



Photos

**Private, on-device technologies to
browse and edit photos and videos
on iOS and iPadOS**

September 2019

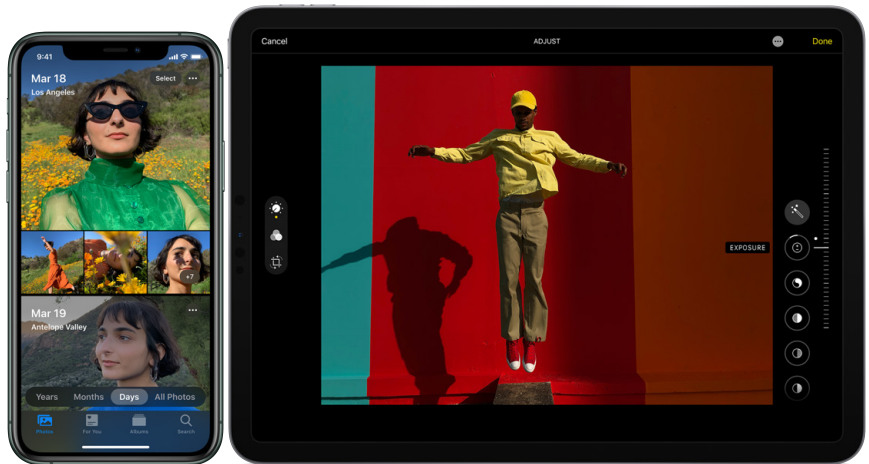
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Overview

The Photos app is powered by advanced on-device technologies that intelligently surface a user's best shots and enhance their photos and videos, all while keeping their precious memories private.

With iOS 13 and iPadOS, Photos introduces an all-new Photos tab that helps users organize and rediscover their significant moments; powerful new photo and video editing controls; and new capabilities in Portrait Lighting that let users control the intensity of light just like a photographer in a studio.



The Photos app

The all-new Photos tab lets a user browse their photo library with different levels of curation, so it's easy to find, relive, and share photos and videos.

An Intelligent Photos Experience

What is on-device intelligence?

With on-device intelligence, all of the processing by the Photos app is done on a user's device, and the results of this analysis are not shared with anyone, not even Apple.

Photos is enabled by powerful machine learning to deliver unique features like Memories, Search Suggestions, and For You. Photos analyzes every photo in a user's photo library using on-device machine learning that delivers a personalized experience for each user. And this analysis is designed from the ground up with privacy in mind, with all of the processing done on device—and the results of this analysis are not shared with anyone, not even Apple.

Photos uses on-device processing to analyze each photo and video in a number of ways, including:

- **Scene classification**

Identifies objects, like an airplane or a bike, and scenes, like a cityscape or a zoo, that visually appear in a photo, using a multilabel network with over a thousand classes.

- **Composition analysis**

Analyzes over 20 subjective attributes, including lighting, subject sharpness, color, timing, symmetry, and framing, using an on-device neural network trained on attributes labeled by photo professionals.

- **People and pets identification**

Identifies whether people, dogs, or cats are visible in a photo.

- **Quality analysis**

Examines the quality of a photo or video by evaluating photographic attributes such as photo sharpness, colorfulness, device orientation, camera motion, stability, and exposure.

- **Quality analysis for faces**

Examines different facial regions and provides a face capture quality score that considers lighting, focus, occlusion, and facial expressions.

- **Audio classification**

Analyzes audio from Live Photos and videos, recognizing environmental sounds such as laughter and applause.

Powerful photo search

With scene classification, users can search for things that appear in their photos like motorcycles, trees, or apples. They can even combine keywords, like "boat" and "beach," to find a specific photo.

The key to Apple's leading-edge approach is the tight integration of hardware and software. Each algorithm is optimized specifically to run locally on Apple devices and take advantage of the powerful A-series processors. For example, scene classification in Photos can identify more than a thousand different categories and is developed specifically to run efficiently on device without requiring any server-side processing. On the A12 Bionic chip and later, scene classification of a single photo takes less than 7 milliseconds, with the chip's Neural Engine processing over 11 billion operations in that time.

Each algorithm in Photos is developed using supervised learning. The algorithm is given input data and a desired output with the goal of learning a general rule that maps those inputs to outputs. For example, the scene classification algorithm is trained by providing labeled pictures, such as images of trees, to allow the model to learn the pattern of what a "tree" looks like.

