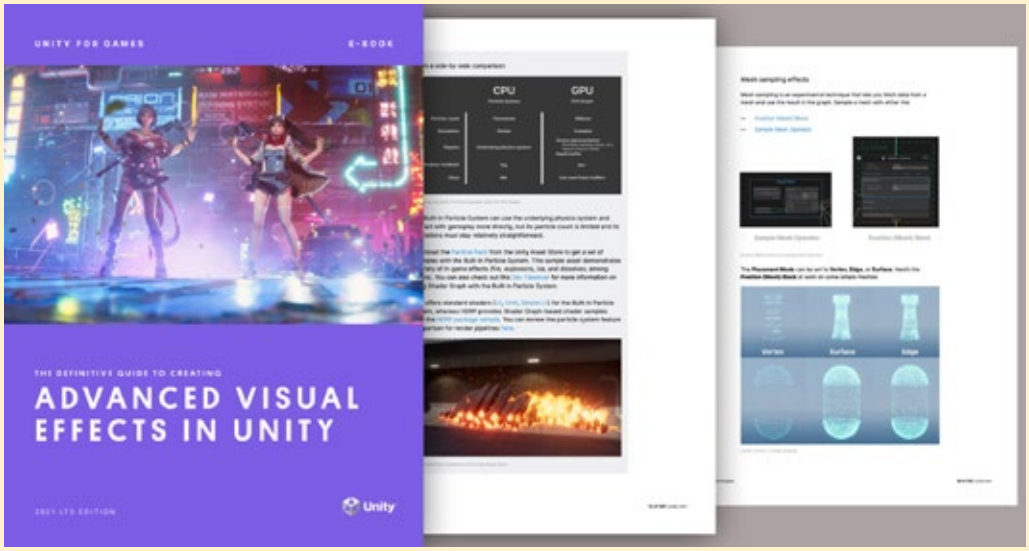
Unity is pushing the boundaries of real-time graphics with tools such as the VFX Graph. This node-based editor enables technical and VFX artists to design dynamic visual effects – from simple common particle behaviors to complex simulations involving particles, lines, ribbons, trails, meshes, and more.



Editing a VFX Graph

To learn more about creating VFX with URP and the VFX Graph download the e-book *The definitive guide to creating advanced visual effects in Unity*.

A smoke effect created using the VFX Graph

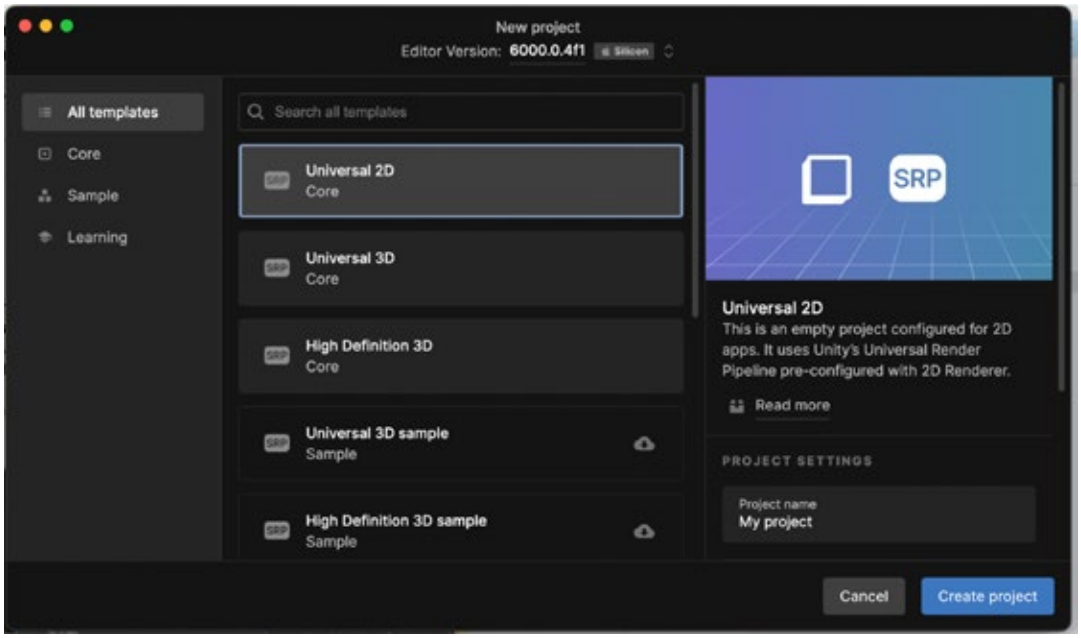


Download the Unity e-book

2D Renderer and 2D lights

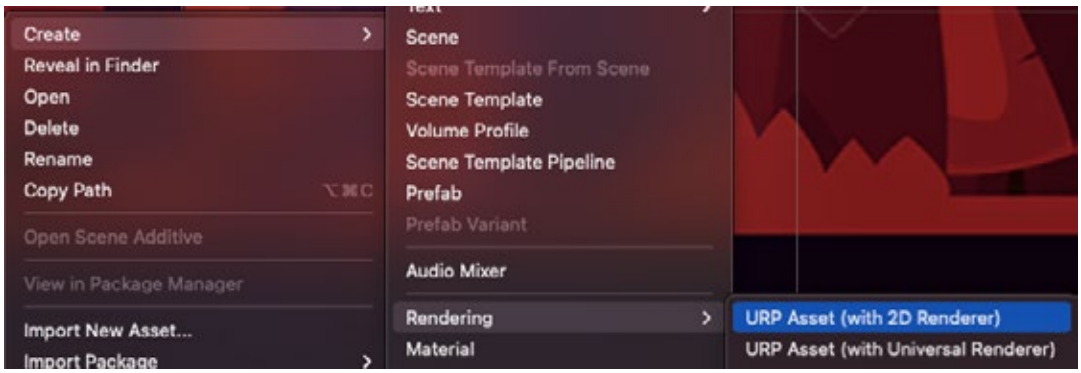
There's no limit to how innovative today's 2D games can be. The evolution of hardware, graphics, and game development software makes it possible to create 2D games with real-time lights, high-resolution textures, and an almost unlimited sprite count.

If you are working on a 2D game, you'll be pleased to know there is a dedicated URP 2D Renderer. The simplest way to get started is to use the 2D URP template from the Unity Hub. This template ensures that your project has a URP 2D Renderer assigned via Project Settings > Graphics > Scriptable Render Pipeline Settings. All verified and precompiled 2D packages are installed with the 2D URP template and the default settings optimized for 2D projects. This also ensures that the project loads faster than installing all the packages manually.



The 2D URP template in the Unity Hub

If you're upgrading an existing project, then you need to find a suitable folder in your project's Assets folder. Right-click and select Create > Rendering > URP Asset (with 2D Renderer). Give it a name, and select it using Project Settings > Graphics > Scriptable Render Pipeline Settings. In the Scene view, be sure to select the 2D button when editing.



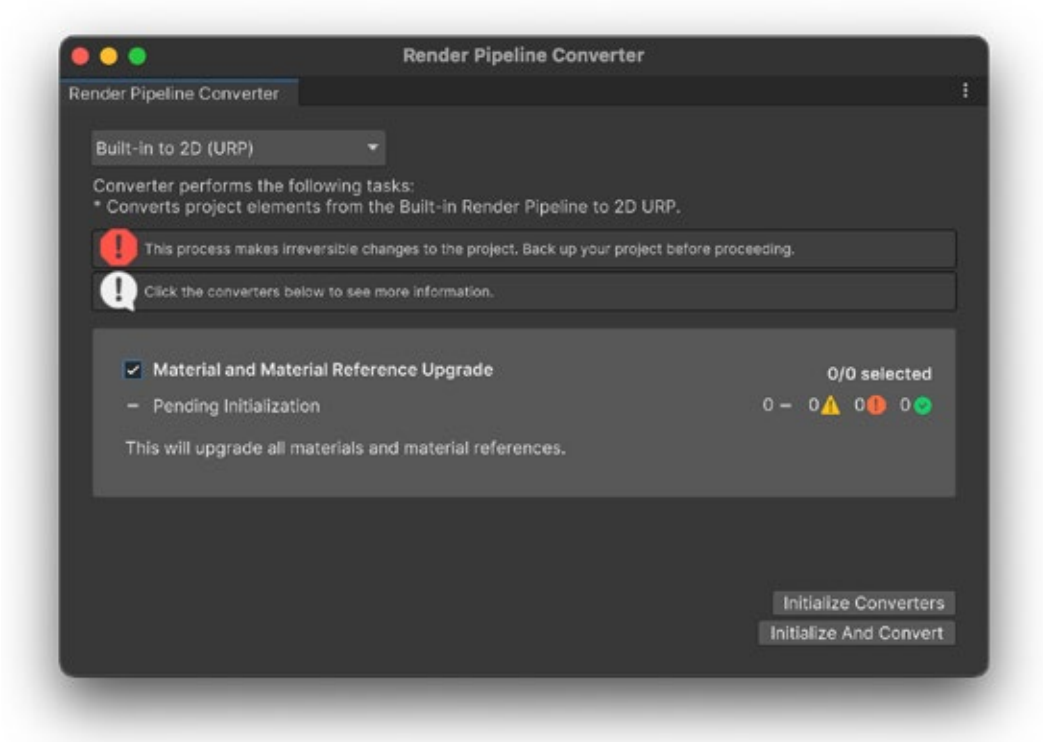
Creating a 2D Renderer and Settings Asset

The appearance of the “classic” magenta color that indicates a rendering error might occur if you’re switching an existing project to the URP 2D Renderer.

Updating an existing project with URP 2D Renderer can result in rendering errors in your scene.

