



Figure 1: Object Dependency Graph

This document describes the plan and progress of the implementation of Vulkayes.

Synchronization

Most parameters in Vulkan require external synchronization. Synchronization is provided in two flavours: Single-thread and multi-thread. Single-thread synchronization primitives are noops, while multi-thread primitives provide actual multi-thread and multi-core synchronization. If single-thread synchronization is chosen, the Rust type system statically prevents use in multiple threads.

Externally Synchronized Parameters

- The `instance` parameter in `vkDestroyInstance`
 - [Consequence of shared pointer usage](#)
- The `device` parameter in `vkDestroyDevice`
 - [Consequence of shared pointer usage](#)
- The `queue` parameter in `vkQueueSubmit`
 - [Synchronized internally](#)
- The `fence` parameter in `vkQueueSubmit`
 - [Synchronized internally](#)
- The `queue` parameter in `vkQueueWaitIdle`
 - [Synchronized internally](#)
- The `memory` parameter in `vkFreeMemory`
 - [Consequence of shared pointer usage](#)
- The `memory` parameter in `vkMapMemory`
 - [Synchronized internally](#)
- The `memory` parameter in `vkUnmapMemory`
 - [Synchronized internally](#)
- The `buffer` parameter in `vkBindBufferMemory`
 - [Handled by API design](#)
- The `image` parameter in `vkBindImageMemory`
 - [Handled by API design](#)

- The `queue` parameter in `vkQueueBindSparse`
- The `fence` parameter in `vkQueueBindSparse`
- The `fence` parameter in `vkDestroyFence`
 - [Consequence of shared pointer usage](#)
- The `semaphore` parameter in `vkDestroySemaphore`
 - [Consequence of shared pointer usage](#)

- The `event` parameter in `vkDestroyEvent`
- The `event` parameter in `vkSetEvent`
- The `event` parameter in `vkResetEvent`
- The `queryPool` parameter in `vkDestroyQueryPool`

- The `buffer` parameter in `vkDestroyBuffer`
 - [Consequence of shared pointer usage](#)
- The `bufferView` parameter in `vkDestroyBufferView`
 - [Consequence of shared pointer usage](#)
- The `image` parameter in `vkDestroyImage`
 - [Consequence of shared pointer usage](#)
- The `imageView` parameter in `vkDestroyImageView`
 - [Consequence of shared pointer usage](#)

- The `shaderModule` parameter in `vkDestroyShaderModule`
- The `pipelineCache` parameter in `vkDestroyPipelineCache`
- The `dstCache` parameter in `vkMergePipelineCaches`
- The `pipeline` parameter in `vkDestroyPipeline`
- The `pipelineLayout` parameter in `vkDestroyPipelineLayout`
- The `sampler` parameter in `vkDestroySampler`
- The `descriptorsetLayout` parameter in `vkDestroyDescriptorSetLayout`
- The `descriptorPool` parameter in `vkDestroyDescriptorPool`
- The `descriptorPool` parameter in `vkResetDescriptorPool`
- The `descriptorPool` member of the `pAllocateInfo` parameter in `vkAllocateDescriptorSets`
- The `descriptorPool` parameter in `vkFreeDescriptorSets`
- The `framebuffer` parameter in `vkDestroyFramebuffer`
- The `renderPass` parameter in `vkDestroyRenderPass`

- The commandPool parameter in `vkDestroyCommandPool`
 - [Consequence of shared pointer usage](#)
- The commandPool parameter in `vkResetCommandPool`
 - [Synchronized internally](#)
- The commandPool member of the pAllocateInfo parameter in `vkAllocateCommandBuffers`
 - [Synchronized internally](#)
- The commandPool parameter in `vkFreeCommandBuffers`
 - [Synchronized internally](#)

- The commandBuffer parameter in `vkBeginCommandBuffer`
- The commandBuffer parameter in `vkEndCommandBuffer`
- The commandBuffer parameter in `vkResetCommandBuffer`
- The commandBuffer parameter in `vkCmdBindPipeline`
- The commandBuffer parameter in `vkCmdSetViewport`
- The commandBuffer parameter in `vkCmdSetScissor`
- The commandBuffer parameter in `vkCmdSetLineWidth`
- The commandBuffer parameter in `vkCmdSetDepthBias`
- The commandBuffer parameter in `vkCmdSetBlendConstants`
- The commandBuffer parameter in `vkCmdSetDepthBounds`
- The commandBuffer parameter in `vkCmdSetStencilCompareMask`
- The commandBuffer parameter in `vkCmdSetStencilWriteMask`
- The commandBuffer parameter in `vkCmdSetStencilReference`
- The commandBuffer parameter in `vkCmdBindDescriptorSets`
- The commandBuffer parameter in `vkCmdBindIndexBuffer`
- The commandBuffer parameter in `vkCmdBindVertexBuffers`
- The commandBuffer parameter in `vkCmdDraw`
- The commandBuffer parameter in `vkCmdDrawIndexed`
- The commandBuffer parameter in `vkCmdDrawIndirect`
- The commandBuffer parameter in `vkCmdDrawIndexedIndirect`
- The commandBuffer parameter in `vkCmdDispatch`
- The commandBuffer parameter in `vkCmdDispatchIndirect`
- The commandBuffer parameter in `vkCmdCopyBuffer`
- The commandBuffer parameter in `vkCmdCopyImage`
- The commandBuffer parameter in `vkCmdBlitImage`
- The commandBuffer parameter in `vkCmdCopyBufferToImage`
- The commandBuffer parameter in `vkCmdCopyImageToBuffer`
- The commandBuffer parameter in `vkCmdUpdateBuffer`
- The commandBuffer parameter in `vkCmdFillBuffer`
- The commandBuffer parameter in `vkCmdClearColorImage`
- The commandBuffer parameter in `vkCmdClearDepthStencilImage`
- The commandBuffer parameter in `vkCmdClearAttachments`
- The commandBuffer parameter in `vkCmdResolveImage`
- The commandBuffer parameter in `vkCmdSetEvent`
- The commandBuffer parameter in `vkCmdResetEvent`
- The commandBuffer parameter in `vkCmdWaitEvents`
- The commandBuffer parameter in `vkCmdPipelineBarrier`
- The commandBuffer parameter in `vkCmdBeginQuery`
- The commandBuffer parameter in `vkCmdEndQuery`
- The commandBuffer parameter in `vkCmdResetQueryPool`
- The commandBuffer parameter in `vkCmdWriteTimestamp`
- The commandBuffer parameter in `vkCmdCopyQueryPoolResults`
- The commandBuffer parameter in `vkCmdPushConstants`
- The commandBuffer parameter in `vkCmdBeginRenderPass`
- The commandBuffer parameter in `vkCmdNextSubpass`
- The commandBuffer parameter in `vkCmdEndRenderPass`