Overnight processing

The Photos app on iOS and iPadOS curates the new Photos tab overnight when the user's device is connected to power. This is designed to conserve the battery, so that photo analysis isn't using processing power when the user is completing other tasks.

The Photos app uses machine learning to provide users with intelligent, personalized experiences throughout the app. It enables powerful search capabilities that help users find the photos they are looking for; advanced editing that helps them fine-tune their photos; and with the new Photos tab, it organizes and displays a curated view of a user's entire photo library.

The New Photos Tab

Each year, over a trillion photos and videos are captured with iPhone. As photo libraries have grown larger, it's become harder for users to organize and rediscover the precious memories of their lives. The new Photos tab is a reimagined photo browsing experience for iPhone, iPad, and Mac that lets users focus on their best shots. Using on-device machine learning, Photos curates the entire library to highlight the best images, automatically hiding clutter and similar photos to showcase significant events from the past day, month, or year.

View everything

The new Photos tab also includes a redesigned All Photos view that lets users see all their photos and videos in a beautiful presentation. Users can zoom in to see photos larger or zoom out to see everything at once.

The new Photos tab is organized into four views: All Photos, Days, Months, and Years. Each view has a different level of curation, providing the user with a unique lens through which to rediscover their photo library.



The Days view

Days surfaces a user's best shots while removing similar photos and clutter.

The Days View

The Days view is a curated and chronological view of a user's library, letting users relive their photos one day at a time. Made possible by on-device photo analysis that intelligently hides similar photos and clutter, the Days view surfaces a user's best photos and videos in a stunning layout, letting the user focus on the photos that matter most.

While All Photos presents all of a user's shots, Days intelligently hides screenshots, screen recordings, blurry photos, and photos with bad framing and lighting. Photos also uses on-device, pretrained models that identify shots with specific objects, like photos of documents and office supplies, and marks them as clutter.

To capture the perfect moment, users often take many pictures of the same thing. The Days view identifies similar photos, picks the user's best shot, and intelligently hides the others. Photos uses its scene classification network to create a description of the objects that appear in each image. It then compares that description with the description of other images on that day, grouping similar photos together. For instance, this method lets Photos identify and group all photos of a "beach sunset" on the same day—even if they're taken from different angles and at different times. After these images have been grouped, Photos selects the photo or video with the best composition, quality, and relevance and curates it in the Days view. This helps to summarize the day while also ensuring that the user doesn't see photos of similar things over and over again.

What is clutter?

In order for the Days view to highlight a user's best shots, photos that are considered clutter are shown in the All Photos view and intelligently hidden in the Days view.

Days automatically hides:

- Screenshots
- Screen recordings
- Blurry photos
- Photos with bad framing and lighting

Photos also identifies specific objects likely considered clutter and hides them in the Days view. They include photos of:

- Whiteboards
- Receipts
- Documents
- Tickets
- Credit cards

Surfacing the Best Shots in Days

After removing clutter and similar photos, the layout of the Days view is designed to tell a story, highlighting a user's important moments through larger, prominent photo previews that represent each day. When selecting each prominent photo, Photos analyzes every image in a number of ways:

• Relevance

Promotes photos and videos that are likely to be interesting to the user, like photos of people who appear often in the user's library or photos taken in a new location.

• Representation

Identifies photos and videos that are representative of the day. For example, if a user went to a concert and took many photos, the Days view will understand that the concert was important and select photos and videos from that event.

• Composition

Prefers well-framed photos and videos with a pleasant composition.

• Liveliness

Autoplays content, finding the right mix of Live Photos, videos, and still images to create a lively viewing experience.

• User activity

Promotes photos or videos a user has edited, shared to other people, or marked as favorites, understanding that these actions are strong indicators that these photos or videos are likely to be important to the user.

The new Photos tab also uses a new saliency engine that intelligently crops photos and videos in image previews, letting the user focus on the best part of a shot. The saliency engine highlights what's noticeable or important in an image, and it was trained using eye-tracking data from human subjects looking at images in a lab environment. Photos uses attention-based saliency, which presents the part of the photo where people are likely to look. The main factors that affect saliency are contrast, subjects, horizon, light, and faces. Faces tend to be the most salient because that is what people tend to look at first.