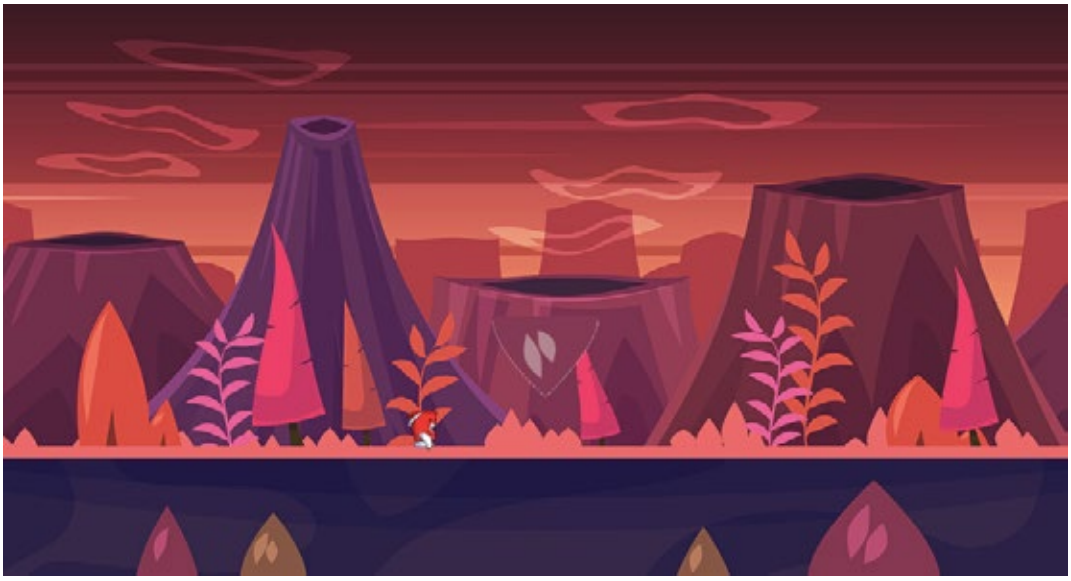
Fortunately, the **Window > Rendering > Render Pipeline Converter** has got you covered. Select **Built-in to 2D (URP)** and click the Material and Material Reference Upgrade panel. Then click Initialize Converters, followed by Convert Assets to be able to deselect some items or Initialize And Convert to handle the process with one click. If you still see magenta-colored sprites, you might need to manually replace the shader in some of your materials. Choose one of the shaders in the following table.

2D shaders available in URP	
Shader	Description
Sprite-Lit-Default	Uses 2D lights when rendering
Sprite-Mask-Default	Works with the stencil buffer
Sprite-Unlit-Default	Uses only the texture colors when rendering



Converting a Built-In Render Pipeline 2D project to URP 2D

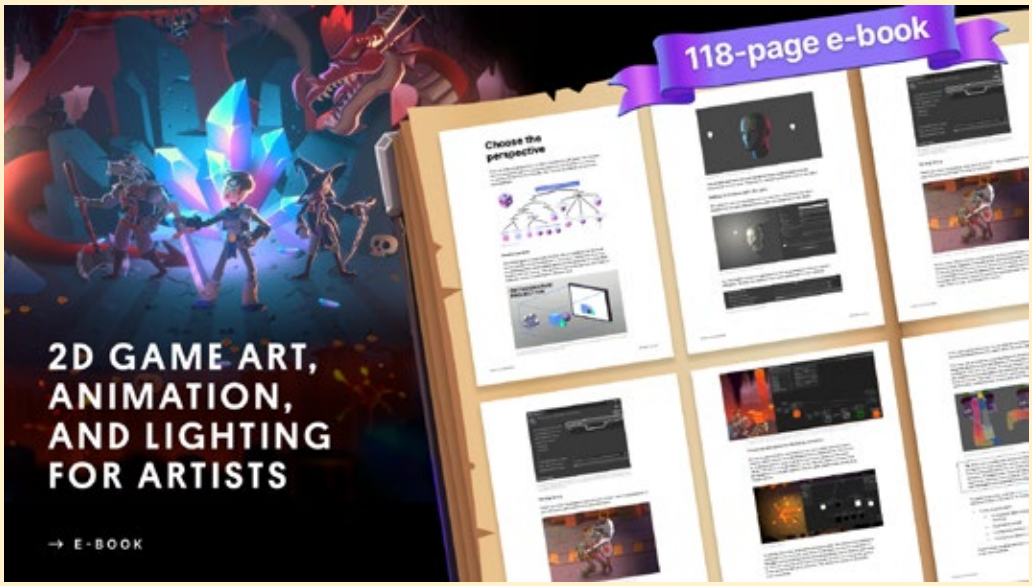
2D lights are available with the URP 2D Renderer. These offer enhanced performance and flexibility. Using the new tools, you can create a more immersive experience and save time preparing different sprite variations by using baked lights to create new gameplay possibilities. If you have migrated an existing project, then you will have no URP 2D lights in your scene. If your sprites use the Sprite-Lit-Default shader, you might be surprised to see a lit render. But with no lights, you get a default Global Light assigned to the scene for an unlit appearance.



With no lights in the scene, the render defaults to Unlit.

2D game development resources from Unity

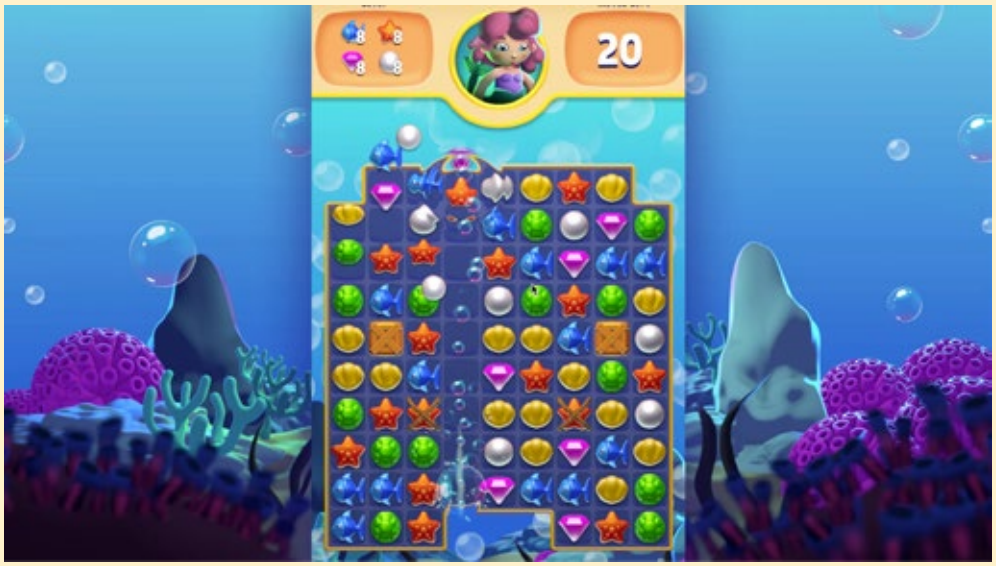
The e-book, *2D game art, animation, and lighting for artists* is our biggest, most comprehensive 2D development guide, created for Unity developers and artists who want to make a commercial 2D game.



Download the Unity e-book about 2D graphics, tools, and animation

2D sample projects from Unity

Gem Hunter Match



Gem Hunter Match shows you how a 2D puzzle/match-3 game can stand out from the competition with eye-catching lighting and visual effects created in URP. Among other techniques, you'll learn how to prepare and light 2D sprites to add depth, apply a Sprite Custom Lit shader for shimmer, and create glare and ripple effects.

- Download *Gem Hunter Match*
- Get an introduction to *Gem Hunter Match*

Happy Harvest

Happy Harvest shows developers how to harness the latest capabilities for creating 2D lights, shadows, and special effects with URP. It incorporates best practices any 2D creator can use, including not baking shadows into a sprite, keeping sprites flat, moving shadow and volume information to secondary textures, advanced Tilemap features, and much more.

- Download *Happy Harvest*
- Get an introduction to *Happy Harvest*

UI Toolkit Sample – Dragon Crashers

This 2D sample project is a vertical slice of a side scrolling Idle RPG game that showcases how the suite of 2D tools can be combined with artwork to make your vision a reality. All of the content in this demo can be added into your own creative projects.

— Download *UI Toolkit – Dragon Crashers*

— Get an introduction to *UI Toolkit – Dragon Crashers*

More Unity 6 features for URP

This section highlights key features in URP in Unity 6 that can improve performance or fidelity on a wide variety of devices.

Spatial-Temporal Post-Processing (STP)

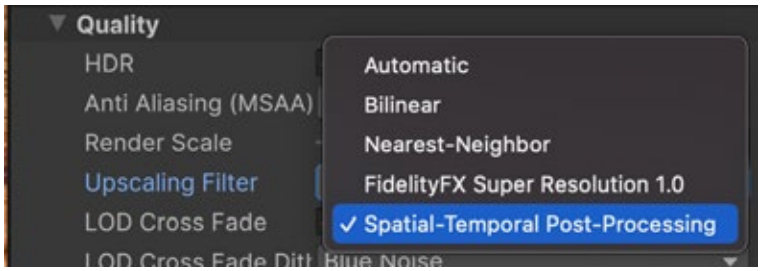
The oasis environment from the URP 3D Sample rendered in three different ways: Render scale 1 at left, Render scale 0.25 in the middle, and Render scale 0.25 with STP enabled at right

The number of competing super resolution techniques is growing, and many of them are specific to a single hardware vendor. Along with this, these solutions are not designed for mobile.

Spatial-Temporal Post-Processing (STP), is Unity's super resolution solution which works on all devices, from mobile to console, and delivers high quality results in URP while keeping overhead low. As you can see from the blended image above the results are high-quality. The left third shows the image with no STP and Render Scale 1. The middle third shows no STP and Render Scale 0.25, resulting in a blurry, low-fidelity image. The right third enables STP while keeping the Render Scale at 0.25, rendering 1/16 of the pixels yet with STP up scaling appearing sharp.

STP is a spatio-temporal anti-aliasing upscaling solution that should work on any device that supports shader model 5.0. It is designed with mobile in mind, aiming at delivering visual quality that's comparable to DLSS2, FSR2, or XeSS, with a lower performance cost.

Enable STP via the active URP Asset using **Quality > Upscaling Filter**. Then set the Render Scale.



Enabling Spatial-Temporal Post-Processing

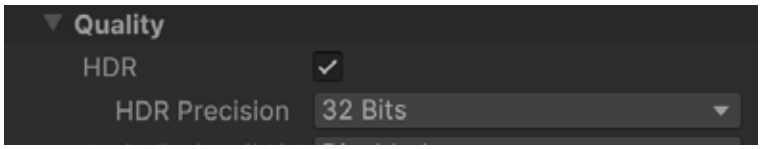
High Dynamic Range display output for PC and consoles

Rendering Debugger > Lighting > HDR Debug Mode > Gamut View

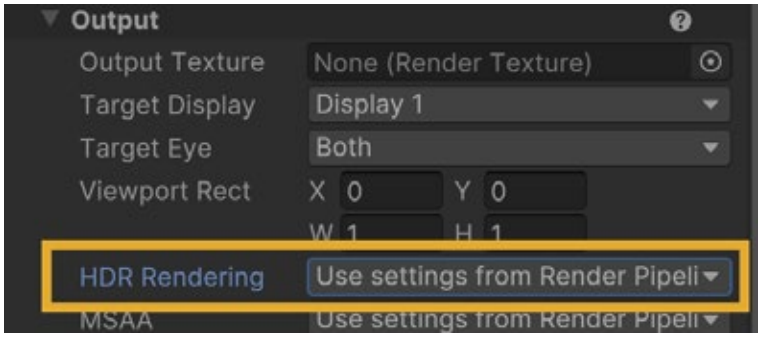
High Dynamic Range (HDR) displays are display devices capable of reproducing images in the higher range of difference in luminance closer to natural lighting conditions. HDR Output allows for better preservation of the contrast and quality of the linear lighting renders and HDR images displayed on these devices.