- The commandBuffer parameter in `vkCmdExecuteCommands`
- The commandBuffer parameter in `vkCmdSetDeviceMask`
- The commandBuffer parameter in `vkCmdDispatchBase`
- The commandPool parameter in `vkTrimCommandPool`
 - Internally synchronized
- The ycbcrConversion parameter in `vkDestroySamplerYcbcrConversion`
- The descriptorUpdateTemplate parameter in `vkDestroyDescriptorUpdateTemplate`
- The descriptorSet parameter in `vkUpdateDescriptorSetWithTemplate`
- The commandBuffer parameter in `vkCmdDrawIndirectCount`
- The commandBuffer parameter in `vkCmdDrawIndexedIndirectCount`
- The commandBuffer parameter in `vkCmdBeginRenderPass2`
- The commandBuffer parameter in `vkCmdNextSubpass2`
- The commandBuffer parameter in `vkCmdEndRenderPass2`
- The surface parameter in `vkDestroySurfaceKHR`
 - Consequence of shared pointer usage
- The surface member of the pCreateInfo parameter in `vkCreateSwapchainKHR`
 - Handled by a combination of API design and swapchain internal synchronization
- The oldSwapchain member of the pCreateInfo parameter in `vkCreateSwapchainKHR`
 - Internally synchronized
- The swapchain parameter in `vkDestroySwapchainKHR`
 - Consequence of shared pointer usage
- The swapchain parameter in `vkAcquireNextImageKHR`
 - Internally synchronized
- The semaphore parameter in `vkAcquireNextImageKHR`
 - Internally synchronized
- The fence parameter in `vkAcquireNextImageKHR`
 - Internally synchronized
- The queue parameter in `vkQueuePresentKHR`
 - Internally synchronized
- The surface parameter in `vkGetDeviceGroupSurfacePresentModesKHR`
- The surface parameter in `vkGetPhysicalDevicePresentRectanglesKHR`
- The display parameter in `vkCreateDisplayModeKHR`
- The mode parameter in `vkGetDisplayPlaneCapabilitiesKHR`
- The commandBuffer parameter in `vkCmdSetDeviceMaskKHR`
- The commandBuffer parameter in `vkCmdDispatchBaseKHR`
- The commandBuffer parameter in `vkCmdPushDescriptorSetKHR`
- The commandBuffer parameter in `vkCmdPushDescriptorSetWithTemplateKHR`
- The descriptorUpdateTemplate parameter in `vkDestroyDescriptorUpdateTemplateKHR`
- The descriptorSet parameter in `vkUpdateDescriptorSetWithTemplateKHR`
- The commandBuffer parameter in `vkCmdBeginRenderPass2KHR`
- The commandBuffer parameter in `vkCmdNextSubpass2KHR`
- The commandBuffer parameter in `vkCmdEndRenderPass2KHR`
- The swapchain parameter in `vkGetSwapchainStatusKHR`
- The ycbcrConversion parameter in `vkDestroySamplerYcbcrConversionKHR`
- The commandBuffer parameter in `vkCmdDrawIndirectCountKHR`
- The commandBuffer parameter in `vkCmdDrawIndexedIndirectCountKHR`
- The callback parameter in `vkDestroyDebugReportCallbackEXT`
- The object member of the pTagInfo parameter in `vkDebugMarkerSetObjectTagEXT`
- The object member of the pNameInfo parameter in `vkDebugMarkerSetObjectNameEXT`
- The commandBuffer parameter in `vkCmdBindTransformFeedbackBuffersEXT`
- The commandBuffer parameter in `vkCmdBeginTransformFeedbackEXT`
- The commandBuffer parameter in `vkCmdEndTransformFeedbackEXT`
- The commandBuffer parameter in `vkCmdBeginQueryIndexedEXT`
- The commandBuffer parameter in `vkCmdEndQueryIndexedEXT`

- The `commandBuffer` parameter in `vkCmdDrawIndirectByteCountEXT`
- The `commandBuffer` parameter in `vkCmdDrawIndirectCountAMD`
- The `commandBuffer` parameter in `vkCmdDrawIndexedIndirectCountAMD`
- The `commandBuffer` parameter in `vkCmdBeginConditionalRenderingEXT`
- The `commandBuffer` parameter in `vkCmdEndConditionalRenderingEXT`
- The `commandBuffer` parameter in `vkCmdProcessCommandsNVX`
- The `commandBuffer` parameter in `vkCmdReserveSpaceForCommandsNVX`
- The `objectTable` parameter in `vkDestroyObjectTableNVX`
- The `objectTable` parameter in `vkRegisterObjectsNVX`
- The `objectTable` parameter in `vkUnregisterObjectsNVX`
- The `commandBuffer` parameter in `vkCmdSetViewportWScalingNV`
- The `swapchain` parameter in `vkGetRefreshCycleDurationGOOGLE`
- The `swapchain` parameter in `vkGetPastPresentationTimingGOOGLE`
- The `commandBuffer` parameter in `vkCmdSetDiscardRectangleEXT`
- The `objectHandle` member of the `pNameInfo` parameter in `vkSetDebugUtilsObjectNameEXT`
- The `objectHandle` member of the `pTagInfo` parameter in `vkSetDebugUtilsObjectTagEXT`
- The `messenger` parameter in `vkDestroyDebugUtilsMessengerEXT`
- The `commandBuffer` parameter in `vkCmdSetSampleLocationsEXT`
- The `validationCache` parameter in `vkDestroyValidationCacheEXT`
- The `dstCache` parameter in `vkMergeValidationCachesEXT`
- The `commandBuffer` parameter in `vkCmdBindShadingRateImageNV`
- The `commandBuffer` parameter in `vkCmdSetViewportShadingRatePaletteNV`
- The `commandBuffer` parameter in `vkCmdSetCoarseSampleOrderNV`
- The `commandBuffer` parameter in `vkCmdWriteBufferMarkerAMD`
- The `commandBuffer` parameter in `vkCmdDrawMeshTasksNV`
- The `commandBuffer` parameter in `vkCmdDrawMeshTasksIndirectNV`
- The `commandBuffer` parameter in `vkCmdDrawMeshTasksIndirectCountNV`
- The `commandBuffer` parameter in `vkCmdSetExclusiveScissorNV`
- The `commandBuffer` parameter in `vkCmdSetLineStippleEXT`