Throughout the Photos tab, Live Photos and videos begin playing as the user scrolls, bringing their photo library to life. The Days view is smart about when to play these videos in the layout. To help focus and remove distractions, Photos

ensures a user will never see more than one Live Photo or video clip play in the view at a given time, and when the user scrolls throughout the view, subtle crossfades highlight the transitions from one prominent video to the next.



The Months view

Months presents photos by events, so users can rediscover the moments that matter most.

The Months View

The next curated view in the new Photos tab is the Months view, a personalized feed of a user's significant events and a powerful anchor for browsing a user's library. The Months view understands if a set of photos is important—like a family outing, concert, birthday party, anniversary, or trip—and highlights these significant moments in a beautiful interface.

Private, on-device knowledge graph

The knowledge graph in Photos organizes photos in ways that are meaningful to users, like displaying significant events in Months. To respect user privacy, the knowledge graph is calculated on device and is never sent to Apple's servers.

The Photos Knowledge Graph

Photos analyzes a user's photo library, deeply connecting and correlating data from their device, to deliver personalized features throughout the app. This analysis yields a private, on-device knowledge graph that identifies interesting patterns in a user's life, like important groups of people, frequent places, past trips, events, the last time a user took a picture of a certain person, and more.

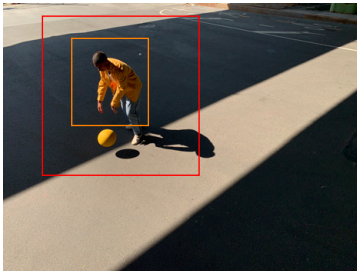
A user's knowledge graph in Photos can consist of thousands of nodes and edges, with data that includes:

- **Events**

Infers when a user has attended an event, like a wedding or a concert, using the scenes of the photos and videos to understand what's happening.

- **User activity**

Understands that there may be personal value in a set of photos if the user has viewed, favorited, edited, or shared many shots from the same day.



Smart photo previews

Photos uses a new saliency engine that identifies what's noticeable or important in an image when cropping photo previews.

- **People**

- **Relationships** infers closeness based on the number of photos of a person, set relationships in Contacts, and frequency of communication in Messages.
- **Social groups** identifies the people who often show up in photos together.

- **Places**

- **Home and work** leverages Contacts and Maps to understand where the user has set "Home" and "Work" addresses.
- **Frequent locations** looks across patterns of time and location to determine if photos and videos were taken at a place where the user frequently takes pictures.
- **Special locations** identifies photos and videos that were taken at new or unique locations.
- **Trips** infers when the user has taken photos and videos in a location that is far away from their home.

- **Dates**

- **Important dates** uses Calendar and Contacts to understand important personal dates like birthdays and anniversaries.
- **Holidays** understands which holidays the user has celebrated based on a list of popular holidays in the user's country and the scenes of photos from those days.

The knowledge graph helps Photos personalize the Photos tab by discovering meaningful patterns and predicting smart correlations. For example, Photos may use the frequency of messages sent to a person as an indicator that the person is important to the user. When this data is correlated with a named person in the People album, Photos will know to show more of that person throughout the app, like in Memories or as a suggestion in Search.

The user's knowledge graph is used to identify the significant events that are shown in the Months view. Significant events in Photos range from trips, weddings, and concerts to everyday events such as a day in the park. Every night when the device is connected to power, Photos uses the on-device knowledge graph to analyze each event and select which events to present in the Months view:

- The Months selection algorithm first checks whether there are any significant events in the month, selecting up to five.
- If there are more than five significant events in the month, the device will narrow down the set, and Photos will attempt to spread out featured events across the month.
- If there are less than five significant events, Months will include other events—like a series of photos taken at home—up to five, so there's always something for the user to explore.

Finding the perfect loop

Autoplaying Live Photos and videos brings the new Photos tab to life. Photos uses machine learning that examines signals like video metadata, stabilization, and dynamism to detect great Live Photo loops and video clips so device knows which videos to present to the user.



The Years view

Rediscovering highlights in Years.

The Years View

The Years view is an ever-changing view into the user's library, letting the user quickly scan through significant events of the past. It's designed to always show something new, prompting rediscovery throughout the entire library.

Contextual Browsing in Years

The Years view analyzes data from the user's device to provide a look back in time that's contextual to what's happening today.

- **On this day**

For the default Years view experience, the device will find the events in past years closest to today's date and present them to the user, prompting rediscovery of past years.