You enable HDR in two places:

1. The URP Asset



2. The Camera Inspector: Set **Output > HDR Rendering** to **Use settings from Render Pipeline Asset**.



With HDR you can turn on the option to take advantage of better quality image render outputs from URP on HDR displays. As a result, you can present final images with colors and contrasts that mimic natural lighting conditions better on these devices.

In addition to the existing desktop and console support that became available in Unity 2022, mobile support is introduced in Unity 6 for the following platforms:

— iOS players (iOS 16+, iPadOS 16+)

— Android players using Vulkan and GLES (Android 9+, depending on device capabilities)

Some common mobile devices that provide HDR display support include iPhone X and newer, Samsung Galaxy S10 and newer, Galaxy Note 10 and newer, and Galaxy Tab S6 and newer.

Using a Pipeline State Object

Unity 6 introduces a new and powerful Pipeline State Object (PSO) tracing and precooking workflow, unlocking a smoother and stutter-less player experience, when targeting modern platforms.

This set of APIs provides a significant upgrade from the “shader warmup” API, previously introduced in older Unity versions. While traditional shader warmup is sufficient for older graphics APIs (e.g. OpenGL, DirectX11), the new PSO workflow allows developers to better utilize modern graphics APIs, such as Vulkan, DirectX12 and Metal.

PSO creation and caching

When targeting modern graphics APIs, the GPU vendor’s graphics drivers will perform runtime shader compilation (and other rendering state translation) as part of the PSO creation process. As a result, PSO creation is a lengthy process, which may lead to noticeable stutters in the runtime application. This overhead can be exacerbated for more complex projects, which require the application to compile a large amount of PSOs on the fly.

You can identify PSO creation stutters in the Unity Profiler, using the GraphicsPipelineImpl markers:

Profiling PSO creation

In many cases, the GPU vendor's graphics drivers will automatically cache any compiled PSO to disk, in order to accelerate PSO creation for subsequent application runs. However, the application may still need to compile PSOs for newly encountered shader variants and materials. Furthermore, OS and driver updates will often invalidate the driver-managed PSO cache.

The ideal way to warm PSOs may vary depending on your application and use case. For example, you may choose to synchronously precook PSOs during level transitions and scene loading. This can be done progressively (time-sliced) in order to increase application responsiveness, creating a fixed amount of PSOs per frame.

Alternatively, you can choose to asynchronously precook PSOs in the application's background. This will not block the application, but may temporarily regress CPU performance for the duration of the warm up.

Tracing a new PSO collection

You should begin by tracing the PSOs created by the application during rendering:

1. In a C# script, create a new GraphicsStateCollection. This collection corresponds to your application's or scene's PSOs.
2. To begin tracing PSOs into your collection, call the GraphicsStateCollection.BeginTrace method. Any new graphics pipelines created by the application will be added to the collection. In most cases, you should begin tracing during scene or application start up.
3. To finalize the tracing process, call the GraphicsStateCollection.EndTrace method. In most cases, you should end tracing during scene or application end.

Once tracing is complete, you can save the PSO collection to disk, using GraphicsStateCollection.SaveToFile.

For additional control, you can inspect the recorded PSOs and variant data, and modify the collection as needed. GraphicsStateCollection.GetVariants can be used to retrieve all shader variants recorded in a PSO collection. You can then read the graphics states used by each variant via GraphicsStateCollection.GetGraphicsStatesForVariant. Lastly, you can modify the graphics states associated with each variant using AddGraphicsStateForVariant / RemoveGraphicsStatesForVariant.

Note:

GPU representation of the PSO may vary across platforms. It is highly recommended to perform tracing in the Player, targeting the relevant graphics API, and to maintain separate collections per target.

When tracing on a target device using Player Connection, you can send the PSO collection to the Editor and save to disk, via GraphicsStateCollection.SendToEditor. You can also query the platform used when tracing the PSO collection via GraphicsStateCollection.runtimePlatform.

Precooking a PSO collection

Once tracing is completed, you can request Unity to precook PSO collection, ideally well ahead of drawing time. In most cases, the ideal time to perform warmup is during application or scene loading sequences.

You can perform PSO precooking using two warm up methods:

— GraphicsStateCollection.WarmUp will schedule the creation of all PSOs in the collection.

— GraphicsStateCollection.WarmUpProgressively will schedule the creation of a set number of PSOs in the collection.

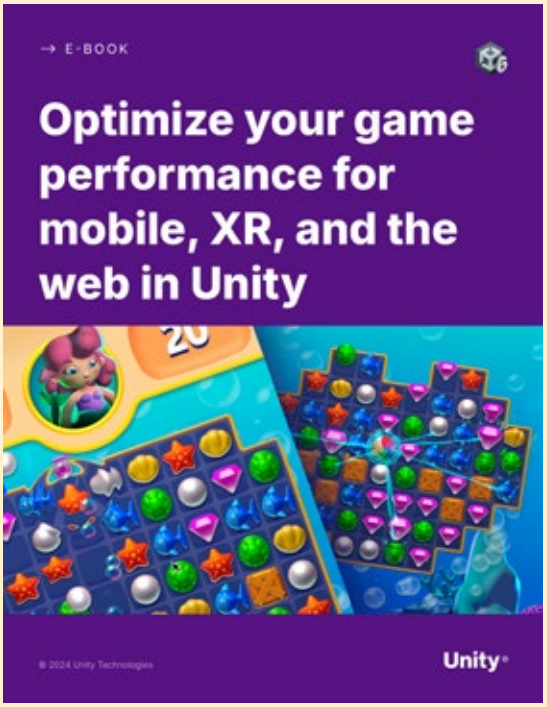
Both methods will return a job handle, which can be used to determine whether PSO Warmup is performed synchronously or asynchronously.

Once the PSOs are created, the drivers will often cache those to disk. Next time the PSOs are precooked, they could be loaded directly from cache.

Platform support

The new PSO workflow is available as of Unity 6, for Players targeting Metal, Vulkan, and Direct3D 12. In coming versions, we will also provide compatibility for older graphics APIs such as OpenGLES and Direct3D 11, in the form of an implicit shader-warmup fallback.

Performance



Get tips for using Unity's profiling tools, programming and code architecture, project configuration and assets, and more. Learn how to enhance your mobile game's performance.
Download

Pick up great tips for extensive profiling of your console and PC projects, programming code and architecture, optimizing assets and graphics, UI, physics, and animation optimizations.
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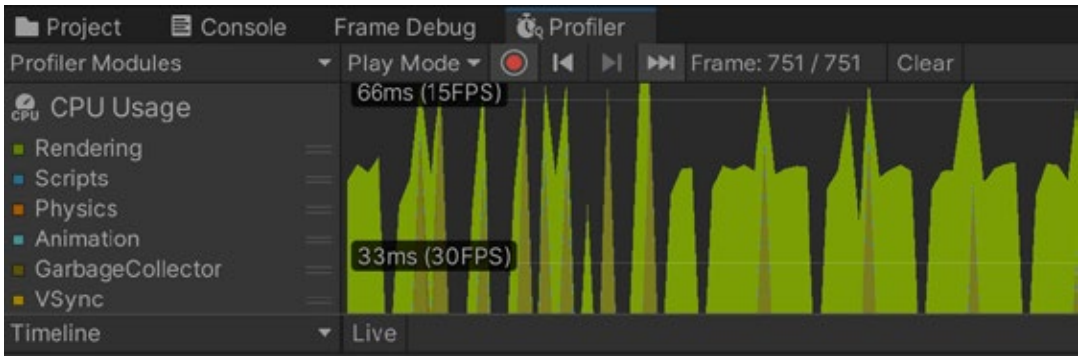
Performance is highly dependent on the project you're working on. Always profile and test your game throughout the development cycle. Open the Profiler via **Window > Analysis > Profiler**, and follow the suggestions in this chapter.



The Profiler window

This section looks at seven ways to improve the performance of your games:

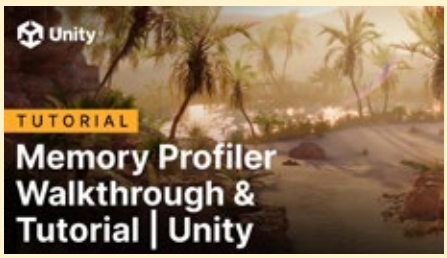
— Managing your lighting
— Light probes
— Reflection probes
— Camera settings
— Pipeline settings
— Frame Debugger
— Profiler

These optimizations are also covered in this tutorial.

And see the following video tutorials for profiling tips:

Watch it

Watch it



Watch it

Optimizing lighting and rendering in URP

URP is built with optimized real-time lighting in mind. The URP Forward Renderer supports up to eight real-time lights per object and up to 256 real-time lights per camera for desktop games, plus 32 real-time lights per camera for mobile and untethered hardware. URP also allows for configurable per-object Light settings inside the Pipeline Asset for refined control over lighting.

As explained in the Lighting chapter, baked lighting is one of the best ways to improve the performance of your scene. Real-time lighting can be expensive, whereas baking lights can help you gain back performance, assuming the lights in your scene are static. The baked lighting textures are batched into a single draw call, without needing to be continuously calculated. This is especially useful if your scene uses multiple lights. Another great reason to bake your lighting is that it allows you to render bounced or indirect lighting in your scene and improve the visual quality of the render.

Global Illumination is similarly covered in the Lighting section. This process simulates rays of light bouncing around the environment and illuminating other nearby objects with the bounced light. The figure below shows three lighting setups for the same scene: with no baked light data, with baked lighting, and with post-processing applied.

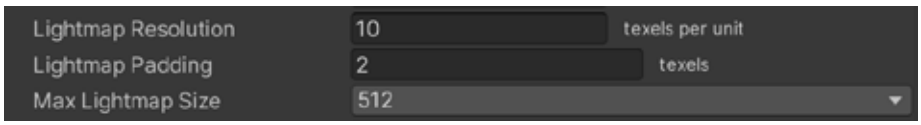
From left to right: no lighting data, baked lighting, post-processing added

When baked, areas of shadow in a scene receive the bounced light and are illuminated. It can be subtle, but this technique spreads the light around a scene more realistically and improves its overall appearance.