Validations

There are two types of validations in Vulkan API: Implicit validations, which talk about technical aspects of the API usage, and explicit validations, which talk about semantical aspects. Vulkayes aims to solve all implicit validations in the core crate. External validations are not always trivial to solve, some of them are statically fulfilled using the type system or the API design, others are left to the user.

External validations resolved statically are enclosed in blue boxes below. Validations optionally checked at runtime are in green boxes.

Implicit validations

Instance

Validations for `vkCreateInstance`:

1. `pCreateInfo` must be a valid pointer to a valid `VkInstanceCreateInfo` structure
 - [Handled by API design \(ash\)](#)
2. If `pAllocator` is not `NULL`, `pAllocator` must be a valid pointer to a valid `VkAllocationCallbacks` structure
 - [Handled by API design \(ash\)](#)
3. `pInstance` must be a valid pointer to a `VkInstance` handle
 - [Handled by API design \(ash\)](#)

Validations for `VkInstanceCreateInfo`:

1. `sType` must be `VK_STRUCTURE_TYPE_INSTANCE_CREATE_INFO`
 - [Handled by API design \(ash\)](#)
2. Each `pNext` member of any structure (including this one) in the `pNext` chain must be either `NULL` or a pointer to a valid instance of `VkDebugReportCallbackCreateInfoEXT`, `VkDebugUtilsMessengerCreateInfoEXT`, `VkValidationFeaturesEXT`, or `VkValidationFlagsEXT`
 - [Handled by API design \(ash\)](#)
3. The `sType` value of each struct in the `pNext` chain must be unique
 - [Handled by API design](#)
4. `flags` must be `0`
 - [Handled by API design \(ash\)](#)
5. If `pApplicationInfo` is not `NULL`, `pApplicationInfo` must be a valid pointer to a valid `VkApplicationInfo` structure
 - [Handled by API design \(ash\)](#)
6. If `enabledLayerCount` is not `0`, `ppEnabledLayerNames` must be a valid pointer to an array of `enabledLayerCount` null-terminated UTF-8 strings
 - [Returns error](#)
7. If `enabledExtensionCount` is not `0`, `ppEnabledExtensionNames` must be a valid pointer to an array of `enabledExtensionCount` null-terminated UTF-8 strings
 - [Returns error](#)

Device

Validations for `vkCreateDevice`:

1. `physicalDevice` must be a valid `VkPhysicalDevice` handle
 - [Handled by API design \(ash\)](#)
2. `pCreateInfo` must be a valid pointer to a valid `VkDeviceCreateInfo` structure
 - [Handled by API design \(ash\)](#)
3. If `pAllocator` is not `NULL`, `pAllocator` must be a valid pointer to a valid `VkAllocationCallbacks` structure
 - [Handled by API design \(ash\)](#)
4. `pDevice` must be a valid pointer to a `VkDevice` handle
 - [Handled by API design \(ash\)](#)

Validations for `VkDeviceCreateInfo`:

1. `sType` must be `VK_STRUCTURE_TYPE_DEVICE_CREATE_INFO`
 - [Handled by API design \(ash\)](#)
2. Each `pNext` member of any structure (including this one) in the `pNext` chain must be either `NULL` or a pointer to a valid instance of `VkDeviceDiagnosticsConfigCreateInfoNV`, `VkDeviceGroupDeviceCreateInfo`, `VkDeviceMemoryOverallocationCreateInfoAMD`, `VkPhysicalDevice16BitStorageFeatures`, `VkPhysicalDevice8BitStorageFeatures`, `VkPhysicalDeviceASTCDecodeFeaturesEXT`, `VkPhysicalDeviceBlendOperationAdvancedFeaturesEXT`, `VkPhysicalDeviceBufferDeviceAddressFeatures`, `VkPhysicalDeviceBufferDeviceAddressFeaturesEXT`, `VkPhysicalDeviceCoherentMemoryFeaturesAMD`, `VkPhysicalDeviceComputeShaderDerivativesFeaturesNV`, `VkPhysicalDeviceConditionalRenderingFeaturesEXT`, `VkPhysicalDeviceCooperativeMatrixFeaturesNV`, `VkPhysicalDeviceCornerSampledImageFeaturesNV`, `VkPhysicalDeviceCoverageReductionModeFeaturesNV`, `VkPhysicalDeviceDedicatedAllocationImageAliasingFeaturesNV`, `VkPhysicalDeviceDepthClipEnableFeaturesEXT`, `VkPhysicalDeviceDescriptorIndexingFeatures`, `VkPhysicalDeviceDeviceGeneratedCommandsFeaturesNV`, `VkPhysicalDeviceDiagnosticsConfigFeaturesNV`, `VkPhysicalDeviceExclusiveScissorFeaturesNV`, `VkPhysicalDeviceFeatures2`, `VkPhysicalDeviceFragmentDensityMapFeaturesEXT`, `VkPhysicalDeviceFragmentShaderBarycentricFeaturesNV`, `VkPhysicalDeviceFragmentShaderInterlockFeaturesEXT`, `VkPhysicalDeviceHostQueryResetFeatures`, `VkPhysicalDeviceImagelessFramebufferFeatures`, `VkPhysicalDeviceIndexTypeUint8FeaturesEXT`, `VkPhysicalDeviceInlineUniformBlockFeaturesEXT`, `VkPhysicalDeviceLineRasterizationFeaturesEXT`, `VkPhysicalDeviceMemoryPriorityFeaturesEXT`, `VkPhysicalDeviceMeshShaderFeaturesNV`, `VkPhysicalDeviceMultiviewFeatures`, `VkPhysicalDevicePerformanceQueryFeaturesKHR`, `VkPhysicalDevicePipelineCreationCacheControlFeaturesEXT`, `VkPhysicalDevicePipelineExecutablePropertiesFeaturesKHR`, `VkPhysicalDeviceProtectedMemoryFeatures`, `VkPhysicalDeviceRayTracingFeaturesKHR`, `VkPhysicalDeviceRepresentativeFragmentTestFeaturesNV`, `VkPhysicalDeviceSamplerYcbcrConversionFeatures`, `VkPhysicalDeviceScalarBlockLayoutFeatures`, `VkPhysicalDeviceSeparateDepthStencilLayoutsFeatures`, `VkPhysicalDeviceShaderAtomicInt64Features`, `VkPhysicalDeviceShaderClockFeaturesKHR`, `VkPhysicalDeviceShaderDemoteToHelperInvocationFeaturesEXT`, `VkPhysicalDeviceShaderDrawParametersFeatures`, `VkPhysicalDeviceShaderFloat16Int8Features`, `VkPhysicalDeviceShaderImageFootprintFeaturesNV`, `VkPhysicalDeviceShaderIntegerFunctions2FeaturesINTEL`, `VkPhysicalDeviceShaderSMBuiltinsFeaturesNV`, `VkPhysicalDeviceShaderSubgroupExtendedTypesFeatures`, `VkPhysicalDeviceShadingRateImageFeaturesNV`, `VkPhysicalDeviceSubgroupSizeControlFeaturesEXT`, `VkPhysicalDeviceTexelBufferAlignmentFeaturesEXT`, `VkPhysicalDeviceTextureCompressionASTCHDRFeaturesEXT`, `VkPhysicalDeviceTimelineSemaphoreFeatures`, `VkPhysicalDeviceTransformFeedbackFeaturesEXT`, `VkPhysicalDeviceUniformBufferStandardLayoutFeatures`, `VkPhysicalDeviceVariablePointersFeatures`, `VkPhysicalDeviceVertexAttributeDivisorFeaturesEXT`, `VkPhysicalDeviceVulkan11Features`, `VkPhysicalDeviceVulkan12Features`, `VkPhysicalDeviceVulkanMemoryModelFeatures`, or `VkPhysicalDeviceYcbcrImageArraysFeaturesEXT`
 - [Handled by API design \(ash\)](#)
3. The `sType` value of each struct in the `pNext` chain must be unique
 - [Handled by API design](#)
4. `flags` must be `0`
 - [Handled by API design \(ash\)](#)
5. `pQueueCreateInfos` must be a valid pointer to an array of `queueCreateInfoCount` valid `VkDeviceQueueCreateInfo` structures
 - [Handled by API design \(ash\)](#)

6. If `enabledLayerCount` is not `0`, `ppEnabledLayerNames` must be a valid pointer to an array of `enabledLayerCount` null-terminated UTF-8 strings
 - [Returns error](#)
7. If `enabledExtensionCount` is not `0`, `ppEnabledExtensionNames` must be a valid pointer to an array of `enabledExtensionCount` null-terminated UTF-8 strings
 - [Returns error](#)
8. If `pEnabledFeatures` is not `NULL`, `pEnabledFeatures` must be a valid pointer to a valid `VkPhysicalDeviceFeatures` structure
 - [Handled by API design \(ash\)](#)
9. `queueCreateInfoCount` must be greater than `0`
 - [Returns error](#)

Queue

Validations for `VkDeviceQueueCreateInfo`:

1. `sType` must be `VK_STRUCTURE_TYPE_DEVICE_QUEUE_CREATE_INFO`
 - [Handled by API design \(ash\)](#)
2. `pNext` must be `NULL` or a pointer to a valid instance of `VkDeviceQueueGlobalPriorityCreateInfoEXT`
 - [Handled by API design \(ash\)](#)
3. The `sType` value of each struct in the `pNext` chain must be unique
 - [Handled by API design](#)
4. `flags` must be a valid combination of `VkDeviceQueueCreateFlagBits` values
 - [Handled by API design \(ash\)](#)
5. `pQueuePriorities` must be a valid pointer to an array of `queueCount` `float` values
 - [Handled by API design \(ash\)](#)
6. `queueCount` must be greater than `0`
 - [Returns error](#)

Validations for `vkGetDeviceQueue`:

1. `device` must be a valid `VkDevice` handle
 - [Handled by API design](#)
2. `pQueue` must be a valid pointer to a `VkQueue` handle
 - [Handled by API design](#)

Validations for `vkGetDeviceQueue2`:

1. `device` must be a valid `VkDevice` handle
 - [Handled by API design](#)
2. `pQueueInfo` must be a valid pointer to a valid `VkDeviceQueueCreateInfo2` structure
 - [Handled by API design](#)
3. `pQueue` must be a valid pointer to a `VkQueue` handle
 - [Handled by API design](#)

Validations for `VkDeviceQueueCreateInfo2`:

1. `sType` must be `VK_STRUCTURE_TYPE_DEVICE_QUEUE_INFO_2`
 - [Handled by API design \(ash\)](#)
2. `pNext` must be `NULL`
 - [Handled by API design \(ash\)](#)
3. `flags` must be a valid combination of `VkDeviceQueueCreateFlagBits` values
 - [Handled by API design \(ash\)](#)

Validations for `vkQueueSubmit`:

1. `queue` must be a valid `VkQueue` handle
 - [Handled by API design](#)
2. If `submitCount` is not `0`, `pSubmits` must be a valid pointer to an array of `submitCount` valid `VkSubmitInfo` structures
 - [Handled by API design](#)
3. If `fence` is not `VK_NULL_HANDLE`, `fence` must be a valid `VkFence` handle
 - [Handled by API design](#)
4. Both of `fence`, and `queue` that are valid handles of non-ignored parameters must have been created, allocated, or retrieved from the same `VkDevice`
 - [Returns error](#)

Validations for `VkSubmitInfo`:

1. `sType` must be `VK_STRUCTURE_TYPE_SUBMIT_INFO`
 - [Handled by API design \(ash\)](#)
2. Each `pNext` member of any structure (including this one) in the `pNext` chain must be either `NULL` or a pointer to a valid instance of `VkD3D12FenceSubmitInfoKHR`, `VkDeviceGroupSubmitInfo`, `VkPerformanceQuerySubmitInfoKHR`, `VkProtectedSubmitInfo`, `VkTimelineSemaphoreSubmitInfo`, `VkWin32KeyedMutexAcquireReleaseInfoKHR`, or `VkWin32KeyedMutexAcquireReleaseInfoNV`
 - [Handled by API design \(ash\)](#)
3. The `sType` value of each struct in the `pNext` chain must be unique
 - [Handled by API design](#)
4. If `waitSemaphoreCount` is not `0`, `pWaitSemaphores` must be a valid pointer to an array of `waitSemaphoreCount` valid `VkSemaphore` handles
 - [Handled by API design \(ash\)](#)
5. If `waitSemaphoreCount` is not `0`, `pWaitDstStageMask` must be a valid pointer to an array of `waitSemaphoreCount` valid combinations of `VkPipelineStageFlagBits` values
 - [Handled by API design \(ash\)](#)
6. Each element of `pWaitDstStageMask` must not be `0`
 - [Handled by API design](#)
7. If `commandBufferCount` is not `0`, `pCommandBuffers` must be a valid pointer to an array of `commandBufferCount` valid `VkCommandBuffer` handles
 - [Handled by API design \(ash\)](#)
8. If `signalSemaphoreCount` is not `0`, `pSignalSemaphores` must be a valid pointer to an array of `signalSemaphoreCount` valid `VkSemaphore` handles
 - [Handled by API design \(ash\)](#)
9. Each of the elements of `pCommandBuffers`, the elements of `pSignalSemaphores`, and the elements of `pWaitSemaphores` that are valid handles of non-ignored parameters must have been created, allocated, or retrieved from the same `VkDevice`
 - [Returns error](#)

Swapchain

Validations for vkCreateSwapchainKHR:

1. device must be a valid VkDevice handle
 - [Handled by API design \(ash\)](#)
2. pCreateInfo must be a valid pointer to a valid VkSwapchainCreateInfoKHR structure
 - [Handled by API design \(ash\)](#)
3. If pAllocator is not NULL, pAllocator must be a valid pointer to a valid VkAllocationCallbacks structure
 - [Handled by API design \(ash\)](#)
4. pSwapchain must be a valid pointer to a VkSwapchainKHR handle
 - [Handled by API design \(ash\)](#)

Validations for VkSwapchainCreateInfoKHR:

1. sType must be VK_STRUCTURE_TYPE_SWAPCHAIN_CREATE_INFO_KHR
 - [Handled by API design \(ash\)](#)
2. Each pNext member of any structure (including this one) in the pNext chain must be either NULL or a pointer to a valid instance of VkDeviceGroupSwapchainCreateInfoKHR, VkImageFormatListCreateInfo, VkSurfaceFullScreenExclusiveInfoEXT, VkSurfaceFullScreenExclusiveWin32InfoEXT, VkSwapchainCounterCreateInfoEXT, or VkSwapchainDisplayNativeHdrCreateInfoAMD
 - [Handled by API design \(ash\)](#)
3. The sType value of each struct in the pNext chain must be unique
 - [Handled by API design](#)
4. flags must be a valid combination of VkSwapchainCreateFlagBitsKHR values
 - [Handled by API design \(ash\)](#)
5. surface must be a valid VkSurfaceKHR handle
 - [Handled by API design \(ash\)](#)
6. imageFormat must be a valid VkFormat value
 - [Handled by API design \(ash\)](#)
7. imageColorSpace must be a valid VkColorSpaceKHR value
 - [Handled by API design \(ash\)](#)
8. imageUsage must be a valid combination of VkImageUsageFlagBits values
 - [Handled by API design \(ash\)](#)
9. imageUsage must not be 0
 - [Returns error](#)

10. `imageSharingMode` must be a valid `VkSharingMode` value
 - [Handled by API design \(ash\)](#)
11. `preTransform` must be a valid `VkSurfaceTransformFlagBitsKHR` value
 - [Handled by API design \(ash\)](#)
12. `compositeAlpha` must be a valid `VkCompositeAlphaFlagBitsKHR` value
 - [Handled by API design \(ash\)](#)
13. `presentMode` must be a valid `VkPresentModeKHR` value
 - [Handled by API design \(ash\)](#)
14. If `oldSwapchain` is not `VK_NULL_HANDLE`, `oldSwapchain` must be a valid `VkSwapchainKHR` handle
 - [Handled by API design \(ash\)](#)
15. If `oldSwapchain` is a valid handle, it must have been created, allocated, or retrieved from `surface`
 - [Handled by API design](#)
16. Both of `oldSwapchain`, and `surface` that are valid handles of non-ignored parameters must have been created, allocated, or retrieved from the same `VkInstance`
 - [Handled by API design](#)

Validations for `vkGetSwapchainImagesKHR`:

1. `device` must be a valid `VkDevice` handle
 - [Handled by API design](#)
2. `swapchain` must be a valid `VkSwapchainKHR` handle
 - [Handled by API design](#)
3. `pSwapchainImageCount` must be a valid pointer to a `uint32_t` value
 - [Handled by API design \(ash\)](#)
4. If the value referenced by `pSwapchainImageCount` is not `0`, and `pSwapchainImages` is not `NULL`, `pSwapchainImages` must be a valid pointer to an array of `pSwapchainImageCount` `VkImage` handles
 - [Handled by API design \(ash\)](#)
5. Both of `device`, and `swapchain` must have been created, allocated, or retrieved from the same `VkInstance`
 - [Handled by API design](#)

Validations for `vkQueuePresentKHR`:

1. `queue` must be a valid `VkQueue` handle
 - [Handled by API design \(ash\)](#)
2. `pPresentInfo` must be a valid pointer to a valid `VkPresentInfoKHR` structure
 - [Handled by API design \(ash\)](#)

Validations for `VkPresentInfoKHR`:

1. `sType` must be `VK_STRUCTURE_TYPE_PRESENT_INFO_KHR`
 - [Handled by API design \(ash\)](#)
2. Each `pNext` member of any structure (including this one) in the `pNext` chain must be either `NULL` or a pointer to a valid instance of `VkDeviceGroupPresentInfoKHR`, `VkDisplayPresentInfoKHR`, `VkPresentFrameTokenGGP`, `VkPresentRegionsKHR`, or `VkPresentTimesInfoGOOGLE`
 - [Handled by API design \(ash\)](#)
3. The `sType` value of each struct in the `pNext` chain must be unique
 - [Handled by API design](#)
4. If `waitSemaphoreCount` is not `0`, `pWaitSemaphores` must be a valid pointer to an array of `waitSemaphoreCount` valid `VkSemaphore` handles
 - [Handled by API design \(ash\)](#)
5. `pSwapchains` must be a valid pointer to an array of `swapchainCount` valid `VkSwapchainKHR` handles
 - [Handled by API design \(ash\)](#)
6. `pImageIndices` must be a valid pointer to an array of `swapchainCount` `uint32_t` values
 - [Handled by API design \(ash\)](#)
7. If `pResults` is not `NULL`, `pResults` must be a valid pointer to an array of `swapchainCount` `VkResult` values
 - [Handled by API design \(ash\)](#)
8. `swapchainCount` must be greater than `0`
 - [Returns error](#)
9. Both of the elements of `pSwapchains`, and the elements of `pWaitSemaphores` that are valid handles of non-ignored parameters must have been created, allocated, or retrieved from the same `VkInstance`
 - [Returns error](#)

Validations for `vkAcquireNextImageKHR`:

1. `device` must be a valid `VkDevice` handle
 - [Handled by API design](#)
2. `swapchain` must be a valid `VkSwapchainKHR` handle
 - [Handled by API design](#)
3. If `semaphore` is not `VK_NULL_HANDLE`, `semaphore` must be a valid `VkSemaphore` handle
 - [Handled by API design](#)
4. If `fence` is not `VK_NULL_HANDLE`, `fence` must be a valid `VkFence` handle
 - [Handled by API design](#)
5. `pImageIndex` must be a valid pointer to a `uint32_t` value
 - [Handled by API design \(ash\)](#)
6. If `semaphore` is a valid handle, it must have been created, allocated, or retrieved from `device`
 - [Returns error](#)
7. If `fence` is a valid handle, it must have been created, allocated, or retrieved from `device`
 - [Returns error](#)
8. Both of `device`, and `swapchain` that are valid handles of non-ignored parameters must have been created, allocated, or retrieved from the same `VkInstance`
 - [Handled by API design](#)

Command Buffer

Validations for `vkCreateCommandPool`:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. pCreateInfo must be a valid pointer to a valid VkCommandPoolCreateInfo structure
 - [Handled by API design \(ash\)](#)
3. If pAllocator is not NULL, pAllocator must be a valid pointer to a valid VkAllocationCallbacks structure
 - [Handled by API design](#)
4. pCommandPool must be a valid pointer to a VkCommandPool handle
 - [Handled by API design \(ash\)](#)

Validations for VkCommandPoolCreateInfo:

1. sType must be VK_STRUCTURE_TYPE_COMMAND_POOL_CREATE_INFO
 - [Handled by API design \(ash\)](#)
2. pNext must be NULL
 - [Handled by API design \(ash\)](#)
3. flags must be a valid combination of VkCommandPoolCreateFlagBits values
 - [Handled by API design \(ash\)](#)

Validations for vkTrimCommandPool:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. commandPool must be a valid VkCommandPool handle
 - [Handled by API design](#)
3. flags must be 0
 - [Handled by API design](#)
4. commandPool must have been created, allocated, or retrieved from device
 - [Handled by API design](#)

Validations for vkResetCommandPool:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. commandPool must be a valid VkCommandPool handle
 - [Handled by API design](#)
3. flags must be a valid combination of VkCommandPoolResetFlagBits values
 - [Handled by API design](#)
4. commandPool must have been created, allocated, or retrieved from device
 - [Handled by API design](#)

Validations for VkCommandBufferAllocateInfo:

1. sType must be VK_STRUCTURE_TYPE_COMMAND_BUFFER_ALLOCATE_INFO
 - [Handled by API design \(ash\)](#)
2. pNext must be NULL
 - [Handled by API design \(ash\)](#)
3. commandPool must be a valid VkCommandPool handle
 - [Handled by API design \(ash\)](#)
4. level must be a valid VkCommandBufferLevel value
 - [Handled by API design \(ash\)](#)

Fence

Validations for vkCreateFence:

1. device must be a valid VkDevice handle
 - [Handled by API design \(ash\)](#)
2. pCreateInfo must be a valid pointer to a valid VkFenceCreateInfo structure
 - [Handled by API design \(ash\)](#)
3. If pAllocator is not NULL, pAllocator must be a valid pointer to a valid VkAllocationCallbacks structure
 - [Handled by API design \(ash\)](#)
4. pFence must be a valid pointer to a VkFence handle
 - [Handled by API design \(ash\)](#)

Validations for VkFenceCreateInfo:

1. sType must be VK_STRUCTURE_TYPE_FENCE_CREATE_INFO
 - [Handled by API design \(ash\)](#)
2. Each pNext member of any structure (including this one) in the pNext chain must be either NULL or a pointer to a valid instance of VkExportFenceCreateInfo or VkExportFenceWin32HandleInfoKHR
 - [Handled by API design \(ash\)](#)
3. The sType value of each struct in the pNext chain must be unique
 - [Handled by API design](#)
4. flags must be a valid combination of VkFenceCreateFlagBits values
 - [Handled by API design \(ash\)](#)

Validations for vkGetFenceStatus:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. fence must be a valid VkFence handle
 - [Handled by API design](#)
3. fence must have been created, allocated, or retrieved from device
 - [Handled by API design](#)

Validations for vkResetFences:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. pFences must be a valid pointer to an array of fenceCount valid VkFence handles
 - [Handled by API design](#)
3. fenceCount must be greater than 0
 - [Handled by API design](#)
4. Each element of pFences must have been created, allocated, or retrieved from device
 - [Handled by API design](#)

Validations for vkWaitForFences:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. pFences must be a valid pointer to an array of fenceCount valid VkFence handles
 - [Handled by API design](#)
3. fenceCount must be greater than 0
 - [Handled by API design](#)
4. Each element of pFences must have been created, allocated, or retrieved from device
 - [Handled by API design](#)