- **Birthdays**

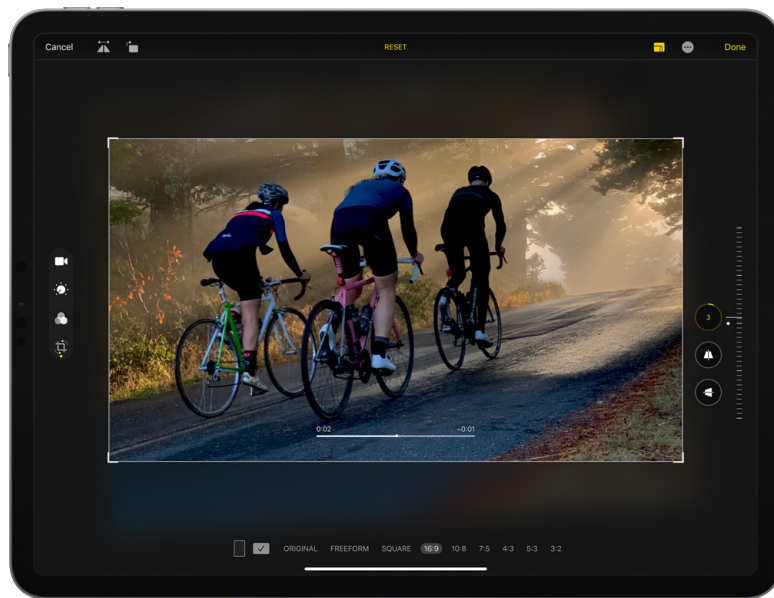
Using the knowledge graph, Photos may determine that it's the birthday of someone that matters to the user. On these days, Photos will update events with photos of the birthday person to highlight a photo with them in it. This creates an effect that transforms Months and Years to celebrate their birthday so the user can relive past memories with the person.

- **Annual conferences and festivals**

The Years view can even display past events that don't happen on the exact same date every year, like an annual conference (for example, WWDC) or a festival (for example, Burning Man). Photos identifies the event using the device's public event classifier. If the event is happening around this time, Years will look for shots from the same event in past years and feature them.

Photo and Video Editing

The Photos app provides powerful photo and video editing tools that help make everyone a creative pro. Using advanced technology, Photos helps users easily create the perfect look with their photos and videos. iOS 13 and iPadOS provide users with more creative possibilities and control over their photos and videos with easy-to-use tools that are powered by advanced technology and designed and optimized for iPhone and iPad.



Editing in Photos

Photo editing is more comprehensive and intuitive with new tools that are easier to apply, adjust, and review at a glance.

Media-specific editing tools

Powerful editing in Photos goes beyond photos and videos. Media types, like Live Photos, Slo-Mo videos, and Portrait mode, all have unique editing capabilities in Photos, like changing the key frame of a Live Photo and adjusting the transition from normal speed to slow motion in a Slo-Mo video.

Editing in Photos is designed to be easy while also providing users with fine-grain control over every aspect of their photos. There are over 17 adjustment tools in the Photos app, ranging from one-tap controls like Auto Enhance to pro-level adjustments like Noise Reduction. These effects include:

- **Auto Enhance**

Automatically adjusts the color and contrast of a photo, bringing the important features, like deep blacks and properly exposed highlights, to the foreground.

- **Exposure**

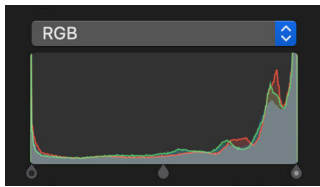
Adjusts the tones—the amount of light—throughout an entire photo.

- **Brilliance**

Applies region-specific adjustments to brighten dark areas, pull in highlights, and add contrast to reveal hidden detail and make a photo look richer and more vibrant.

- **Highlights**

Changes the highlight detail, the brightest areas of a photo. By decreasing the Highlights value, the brightest areas of the photo will become more dark.



What is a photo histogram?

A photo histogram represents the number of pixels in an image in a certain area of the tonal scale. In a photo histogram, the graph shows the number of pixels for each brightness level from black (0% brightness) to white (100% brightness).

A histogram helps a user understand the balance of light within a photo. For example, the histogram above depicts a photograph that's clipping highlights, as pixels are stacked toward the right of the histogram in the brightest tones.

Photos uses image histograms, along with tonal curves and pixel statistics, to perform a number of intelligent editing adjustments that include Auto Enhance, Brilliance, and Shadows.