In the previous image, you can see that the specular highlights on the ground are lost when baking. Baked lights only contain diffuse lighting. Whenever possible, compute the direct lighting contribution from real-time, and have Global Illumination come from Image Based Lighting (IBL)/shadow maps/Probes.

The effect of light baking on shadows: before baking on the left, and after baking on the right

Use the lowest possible **Lightmap Resolution** and **Lightmap Size** when baking your lights; Go to **Window > Rendering > Lighting > Scene**. This helps to lower the texture memory requirement.

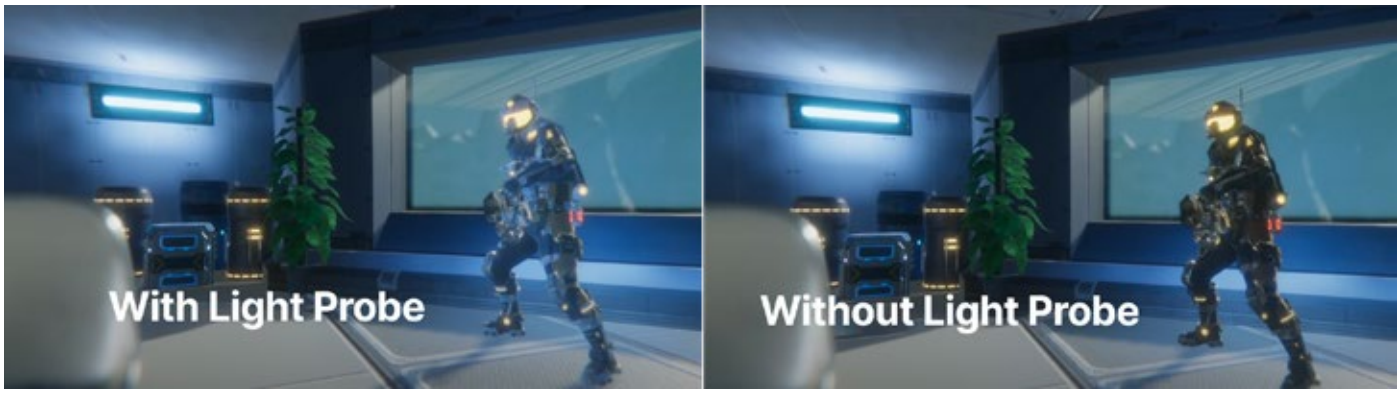


Setting the Lightmap Resolution and Max Lightmap Size

Light probes

As explained in the Lighting section, light probes sample the lighting data in the scene during baking and allow the bounced light information to be used by dynamic objects as they move or change. This helps them blend into and feel more natural in the baked lighting environment. (The Unity engine now has an alternative to Light Probes, see the APV section).

Light probes add naturalism to a render without increasing the processing time for a rendered frame. This makes them suitable for all hardware, even low-end mobile devices.



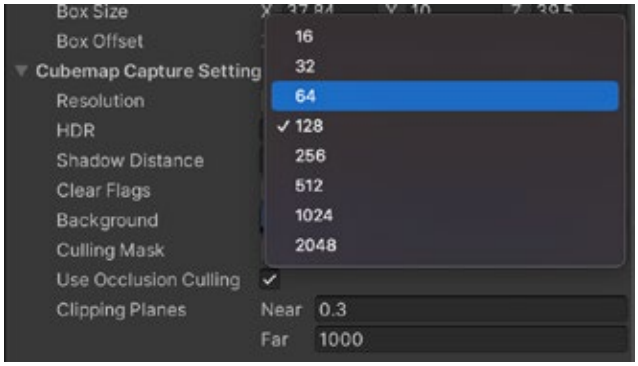
The effect of using light probes when rendering a dynamic object: with light probe on the left, and without on the right

Reflection probes

You can also use reflection probes to optimize your scene. Reflection probes project parts of the environment onto nearby geometry to create more realistic reflections. By default, Unity uses the Skybox as the reflection map. But by using one or more reflection probes, the reflections will match their surroundings more closely.

The effect of using reflection probes on smooth surfaces: with reflection probes on the left and without on the right

The size of the cubemap generated when baking the reflection probes depends on how close the camera gets to a reflective object. Always make sure to use the smallest map size that suits your needs to optimize your scene.



Adjusting the size of the reflection probe cubemap

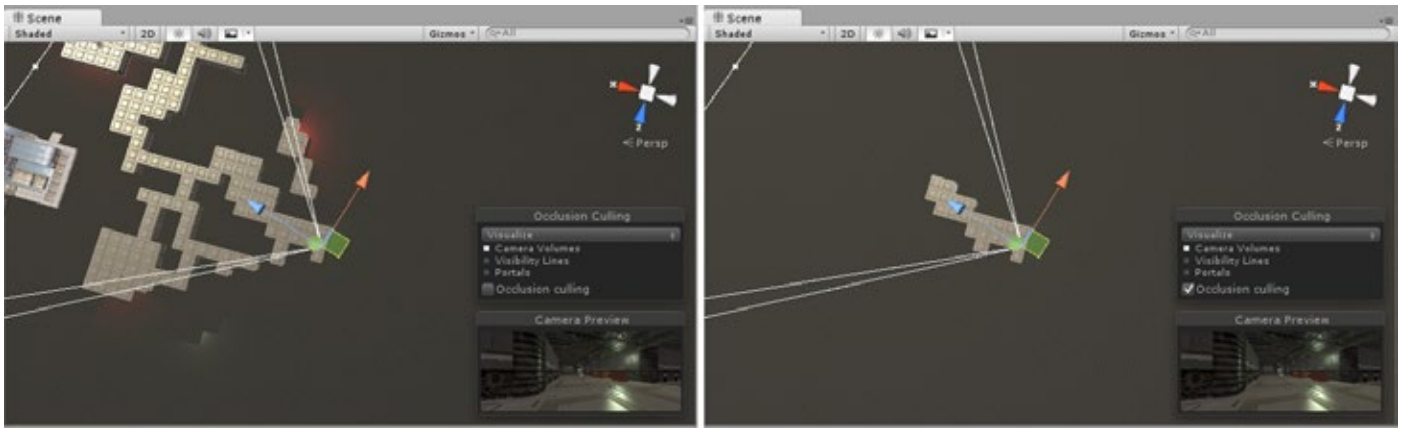
Camera settings

The URP enables you to disable unwanted renderer processes on your cameras for performance optimization. This is useful if you're targeting both high- and low-end devices in your project. Disabling expensive processes, such as post-processing, shadow rendering, or depth texture can reduce visual fidelity but improve performance on low-end devices.

Occlusion culling

Another great way to optimize your Camera is with occlusion culling. By default, the Camera in Unity will always draw everything in the Camera's frustum, including geometry that might be hidden behind walls or other objects. There's no point in drawing geometry that the player can't see, and that takes up precious milliseconds. This is where occlusion culling comes in.

Occlusion culling is best suited to a scene where significant numbers of objects might be masked when another item appears between them and the Camera. A cellular corridor maze-type game is an ideal candidate for using occlusion culling, as seen in the images below.

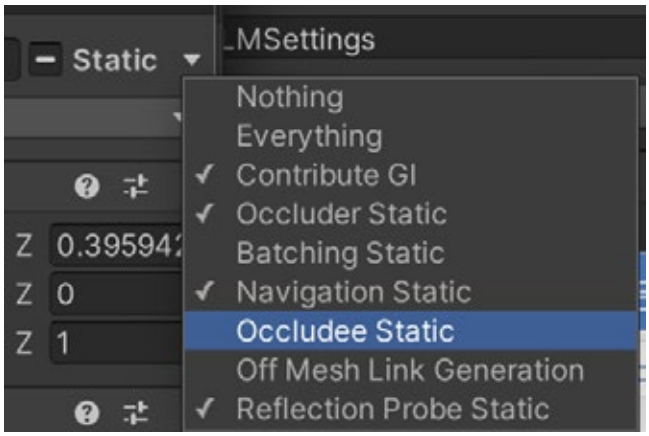


Frustum culling in the image on left, and occlusion culling in the image on right

By baking occlusion data, Unity ignores the parts of your scene that are blocked. Reducing the geometry being drawn per frame provides a significant performance boost.

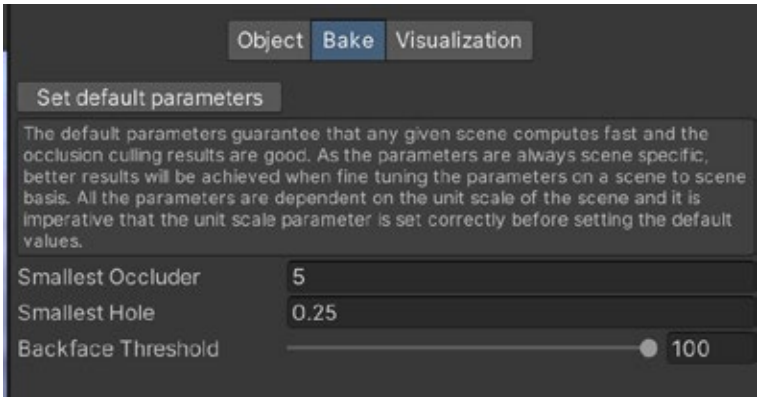
To enable occlusion culling in your scene, mark any geometry as either **Occluder Static** or **Occludee Static**. Occluders are medium to large objects that can occlude objects marked as Occludees. To be an Occulder, an object must be opaque, have a Terrain or Mesh Renderer component, and not move at runtime. Occludees can be any object with a Renderer component, including small and transparent objects that similarly do not move at runtime.

You set the static properties using the usual drop-down.



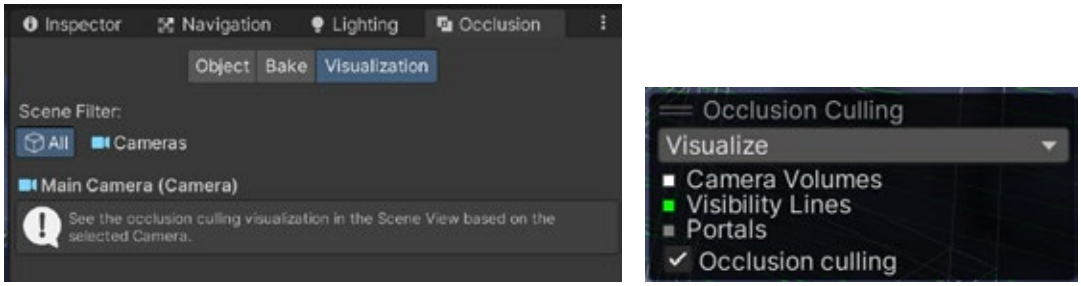
Settings for an object included in occlusion data

Open **Window > Rendering > Occlusion Culling**, and select the **Bake** tab. In the bottom-right corner of the **Inspector**, press **Bake**. Unity generates occlusion data, saving the data as an asset in your project and linking the asset to the current scene.



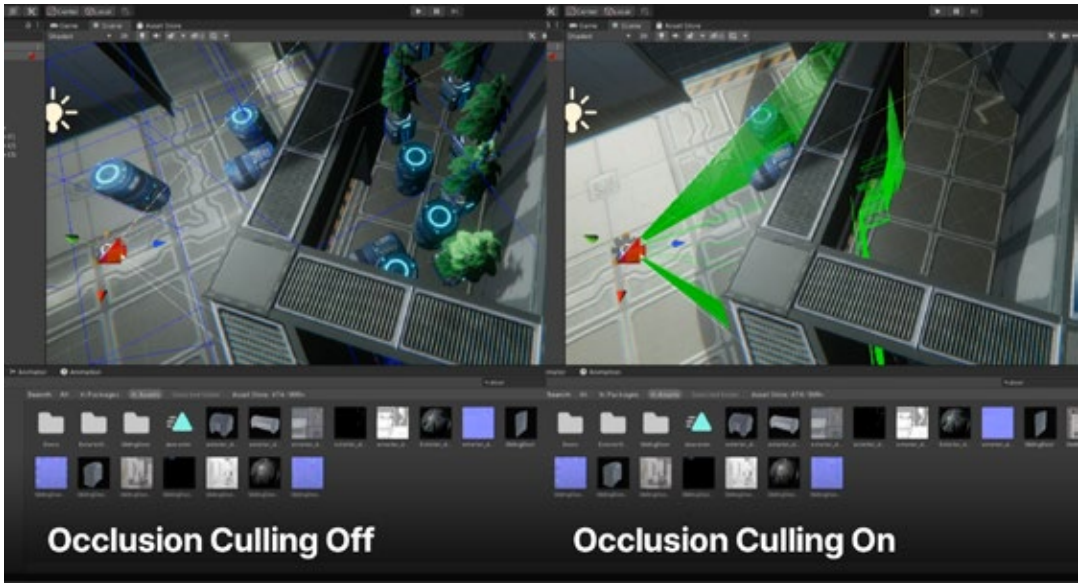
Occlusion culling Bake tab

You can see occlusion culling in action using the **Visualization** tab. Select the **Camera** in the scene and use the **Occlusion Culling** pop-up window in the **Scene** view to configure the visualization. The pop-up might be hidden behind the small Camera view window. Right-click the double-line icon and choose **Collapse** if this is the case. Move the pop-up, then restore the Camera view using right-click expand.



Visualization tab and Occlusion Culling pop-up

As you move the Camera, you should see objects popping on and off.



The effect of occlusion culling off in the left image, and on in the right image

If you are using GPU Resident Drawer in Unity 6, then you can use GPU Occlusion Culling.

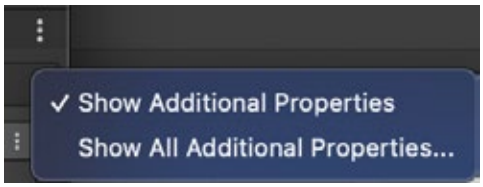
Pipeline settings

While the effects of changing the settings for the URP Asset and using different Quality tiers were previously covered, here are some additional tips for experimenting with Quality tiers to get the best results for your project:

— Reduce Shadow Resolution and distance for performance gains.

— Disable features that your project does not require, such as depth texture and opaque texture.

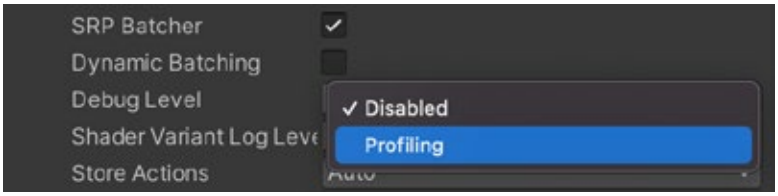
— Enable the SRP Batcher to use the new batching method. The SRP Batcher will automatically batch together meshes that use the same shader variant, thereby reducing draw calls. If you have numerous dynamic objects in your scene, this can be a useful way to gain performance. If the SRP Batcher checkbox is not visible, then click the three vertical dots icon (⋮) and select **Show Additional Properties**.



Enabling additional properties for the URP Asset Inspector

Frame Debugger

Use the Frame Debugger to gain a better understanding of what's happening during rendering. To view additional information in the Frame Debugger window, adjust the **Debug Level** using the **URP Asset**. As with the SRP Batcher checkbox, this is only visible in the Inspector with **Show Additional Properties** enabled.

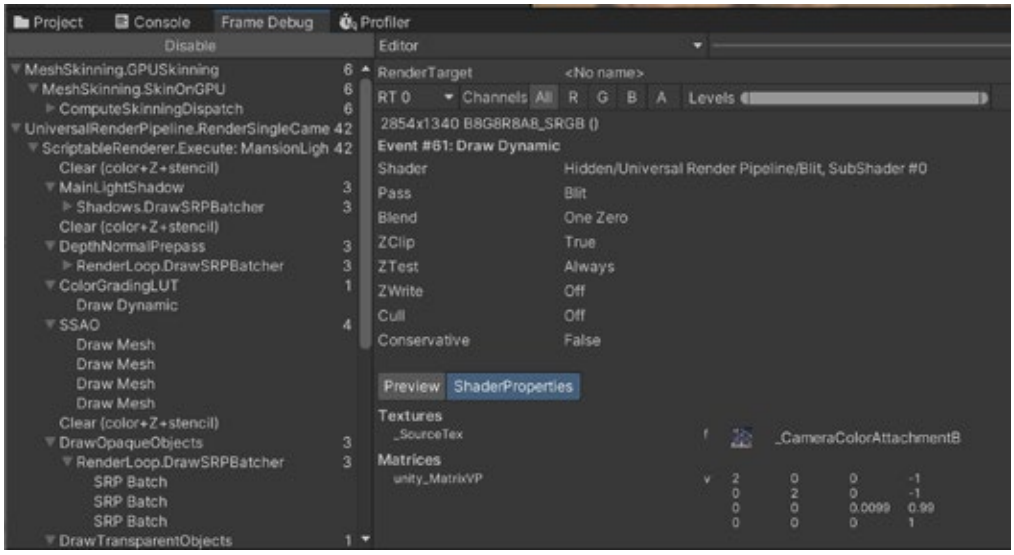


Setting the Debug Level

Adjusting the Debug Level can affect performance. Always turn it off when the Frame Debugger is not in use.

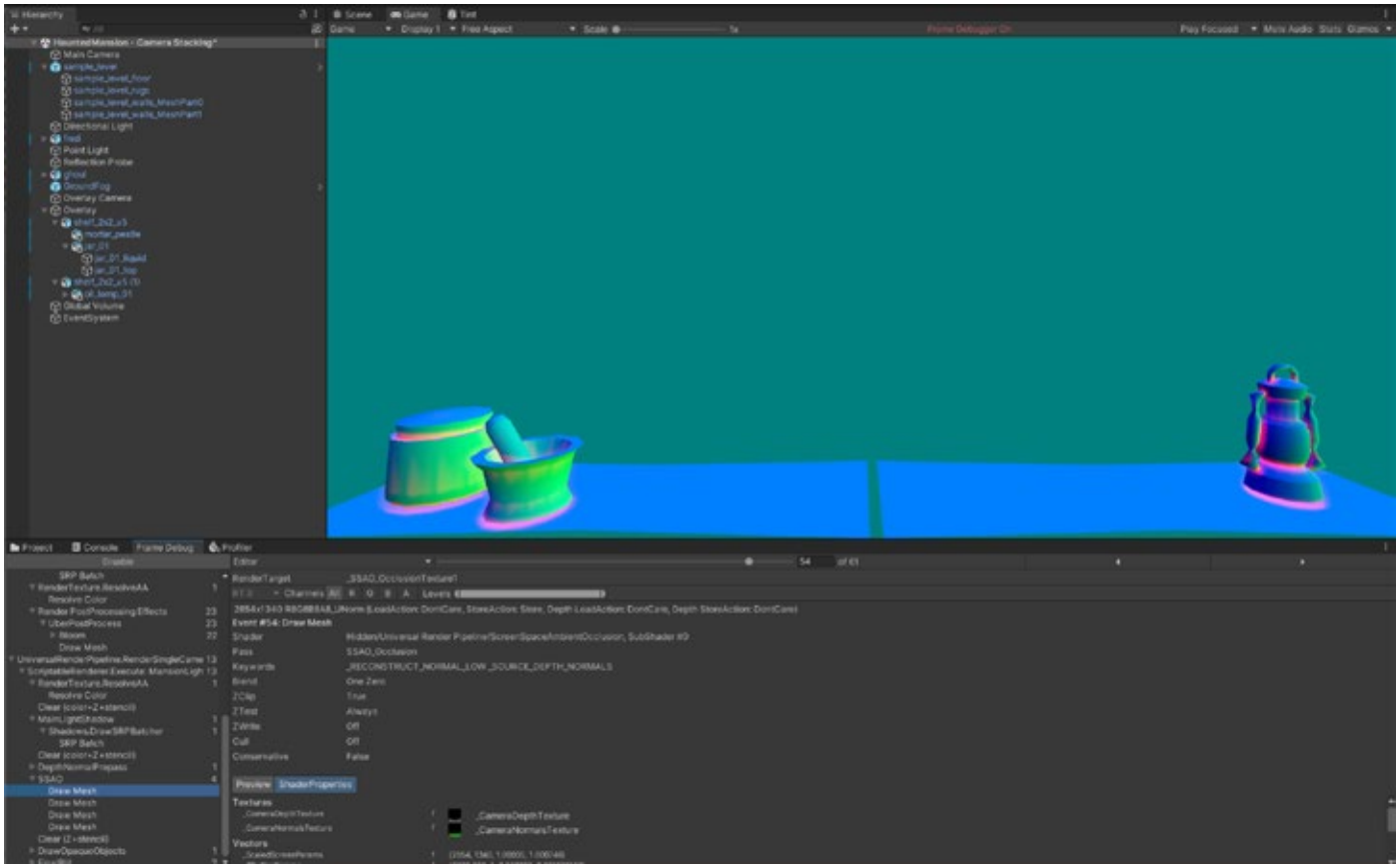
The Frame Debugger shows a list of all the draw calls made before rendering the final image and can help you pinpoint why certain frames are taking a long time to render. It can also identify why your scene's draw call count is so high.