- **Shadows**

Adjusts the detail that appears in shadows and other dark areas. By increasing Shadows, the darkest areas of a photo will become more bright.

- **Contrast**

Controls contrast, the range between the lightest and darkest parts of a photo.

- **Brightness**

Adjusts the brightness—the overall lightness or darkness—by raising the midtones of a photo.

- **Black Point**

Sets the point at which the darkest parts of an image become completely black without any detail. Setting the black point can improve the contrast in a washed-out image.

- **Saturation**

Adjusts a photo's overall color intensity.

- **Vibrance**

Boosts muted colors to make a photo more rich without affecting skin tones and saturated colors.

- **Warmth**

Balances the warmth of an image by adjusting color temperature (blue to yellow).

- **Tint**

Adjusts the warmth of an image by adjusting color tint (green to magenta).

- **Sharpness**

Changes a photo by making its edges crisper and better defined.

- **Definition**

Increases image clarity by adjusting the definition slider.

- **Noise Reduction**

Reduces or eliminates noise (such as graininess or speckles) in a photo.

- **Vignette**

Adds shading to the edges of a photo to highlight a powerful moment.

Auto Enhance

Auto Enhance is the best place for a user to start when creating the right look for their photo or video. With just a tap, Auto Enhance approaches the image how a pro photographer would, analyzing each and every pixel of the image and automatically adjusting the tonal extremes of the photo, bringing the important features, like deep blacks and properly exposed highlights, to the foreground. And in iOS 13 and iPadOS, Auto Enhance now lets users control the intensity of their automatic adjustments. As users increase or decrease Auto Enhance, they'll see other adjustments—including Exposure, Brilliance, Highlights, Shadows, Contrast, Brightness, Black Point, Saturation, and Vibrance—intelligently change with it.

Because every photo is unique, Auto Enhance is designed to optimize each and every photo in an intelligent way. Each editing adjustment relates to the others to create a balanced, properly exposed image.

When a user taps the Auto Enhance button, the following steps happen:

- **Image analysis**

Analyzes the tone curve of the full image using a histogram, and corrects for common lighting scenarios like a backlit or underexposed photo.

- **Face detection**

Intelligently determines if there's a face in the photo and adjusts the white balance, Warmth and Tint, to account for skin tone. This ensures that the automatic adjustments do not wash out the person's skin tone.

- **Sets initial adjustment values**

Sets the initial values for each adjustment, letting the user view the results. Each individual adjustment, like Brilliance or Vibrance, can then be independently controlled to fine-tune a single aspect of the user's photo.

- **Determines Auto Enhance range**

Generates the relationship between each of the adjustments for a specific shot, letting the user turn up or turn down the Auto Enhance effect using a macro slider that controls many adjustments at once.

Auto Enhance is designed to simplify the photo and video editing process, whether the user is a professional photographer or just getting started. As the slider changes, there's visual indication that other adjustments are changing with it. This enables the user to view and modify what's happening to their photos, providing them with a unique look at how each adjustment relates to the others. As the user slides to the right, Auto Enhance makes the image brighter without blowing out the highlights and affecting the image's white balance. As the user slides to the left, the effect darkens the image without losing shadow detail.

Smart Adjustments with Brilliance and Shadows

Brilliance and perceived color

Brilliance is a color-neutral adjustment, which means that no saturation is applied. However, there may be a perceived change in color because brighter images with more contrast often appear more vibrant.

While many tools, like Exposure, provide global adjustments, meaning that they apply adjustment levels uniformly across the entire range of a photo, Brilliance and Shadows are designed with even more power for smart, spatially localized image editing. Both Shadows and Brilliance apply region-specific adjustments that produce dramatic effects without impacting the overall image. For example, with Shadows, the user can adjust the detail that appears in shadows without impacting highlights. With Brilliance, the user can brighten dark areas, pull in highlights, and add contrast to reveal hidden detail and make their photo look richer and more vibrant.

To create these effects, Photos divides the image into a 31x31 grid in real time, taking a closer look into each region of the shot. The device identifies one or more image characteristics for each tile, creating a region-specific histogram and tonal curve. This provides the device with an approximation of the exposure

of each area of the image, and the Photos app treats each region as if it were a tiny image itself, computing the proper Brilliance or Shadows adjustment for that region.

The device combines the results of these regions and preserves areas where adjustments are different between regions. This helps ensure that spatially adjusted regions don't create artifacts in the areas of an image that transition from dark (underexposed) to bright (overexposed), such as where the foreground transitions to the background of a photo of a backlit subject. Finally, the device creates an adjustment curve for each pixel, determines the range for the slider, and adjusts the original photo, completing the user's edits.



Photo editing

Adjustments, filters, and crop support video editing, so users can rotate, increase exposure, or even apply filters to their videos.

Powerful Video Editing

Video editing support

Video editing supports all formats captured on iPhone, including video in 4K at 60 fps and slo-mo in 1080p at 240 fps. It also works with videos imported in industry-standard formats like M4V, MP4, AVC, AVCI, and MOV.

iPhone doesn't just capture still photos—it's a professional-level video camera that's always with users, allowing them to capture high-quality 4K video with extended dynamic range. With iOS 13 and iPadOS, users can now access the powerful photo editing tools in video. Adjustments, filters, and crop support video editing, so users can rotate, increase exposure, or even apply filters to their videos.

Users can edit a video in the Photos app in 32 ways:

- Trim
- Highlights
- Black Point
- Tint
- Vignette
- Dramatic
- Silvertone
- Rotate
- Sound on/off
- Shadows
- Saturation
- Sharpness
- Vivid
- Dramatic Warm
- Noir
- Straighten
- Auto Enhance
- Contrast
- Vibrance
- Definition
- Vivid Warm
- Dramatic Cool
- Flip
- Vertical
- Exposure
- Brightness
- Warmth
- Noise Reduction
- Vivid Cool
- Mono
- Crop
- Horizontal

When editing a video, the device renders an adjusted video in real time, letting the user add or remove multiple adjustments in a single session. Video adjustments apply to each and every frame of the video, providing temporal consistency throughout the user's video. This ensures that each frame of the user's video has a consistent look. When adjustments are saved by the user, the device renders the changes frame-by-frame, across every pixel of each frame, throughout the video. This process is optimized to run efficiently on the device's GPU, quickly rendering a beautiful video that's ready to share.

Video edits are nondestructive, so the user can remove any effect, like a filter, or undo a trim to return to their original video. When the rendering process is complete, the device creates an auxiliary video file that includes the adjusted video paired with the original. This allows the user—at any point—to update an adjustment value or revert all changes.

Portrait Lighting

Portrait Lighting is inspired by the real techniques of professional studio photographers, who move the position of light sources—like soft-boxes, reflectors, diffusers, absorbers, and spotlights—to change the look and feel of a portrait photograph. Portrait Lighting brings this ability to iPhone users with advanced on-device machine learning to virtually re-create these effects while capturing in Camera and while editing in Photos.



Portrait Lighting

Users can virtually adjust the position and intensity of studio lighting.

Preserving Details with Semantic Segmentation

To achieve the level of precision needed for fine-grain Portrait Lighting adjustments, the Photos app uses an advanced segmentation technology that locates and separates the subject from the background of an image with great detail and clarity. With iOS 13, this technology has been updated to identify specific facial regions, semantically allowing the device to isolate hair, skin, and teeth in a photo. Semantic segmentation allows the device to understand which regions of the face to light, like skin, while determining which areas, like beards, need to be preserved when simulating studio-quality lighting effects across different parts of the face.

What is segmentation?

Segmentation is the process of locating and separating the subject, or specific regions, from the background of an image with great detail and clarity.



Segmentation mattes

Person, hair, skin, and teeth segmentation mattes.

When a user takes a Portrait mode photo, the Camera app uses the Apple Neural Engine in the A12 Bionic chip (and later) and runs multiple on-device machine learning models. This process analyzes data from the camera sensor, depth data, segmentation, and the pixels of the image itself to determine if a person is visible and locates the unique geometry of the subject's face.

If a face is visible in the photo, the device will generate a final output image, as well as multiple auxiliary images, like person, hair, skin, eyes, and teeth segmentation mattes. Each of these images is used when applying the following Portrait Lighting effects, all of which are accessible by third-party developers:

- **Primary image**

Displays the user's Portrait mode shot with all effects. For example, the subject on a blurred background with a depth-of-field effect.

- **Depth map**

Indicates distance from the camera to that part of the image (either in absolute terms or relative to other pixels in the depth map).

- **Person segmentation matte**

Separates the subject from the background.

- **Hair segmentation matte**

Separates the subject's hair region from the non-hair regions. It even separates hair details, like small strands of hair, from the background.