Open the Frame Debugger by going to **Window > Analysis > Frame Debugger**. When your game is playing, select the **Enable** button. This will pause the game and let you examine the draw calls.



Frame Debugger detail

Clicking a stage in the render pipeline (left pane) will show a preview of this stage in **Game** view.



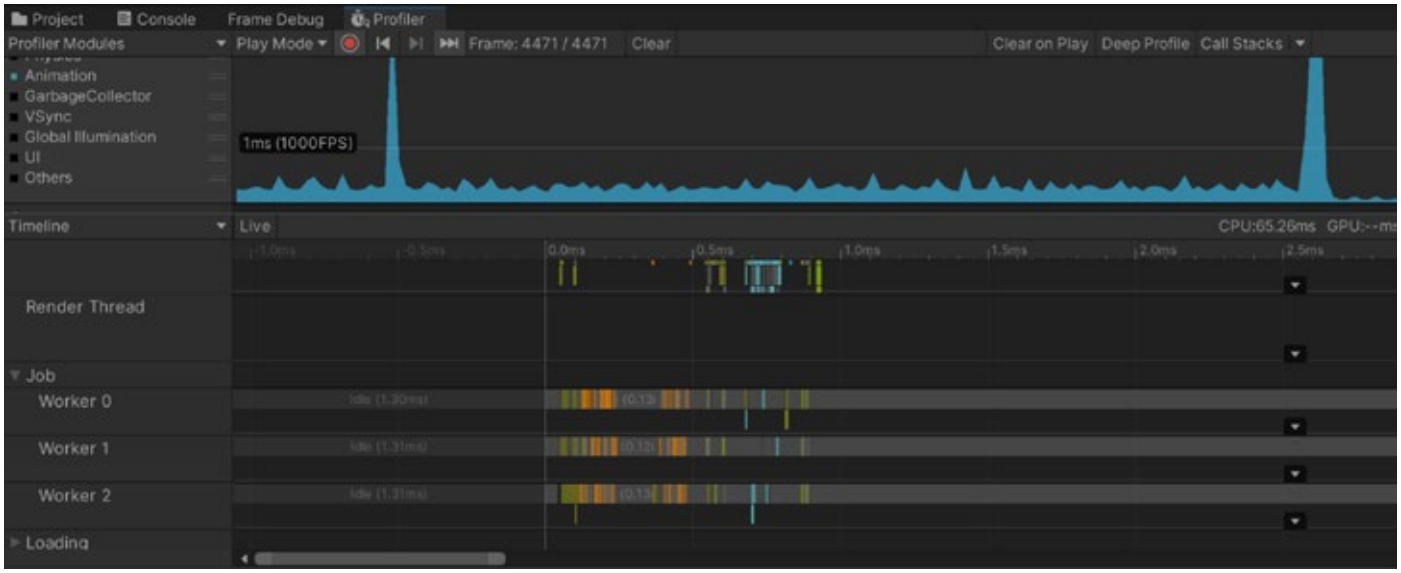
The Frame Debugger shows every step of the rendering process in the Game View – in this case, the SSAO generation step.

Unity Profiler

Like the Frame Debugger, the Profiler is a great way to determine how long it takes to complete a frame cycle in your project. It provides an overview of rendering, memory, and scripting. You can identify scripts that take a long time to complete, helping you to pinpoint potential bottlenecks in your code.

Open the Profiler via **Window > Analysis > Profiler**. When in **Play Mode**, the window provides an overview of the overall performance of your game. You can also pause the live view and use the **Hierarchy Mode** to get a breakdown of the time taken to complete a single frame. The Profiler will show you each call Unity has made during the frame.

For an even more detailed analysis, use the low-level native plug-in Profiler API. You can use this Profiler API to extend the Profiler, and profile the performance of native plug-in code, or to prepare profiling data to send to third-party profiling tools such as Razor for Sony Playstation, PIX for Microsoft (Windows and Xbox), as well as Chrome Tracing, ETW, ITT, VTune, or Telemetry.



The Profiler window using the low-level native plug-in Profiler API

Here's an example of using the low-level native plug-in Profiler API:

```
#include <IUnityInterface.h>
#include <IUnityProfiler.h>
static IUnityProfiler* s_UnityProfiler = NULL;
static const UnityProfilerMarkerDesc* s_MyPluginMarker = NULL;
static bool s_IsDevelopmentBuild = false;
static void MyPluginWorkMethod()
{
	if (s_IsDevelopmentBuild)
	s_UnityProfiler->BeginSample(s_MyPluginMarker);
	// Code I want to see in Unity Profiler as “MyPluginMethod”.
	// ...
	if (s_IsDevelopmentBuild)
	s_UnityProfiler->EndSample(s_MyPluginMarker);
}
extern “C” void UNITY_INTERFACE_EXPORT UNITY_INTERFACE_API UnityPluginLoad(IUnityInterfaces*
unityInterfaces)
{
	s_UnityProfiler = unityInterfaces->Get<IUnityProfiler>();
	if (s_UnityProfiler == NULL)
	return;
	s_IsDevelopmentBuild = s_UnityProfiler->IsAvailable() != 0;
```

```
        s_UnityProfiler->CreateMarker(&s_MyPluginMarker,
        “MyPluginMethod”, kUnityProfilerCategoryOther,
        kUnityProfilerMarkerFlagDefault, 0);
}
extern “C” void UNITY_INTERFACE_EXPORT UNITY_INTERFACE_API UnityPluginUnload()
{
        s_UnityProfiler  = NULL;
}
```

Additional resources

If you’re interested in building advanced profiling skills in Unity, start by downloading the free e-book *Ultimate guide to profiling Unity games*. This guide brings together advanced advice and knowledge on how to profile an application in Unity, manage its memory, and optimize its power consumption from start to finish.

A couple of other useful resources include Measuring Performance by Catlike Coding, and Unity Draw Call Batching by The Gamedev Guru.

The URP 3D sample

The URP 3D sample is available in the Unity Hub and features four environments, each with its own art style, rendering path, and scene complexity, to represent the variety of 3D projects built with URP.

The URP 3D sample replaces the construction scene that will be familiar to many developers who have been using URP for a few years. The new sample project contains several mini-scenes that illustrate the capabilities of URP.

Let's go through each scene.

The garden

This scene illustrates how you can efficiently scale your content with URP to suit multiple platforms, from mobile and console to high-end gaming desktops. It features stylized PBR rendering, customizable vegetation, and rendering numerous lights with the new Forward+ renderer that surpasses previous light count limits.

The oasis

This is a photorealistic scene with highly detailed textures, VFX Graph effects, SpeedTree, and a custom water solution. It targets devices that support compute shaders.

The cockpit

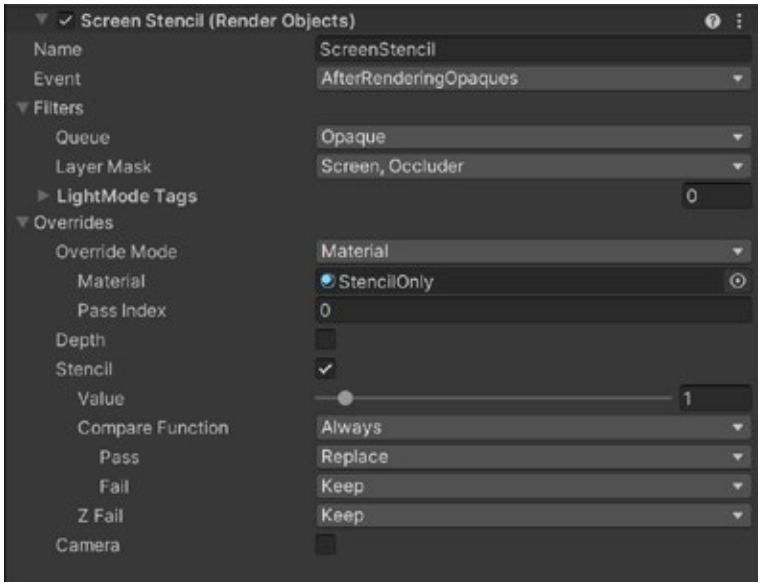
This scene uses custom lighting code with Shader Graph. It's designed for untethered VR devices such as Meta Quest 2.

The terminal

This scene is the link between the other sample scenes, providing a transition effect to move from one scene to the next.

Moving between the scenes

The sample project uses a transition effect to move between scenes. The transition effect uses an off-screen render target to render the incoming scene before the transition is complete. The incoming scene is then rendered to large monitors placed in the outgoing scene using a custom shader created with Shader Graph, and the full-screen swap is handled using a stencil via a Render Objects Renderer Feature.



Screen Stencil Renderer Feature

To see the effect in action, walk toward the pedestal until the Unity logo is displayed, then keep the logo in the center of the screen. This will trigger the transition.

All scene assets are loaded at load time, but only a single scene is enabled. The cameras used at runtime, when starting from The Terminal scene, are the same as those found in the FPS_Controller GameObject. **MainCamera** renders the active scene, and **ScreenCamera** the scene displayed on the monitors.

FPS_Controller for The Terminal Scene

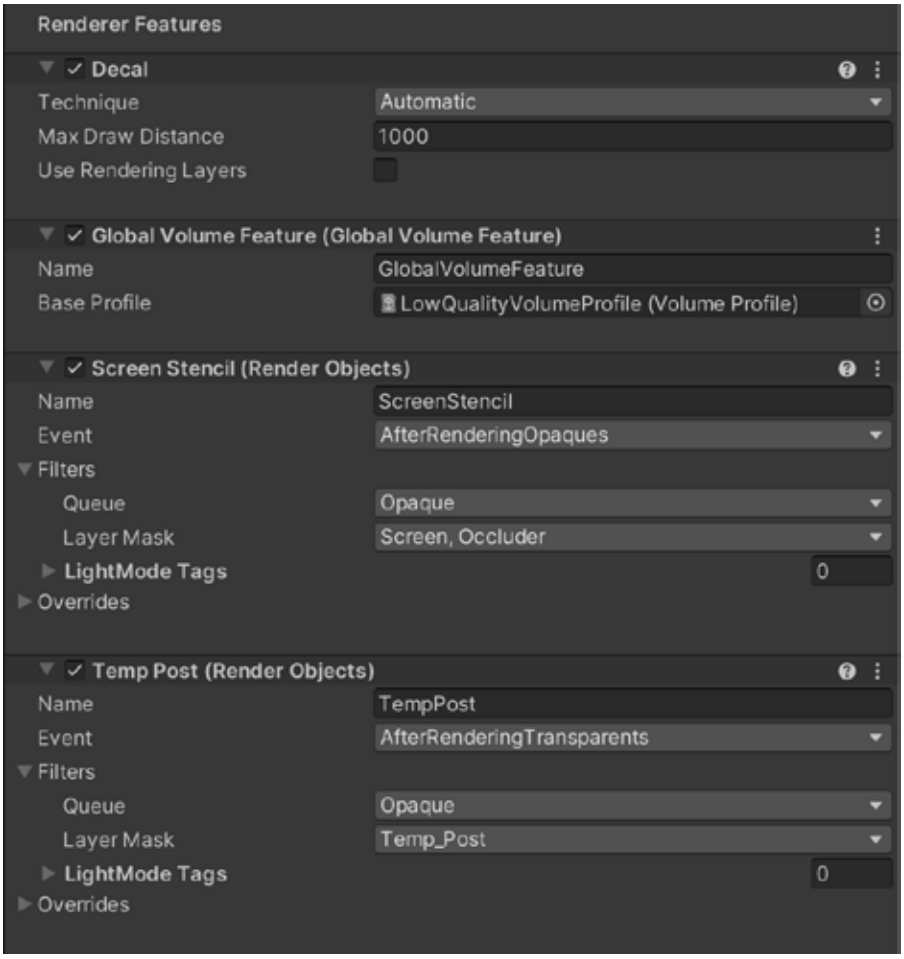
During a transition, the incoming scene camera is rendered to the render target. This creates a potential problem since URP only supports one main directional light. A script called **Scripts > SceneManagement > SceneTransitionManager.cs** runs before rendering, enabling the active scene's main light and disabling the other to keep to this restriction.

Take a look at the script below. In the **OnBeginCameraRendering** method, we first check whether we're rendering the main camera. If **isMainCamera** is true, then the **ToggleMainLight** calls activate the main directional light for the **currentScene** and disable the main directional light for the **screenScene**, the incoming scene. However, if **isMainCamera** is false, then the reverse will be the case.

The same script handles switching the fog, reflection, and skybox to suit the scene being rendered by adjusting the settings of the RenderSettings object.

```
179         /// <summary>
180         /// This function is called per camera by the render pipeline.
181         /// We use it to set up light and render settings (skybox etc) for the different scenes as they are displayed
182         /// </summary>
183         void OnBeginCameraRendering(ScriptableRenderContext context, Camera camera)
184         {
185             bool isMainCamera = camera.CompareTag("MainCamera");
186
187             if (!isMainCamera && screenScene == null)
188             {
189                 //If no screen scene is loaded, no setup needs to be done for it
190                 return;
191             }
192
193             //Toggle main light
194             ToggleMainLight(currentScene, isMainCamera);
195             ToggleMainLight(screenScene, !isMainCamera);
196
197             //Setup render settings
198             SceneMetaData sceneToRender = isMainCamera ? currentScene : screenScene;
199             RenderSettings.fog = sceneToRender.FogEnabled;
200             RenderSettings.skybox = sceneToRender.skybox;
201             if (sceneToRender.reflection != null)
202             {
203                 RenderSettings.customReflectionTexture = sceneToRender.reflection;
204             }
205
206             if (!isMainCamera && camera.cameraType == CameraType.Game)
207             {
208                 camera.GetComponent<OffsetCamera>().UpdateWithOffset();
209             }
210         }
211
212         private void ToggleMainLight(SceneMetaData scene, bool value)
213         {
214             if (scene != null && scene.mainLight != null)
215             {
216                 scene.mainLight.SetActive(value);
217             }
218         }
```

The transition between the incoming and outgoing scenes is handled using a **Render Objects Renderer Feature**. By writing a value to the stencil buffer, this can be checked in a subsequent pass. If the pixel being rendered has a certain stencil value, then you keep what is already in the color buffer; otherwise, you can freely overwrite it. **Renderer Features** are a highly flexible way to build a final render using combinations of passes.



Renderer Features for the Mobile Foward+ Renderer

To match camera positions during a transition, the project has a **SceneMetaData** script for each scene that stores an offset Transform, while a **SceneTransitionManager** script handles the incoming and outgoing scenes during the transition. The **Update** method tracks the progress of the transition. When **ElapsedTimeInTransition** is greater than **m_TransitionTime**, then **TriggerTeleport** is called, which in turn calls the **Teleport** method. This repositions and orientates the player to create a seamless switch from the outgoing scene to the incoming scene.

```
120     void Update()
121     {
122         float t = m_OverrideTransition ? m_ManualTransition : ElapsedTimeInTransition / m_TransitionTime;
123
124         if (InTransition)
125         {
126             ElapsedTimeInTransition += Time.deltaTime;
127
128             if (ElapsedTimeInTransition > m_TransitionTime)
129             {
130                 TriggerTeleport();
131             }
132
133             ElapsedTimeInTransition = Mathf.Min(m_TransitionTime, ElapsedTimeInTransition);
134         }
135         else
136         {
137             ElapsedTimeInTransition -= Time.deltaTime * 3;
138
139             if (ElapsedTimeInTransition < 0 && CoolingOff)
140             {
141                 CoolingOff = false;
142             }
143
144             ElapsedTimeInTransition = Mathf.Max(0, ElapsedTimeInTransition);
145         }
146
147         //Update weights of post processing volumes
148         if (m_Loader != null && !CoolingOff)
149         {
150             float tSquared = t * t;
151             m_Loader.SetVolumeWeights(1 - tSquared);
152         }
153
154         Shader.SetGlobalFloat(m_TransitionAmountShaderProperty, t);
155     }
```

ScreenTransitionManager.cs Update method

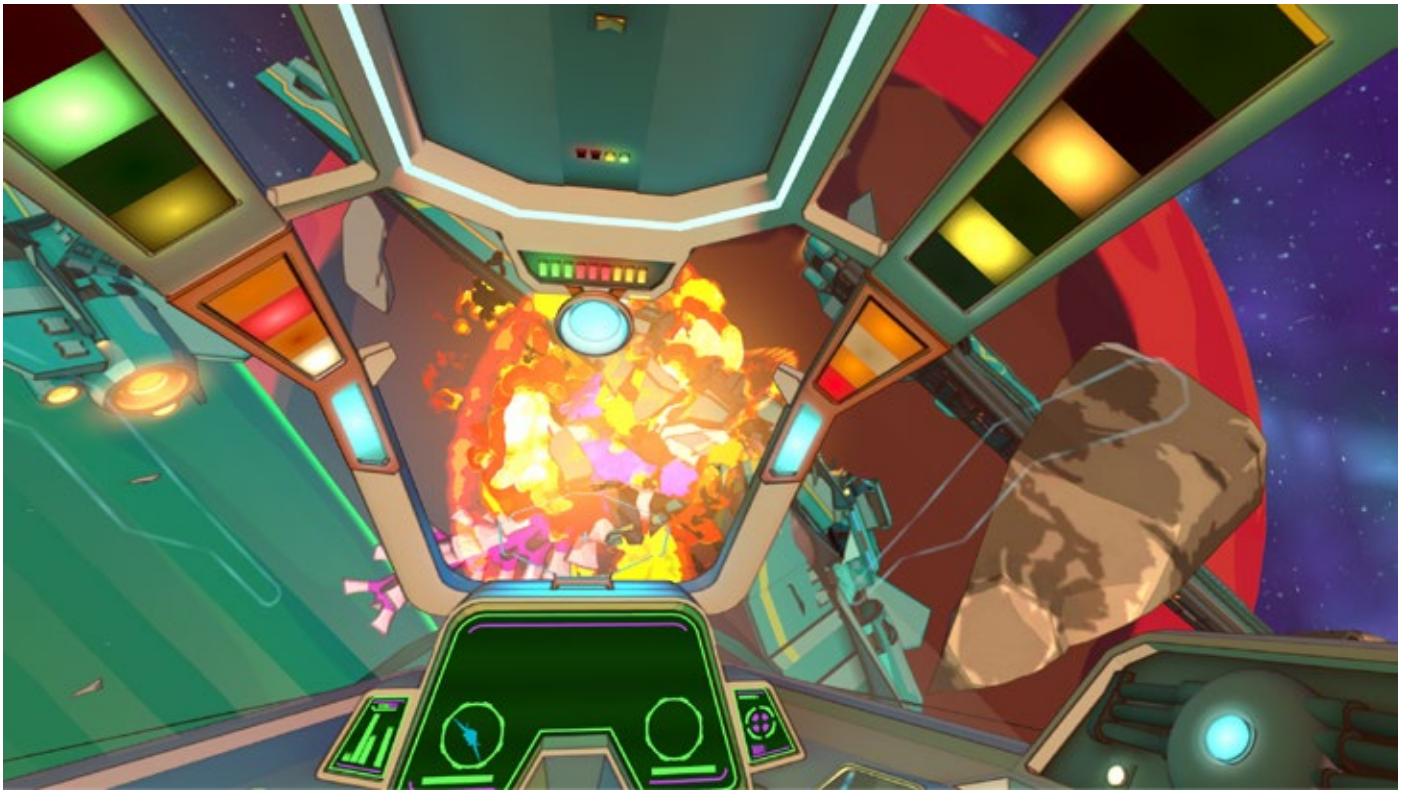
Scalability

URP supports a wide range of hardware, and there are several ways the new sample scenes illustrate how to work with different devices. You'll notice the different options in **Project Settings > Quality**.