- **Skin segmentation matte**

Locates the skin regions of the subject.

- **Teeth segmentation matte**

Locates the subject's teeth when they are visible.

Using Machine Learning to Move Light Virtually

With the ability to analyze unique facial regions in real time, Portrait Lighting now lets users virtually move the position of light sources right on their iPhone, helping them dial in their portraits—whether they're shooting in Camera or editing in Photos.

Mapping light

To develop Portrait Lighting, Apple designed studies with studio photographers. In one study, Apple developed a 360-degree environment map of studio lighting scenarios to radiometrically measure the real position and the amount of light emanating to the subject from light sources in all directions.

Understanding Each Lighting Effect

Portrait Lighting is inspired by the real studio lighting setups of the world's best image makers. Each effect is designed to create a slightly different look, representing unique lighting arrangements of soft-boxes, reflectors, diffusers, absorbers, and spotlights:

- **Studio Light**

Emulates the use of a soft-box light, along with kick lights and a reflector to evenly illuminate the sides and the area underneath the subject, surrounding and filling in the face evenly with light.

- **Contour Light**

Simulates a black velvet absorber draped on the side of the face, preventing light coming from underneath the subject, leading to a contour effect on the sides of the face from a soft-box.

- **Stage Light**

Creates a look that's similar to the Contour Light effect, with a spotlight face against a deep black background.

- **Stage Light Mono**

Similar to the Stage Light effect, but the photo is in classic black and white.

- **High-Key Light Mono**

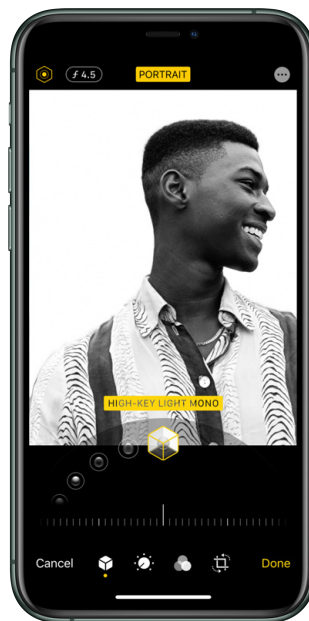
Emulates the use of a soft-box, similar to the Studio Light effect, with more contrast in the face, a monochrome black-and-white subject, and a high-key white background.

High-Key Light Mono

iOS 13 introduces High-Key Light Mono, a new Portrait Lighting effect that creates a beautiful, classic look with a black-and-white subject on a white background.

High-key photography is a challenging portrait technique to achieve, even in a studio environment. Because the lighting is so extreme, the effect can often overwhelm the dynamic range of camera sensors, causing washed-out shadows or overexposed faces. Even with postprocessing, achieving the effect requires a deep understanding to ensure that hair and other edges are properly segmented from the bright white background.

With the powerful new software in iOS 13, along with the Apple Neural Engine in the A12 Bionic chip and later, iPhone users can now achieve this stunning look with just the tap of a button. With a quick snap, users can take high-contrast black-and-white portraits with properly exposed faces, deep blacks, and high-key whites.



Portrait Lighting

Users can virtually adjust the position and intensity of studio lighting.

Portrait Lighting Control

Each Portrait Lighting effect now includes a slider that lets users control the intensity of each studio lighting effect. This slider virtually changes the relative size of the primary light source to the relative size of the face. As the user virtually moves the light source closer, moving the slider to the right, the effect adds more light to the face, making it appear brighter and softer. Moving the slider to the left virtually moves the lights away from the subject, adding subtle contrast to the face.

Increasing the intensity of each Portrait Lighting effect creates the look of sharpening eyes, brightening facial features, and smoothing skin. To sharpen eyes, the device identifies the eye regions and enhances the details, increasing clarity and sharpness by preserving the blacks while brightening the area. Portrait Lighting then analyzes the local contrast of skin regions of the face,

providing an even illumination across the entire face while adding light to shadow areas. This creates an effect similar to a soft-box in a photo studio, where the light removes contrast throughout the face, including regions like wrinkles.

Portrait Lighting isn't designed to remove all the contrast of the face. For example, there are many regions, like beards, beauty marks, and freckles, where the device preserves contrast for the image to appear realistic. To do this, Portrait Lighting uses the embedded skin segmentation matte and analyzes each pixel of the face, using a frequency separation process that determines which areas should be left alone.