Quality levels

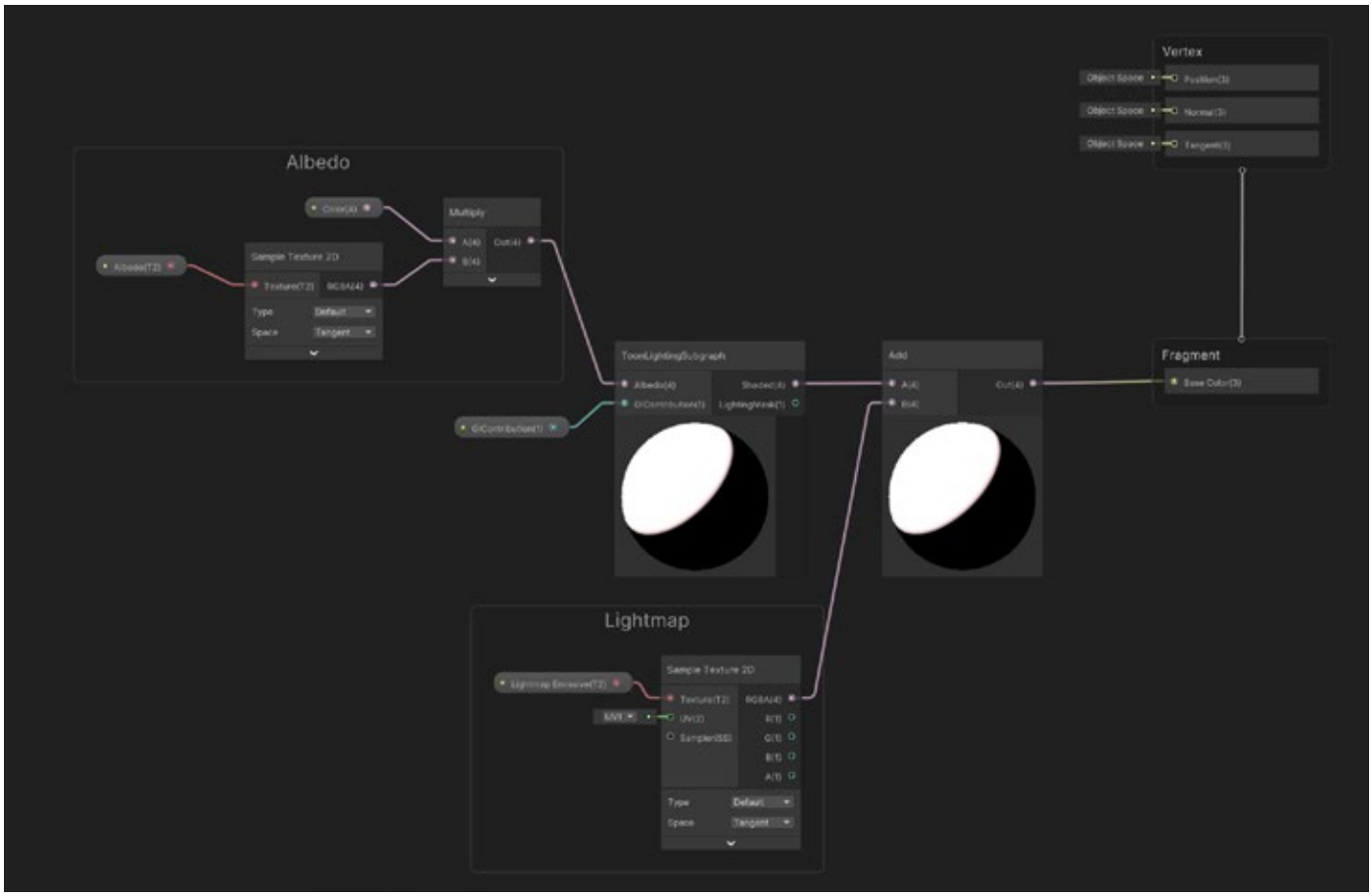
Each option uses a different **Render Pipeline Asset**. As explained in the Quality section, URP handles Quality using a combination of this panel together with the settings of the Render Pipeline Asset.

Standalone VR headsets present a significant challenge when displaying real-time 3D graphics. They have high-resolution screens, and each eye must be handled separately, resulting in each rendered frame requiring twice the work. Additionally, with a minimum target fps of 72, you'll need a lot of pixels per second. A workaround for this challenge is to use stylized lighting. The Cockpit scene below uses a Toon Shaded lighting model.



The cockpit environment from the URP 3D sample

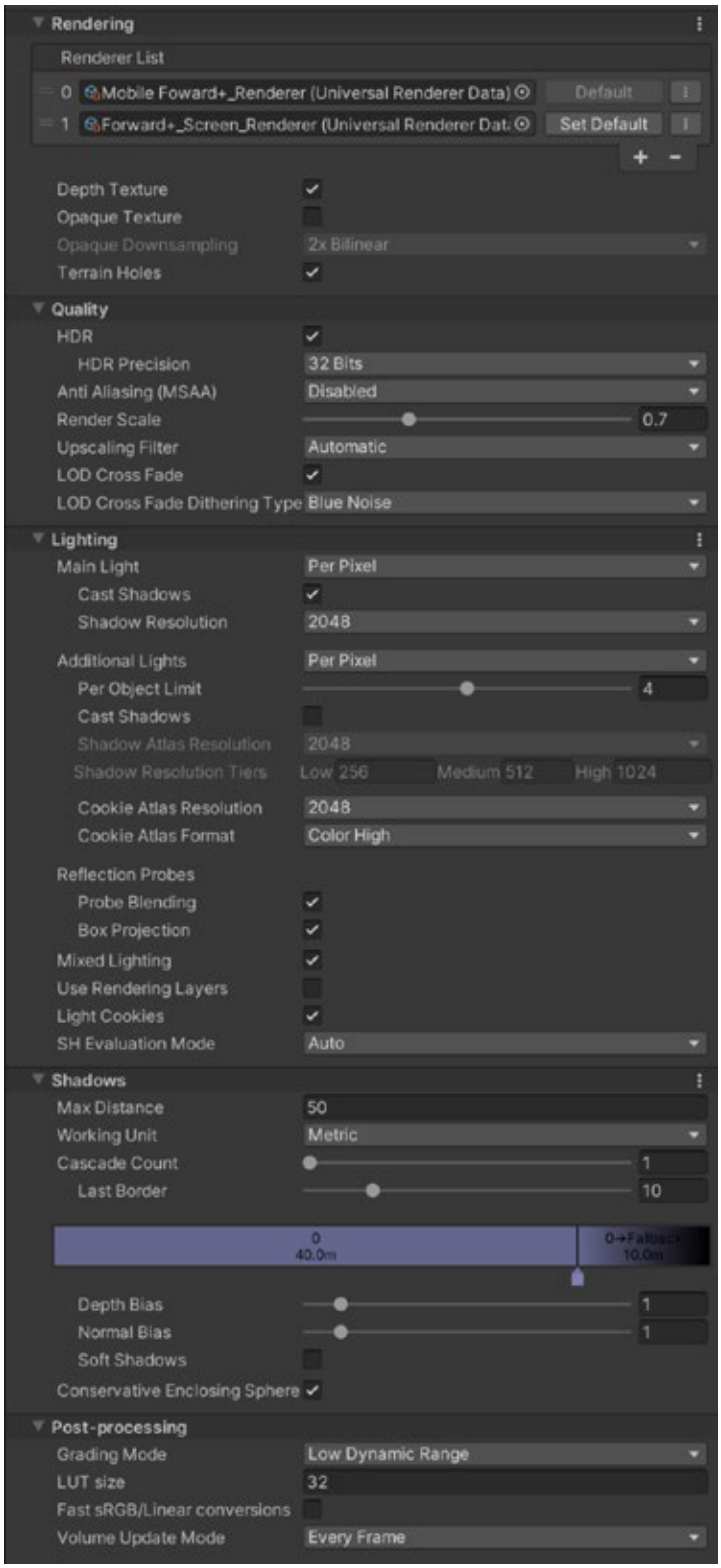
The custom lighting is handled using Shader Graph, with minimal coding.



As usual for a Toon shader, it combines the normal vector and the Main light direction using a dot product to determine the lighting level. It then uses a ramp to set staged levels of light rather than smoothly changing values. The lighting model used in The Cockpit scene also uses Baked Global Illumination in the calculation and does some edge detection to add a subtle outline effect. Custom lighting is handled using Shader Graph.

See *The Universal Render Pipeline cookbook* for a tutorial about creating Toon Shaders.

Running the sample project on a mobile device



The Mobile Forward+ URP Asset

A common problem for game developers is getting a game running smoothly on a mobile device. The new sample project includes a **Mobile Forward+** URP Asset in the **Settings** folder. Remember that the URP Asset is the principal way you can adjust quality settings. Forward+ relies on the CPU to do significant culling operations per frame and so is not necessarily the best option for a low-end mobile device. The best option for such devices is the Deferred renderer, which is used by a URP asset in the sample project.

The image to the left shows the settings for the Mobile Forward+ asset.

The **Renderer List** has two Universal Renderer Data assets: one for the active scene, **Mobile Forward+_Renderer**, and the other for rendering the screen scene, **Forward+_Screen_ Renderer**. The Depth Texture is enabled. Note that Additional Lights do not cast shadows. This is a very expensive option and for mobile devices can often be mimicked using light cookies. The Garden scene in particular has lots of lights, and many use cookies to give a suggestion of shadows. Notice the lighting on the rocks in the bottom left of the image below with and without cookies.

Garden environment point light with and without cookies

Here are three top tips when targeting mobile platforms.

- Reduce the number of pixels rendered. Most modern mobiles have a high DPI or dots-per-inch count. For most games, a DPI of 96 is sufficient. If Screen.DPI is 300, for example, then a render scale of 96/300 on a 2400 × 1200 screen would mean rendering 768 × 384 pixels, almost a tenth of the pixels, which is a massive performance boost. You can set the render scale in the URP Asset or adjust the value at runtime.
- Notice that the Mobile Forward+_Renderer asset has a Decal renderer feature with its Technique option set to Automatic. This will switch to Screen Space on GPUs with hidden surface removal. This provides a performance boost by avoiding a depth prepass, which is a waste of resources on these devices.
- Use Deferred rendering on devices where the CPU overhead of Forward+ is too expensive.
- To enable more aggressive render pass merging by the Render Graph system, consider the following:
    - If not needed in your project, disable the Depth Texture and Opaque Texture setting in the URP Asset settings.
    - If using Opaque Texture, set Opaque Downsampling to “None”. Downsampling the opaque texture will introduce a resolution change in the URP intermediate textures, preventing pass merging.

— If using Depth Texture, set Depth Texture Mode to “After Transparents”. Doing so will avoid injecting a CopyDepth pass between the main render passes (Opaque, Sky, Transparents), and allow Render Graph to successfully merge those passes.

A careful study of these four scenes alongside their URP Asset settings and documentation will help you learn how to use the techniques on display in your own projects.

Conclusion

For developers and artists looking to switch to URP, be sure to check out the full Unity Documentation, as well as Unity Learn, the Unity Blog, and Discussions.

The Unity Product Board provides an overview of current URP features being developed, in addition to what's coming up next. You can even add your own feature requests.

Good luck with your game development.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