Designed for Privacy

Whether it's curating the Photos tab, intelligently editing photos, or generating real-time segmentation mattes for Portrait Lighting, the Photos app is designed to deliver intelligent features that reflect a user's unique photo library while putting users in control of their privacy.

Using On-Device Processing for Powerful Features

Unlike other services that gather user photos and analyze them on their servers, learning everything about those photos in the process, Apple uses on-device intelligence. This means that the user's photos never leave their device to be analyzed. For example:

Syncing the People album

Photos recognizes the faces of people in photos and groups them together, enabling a user to explore all the photos that a person appears in. When a name is added to a person in the People album, their name and face will appear in Photos across all of a user's devices.

Only face names and contacts that have been manually associated will sync off of the device. When a user's photo library is accessed by their new device, the name and contact card reference data, if present, along with the primary photo of the face, will sync with it.

On the new device, facial analysis will run locally using the primary photo of the person, generating a new, on-device People album.

- **Photos** uses powerful on-device intelligence to identify similar photos and clutter, deliver a personalized browsing experience, and present the user's photo library in a stunning layout.
- **For You** analyzes a user's on-device knowledge graph to generate Sharing Suggestions, highlight Memories, and display Featured Photos.
- **Albums** recognizes the faces of people in a user's photos and groups them together into a People album with on-device facial recognition.
- **Search** allows a user to find photos based on what's in the photo, like "flowers," using on-device scene classification.
- **Editing** uses on-device image processing that lets users intelligently adjust and fine-tune their look.
- **Portrait Lighting** lets a user apply studio-quality lighting effects to their Portrait mode photos powered by on-device machine learning models that generate segmentation mattes.

All of this analysis, including scene classification and the knowledge graph in Photos, is performed on photos and videos on the user's device, and the results of this analysis data are not available to third parties or Apple. Additionally, this on-device work is optimized for Apple devices. For example, when a user edits a photo or video, the entire editing process is run on device and optimized for the A-series chips and GPUs in Apple products.

Shared Albums

When creating a Shared Album, the user controls which photos get added to shared photo streams and which do not. The user also controls who has access to their shared photo stream.

Sharing

When a photo is shared from a user's device, the user has transparency and control. Photos offers sharing controls that allow users to stay in control of what they share, whether with another Apple user or to third-party apps using Photo Picker inside an app or through the Share Sheet in Photos. For example, when sharing a photo with the Share Sheet in Photos, the user can control which metadata, like the Live Photos video or location information, is shared along with the photo. The user can remove the location of the photo or video and choose whether to include All Photos Data, like edit history and depth data, when sharing the image.

There are two ways to share a photo with a third-party app: from inside Photos using the Share Sheet or from inside an app using Photo Picker. With the Share Sheet from inside Photos, the user selects the photos to share with an app and

then selects the app to share with, defining which photos they'd like to share based on parameters that are specific to each application. Only the photos that the user selects are shared with the app. When using Photo Picker from inside an app, the user can either select the photo they want to share, or they can choose to grant the app access to their entire photo library. If the user wants to disable the app's ability to access Photos from their photo library at any point, they can go to Settings > Privacy > Photos on their iPhone and change the app's setting to "Never."

Two-factor authentication

iCloud Photos supports two-factor authentication, an extra layer of security that's designed to ensure that the only person who can access the user's account is the user, even if someone else knows their password.

With two-factor authentication, a user's account—and their photos—can only be accessed on devices the user trusts, like their iPhone, iPad, or Mac.

iCloud Photos

Apple also protects user photo data if the user chooses to back up their photo library to iCloud Photos, so that every photo and video they take is kept in one place and accessible across their Apple devices. When syncing photos and videos to iCloud Photos, each file is broken into multiple pieces and encrypted by iCloud using 128-bit AES encryption. A key is then derived from the contents of each piece. This key utilizes SHA-256 encryption. Apple stores the keys needed to decrypt the file, along with the file's metadata, in the user's iCloud account. The encrypted pieces of the file are stored, without any user-identifying information or the keys, using both Apple and third-party storage services.

Unlike other photo services, Apple minimizes the data that leaves a user's device to only what's needed to provide the service. Apple doesn't access user photos and doesn't use them for advertising or for research and development. Additionally, on-device analysis, like the user's knowledge graph, isn't synced or shared with Apple.