Semaphore

Validations for vkCreateSemaphore:

1. device must be a valid VkDevice handle
 - [Handled by API design \(ash\)](#)
2. pCreateInfo must be a valid pointer to a valid VkSemaphoreCreateInfo structure
 - [Handled by API design \(ash\)](#)
3. If pAllocator is not NULL, pAllocator must be a valid pointer to a valid VkAllocationCallbacks structure
 - [Handled by API design \(ash\)](#)
4. pSemaphore must be a valid pointer to a VkSemaphore handle
 - [Handled by API design \(ash\)](#)

Validations for VkSemaphoreCreateInfo:

1. sType must be VK_STRUCTURE_TYPE_SEMAPHORE_CREATE_INFO
 - [Handled by API design \(ash\)](#)
2. Each pNext member of any structure (including this one) in the pNext chain must be either NULL or a pointer to a valid instance of VkExportSemaphoreCreateInfo, VkExportSemaphoreWin32HandleInfoKHR, or VkSemaphoreTypeCreateInfo
 - [Handled by API design \(ash\)](#)
3. The sType value of each struct in the pNext chain must be unique
 - [Handled by API design](#)
4. flags must be 0
 - [Handled by API design \(ash\)](#)

Validations for VkSemaphoreTypeCreateInfo:

1. sType must be VK_STRUCTURE_TYPE_SEMAPHORE_TYPE_CREATE_INFO
 - [Handled by API design \(ash\)](#)
2. semaphoreType must be a valid VkSemaphoreType value
 - [Handled by API design \(ash\)](#)

Image

Validations for vkCreateImage:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. pCreateInfo must be a valid pointer to a valid VkImageCreateInfo structure
 - [Handled by API design \(ash\)](#)
3. If pAllocator is not NULL, pAllocator must be a valid pointer to a valid VkAllocationCallbacks structure
 - [Handled by API design](#)
4. pImage must be a valid pointer to a VkImage handle
 - [Handled by API design \(ash\)](#)

Validations for VkImageCreateInfo:

1. sType must be VK_STRUCTURE_TYPE_IMAGE_CREATE_INFO
 - [Handled by API design \(ash\)](#)
2. Each pNext member of any structure (including this one) in the pNext chain must be either NULL or a pointer to a valid instance of VkDedicatedAllocationImageCreateInfoNV, VkExternalFormatANDROID, VkExternalMemoryImageCreateInfo, VkExternalMemoryImageCreateInfoNV, VkImageDrmFormatModifierExplicitCreateInfoEXT, VkImageDrmFormatModifierListCreateInfoEXT, VkImageFormatListCreateInfo, VkImageStencilUsageCreateInfo, or VkImageSwapchainCreateInfoKHR
 - [Handled by API design \(ash\)](#)
3. The sType value of each struct in the pNext chain must be unique
 - [Handled by API design](#)
4. flags must be a valid combination of VkImageCreateFlagBits values
 - [Handled by API design](#)
5. imageType must be a valid VkImageType value
 - [Handled by API design \(ash\)](#)
6. format must be a valid VkFormat value
 - [Handled by API design \(ash\)](#)
7. samples must be a valid VkSampleCountFlagBits value
 - [Handled by API design \(ash\)](#)
8. tiling must be a valid VkImageTiling value
 - [Handled by API design \(ash\)](#)
9. usage must be a valid combination of VkImageUsageFlagBits values
 - [Handled by API design](#)
10. usage must not be 0
 - [Returns error](#)
11. sharingMode must be a valid VkSharingMode value
 - [Handled by API design \(ash\)](#)
12. initialLayout must be a valid VkImageLayout value
 - [Handled by API design \(ash\)](#)

Validations for vkBindImageMemory:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. image must be a valid VkImage handle
 - [Handled by API design](#)
3. memory must be a valid VkDeviceMemory handle
 - [Handled by API design](#)
4. image must have been created, allocated, or retrieved from device
 - [Handled by API design](#)
5. memory must have been created, allocated, or retrieved from device
 - [Returns error](#)

Validations for vkCreateImageView:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. pCreateInfo must be a valid pointer to a valid VkImageViewCreateInfo structure
 - [Handled by API design \(ash\)](#)
3. If pAllocator is not NULL, pAllocator must be a valid pointer to a valid VkAllocationCallbacks structure
 - [Handled by API design](#)
4. pView must be a valid pointer to a VkImageView handle
 - [Handled by API design \(ash\)](#)

Validations for VkImageViewCreateInfo:

1. sType must be VK_STRUCTURE_TYPE_IMAGE_VIEW_CREATE_INFO
 - [Handled by API design \(ash\)](#)
2. Each pNext member of any structure (including this one) in the pNext chain must be either NULL or a pointer to a valid instance of VkImageViewASTCDecodeModeEXT, VkImageViewUsageCreateInfo, or VkSamplerYcbcrConversionInfo
 - [Handled by API design \(ash\)](#)
3. The sType value of each struct in the pNext chain must be unique
 - [Handled by API design](#)
4. flags must be a valid combination of VkImageViewCreateFlagBits values
 - [Handled by API design](#)
5. image must be a valid VkImage handle
 - [Handled by API design](#)
6. viewType must be a valid VkImageViewType value
 - [Handled by API design](#)
7. format must be a valid VkFormat value
 - [Handled by API design](#)
8. components must be a valid VkComponentMapping structure
 - [Handled by API design](#)
9. subresourceRange must be a valid VkImageSubresourceRange structure
 - [Handled by API design](#)

Buffer

Validations for vkCreateBuffer:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. pCreateInfo must be a valid pointer to a valid VkBufferCreateInfo structure
 - [Handled by API design \(ash\)](#)
3. If pAllocator is not NULL, pAllocator must be a valid pointer to a valid VkAllocationCallbacks structure
 - [Handled by API design](#)
4. pBuffer must be a valid pointer to a VkBuffer handle
 - [Handled by API design \(ash\)](#)

Validations for VkBufferCreateInfo:

1. sType must be VK_STRUCTURE_TYPE_BUFFER_CREATE_INFO
 - [Handled by API design \(ash\)](#)
2. Each pNext member of any structure (including this one) in the pNext chain must be either NULL or a pointer to a valid instance of VkBufferDeviceAddressCreateInfoEXT, VkBufferOpaqueCaptureAddressCreateInfo, VkDedicatedAllocationBufferCreateInfoNV, or VkExternalMemoryBufferCreateInfo
 - [Handled by API design \(ash\)](#)
3. The sType value of each struct in the pNext chain must be unique
 - [Handled by API design](#)
4. flags must be a valid combination of VkBufferCreateFlagBits values
 - [Handled by API design](#)
5. usage must be a valid combination of VkBufferUsageFlagBits values
 - [Handled by API design](#)
6. usage must not be 0
 - [Return error](#)
7. sharingMode must be a valid VkSharingMode value
 - [Handled by API design](#)

Validations for vkBindBufferMemory:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. buffer must be a valid VkBuffer handle
 - [Handled by API design](#)
3. memory must be a valid VkDeviceMemory handle
 - [Handled by API design](#)
4. buffer must have been created, allocated, or retrieved from device
 - [Handled by API design](#)
5. memory must have been created, allocated, or retrieved from device
 - [Returns error](#)

Validations for vkCreateBufferView:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. pCreateInfo must be a valid pointer to a valid VkBufferViewCreateInfo structure
 - [Handled by API design \(ash\)](#)
3. If pAllocator is not NULL, pAllocator must be a valid pointer to a valid VkAllocationCallbacks structure
 - [Handled by API design](#)
4. pView must be a valid pointer to a VkBufferView handle
 - [Handled by API design \(ash\)](#)

Validations for VkBufferViewCreateInfo:

1. sType must be VK_STRUCTURE_TYPE_BUFFER_VIEW_CREATE_INFO
 - [Handled by API design \(ash\)](#)
2. pNext must be NULL
 - [Handled by API design \(ash\)](#)
3. flags must be 0
 - [Handled by API design](#)
4. buffer must be a valid VkBuffer handle
 - [Handled by API design \(ash\)](#)
5. format must be a valid VkFormat value
 - [Handled by API design \(ash\)](#)

Memory

Validations for vkMapMemory:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. memory must be a valid VkDeviceMemory handle
 - [Handled by API design](#)
3. flags must be 0
 - [Handled by API design](#)
4. ppData must be a valid pointer to a pointer value
 - [Handled by API design \(ash\)](#)
5. memory must have been created, allocated, or retrieved from device
 - [Handled by API design](#)

Validations for vkFlushMappedMemoryRanges:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. pMemoryRanges must be a valid pointer to an array of memoryRangeCount valid VkMappedMemoryRange structures
 - [Handled by API design](#)
3. memoryRangeCount must be greater than 0
 - [Handled by API design](#)

Validations for vkInvalidateMappedMemoryRanges:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. pMemoryRanges must be a valid pointer to an array of memoryRangeCount valid VkMappedMemoryRange structures
 - [Handled by API design](#)
3. memoryRangeCount must be greater than 0
 - [Handled by API design](#)

Validations for VkMappedMemoryRange:

1. sType must be VK_STRUCTURE_TYPE_MAPPED_MEMORY_RANGE
 - [Handled by API design \(ash\)](#)
2. pNext must be NULL
 - [Handled by API design \(ash\)](#)
3. memory must be a valid VkDeviceMemory handle
 - [Handled by API design](#)

Descriptors

Validations for vkCreateDescriptorSetLayout:

1. device must be a valid VkDevice handle
 - [Handled by API design](#)
2. pCreateInfo must be a valid pointer to a valid VkDescriptorSetLayoutCreateInfo structure
 - [Handled by API design](#)
3. If pAllocator is not NULL, pAllocator must be a valid pointer to a valid VkAllocationCallbacks structure
 - [Handled by API design](#)
4. psetLayout must be a valid pointer to a VkDescriptorSetLayout handle
 - [Handled by API design \(ash\)](#)

Validations for VkDescriptorSetLayoutCreateInfo:

1. sType must be VK_STRUCTURE_TYPE_DESCRIPTOR_SET_LAYOUT_CREATE_INFO
 - [Handled by API design \(ash\)](#)
2. pNext must be NULL or a pointer to a valid instance of VkDescriptorSetLayoutBindingFlagsCreateInfo
 - [Handled by API design \(ash\)](#)
3. The sType value of each struct in the pNext chain must be unique
 - [Handled by API design](#)
4. flags must be a valid combination of VkDescriptorSetLayoutCreateFlagBits values
 - [Handled by API design](#)
5. If bindingCount is not 0, pBindings must be a valid pointer to an array of bindingCount valid VkDescriptorSetLayoutBinding structures
 - [Handled by API design](#)

Validations for VkDescriptorSetLayoutBinding:

1. descriptorType must be a valid VkDescriptorType value
 - Handled by API design

Pipeline

Validations for vkCreatePipelineLayout:

1. device must be a valid VkDevice handle
 - Handled by API design
2. pCreateInfo must be a valid pointer to a valid VkPipelineLayoutCreateInfo structure
 - Handled by API design
3. If pAllocator is not NULL, pAllocator must be a valid pointer to a valid VkAllocationCallbacks structure
 - Handled by API design
4. pPipelineLayout must be a valid pointer to a VkPipelineLayout handle
 - Handled by API design (ash)

Creation validation

Validations of correct usage in create functions as dictated by the Vulkan specification.

Instance

Validations for vkCreateInstance:

1. All required extensions for each extension in the VkInstanceCreateInfo::ppEnabledExtensionNames list must also be present in that list.

Device

Validations for vkCreateDevice:

1. All required extensions for each extension in the VkDeviceCreateInfo::ppEnabledExtensionNames list must also be present in that list.

Validations for VkDeviceCreateInfo:

1. The queueFamilyIndex member of each element of pQueueCreateInfos must be unique within pQueueCreateInfos, except that two members can share the same queueFamilyIndex if one is a protected-capable queue and one is not a protected-capable queue
2. If the pNext chain includes a VkPhysicalDeviceFeatures2 structure, then pEnabledFeatures must be NULL
 - Handled by API design
3. ppEnabledExtensionNames must not contain VK_AMD_negative_viewport_height
4. ppEnabledExtensionNames must not contain both VK_KHR_buffer_device_address and VK_EXT_buffer_device_address

5. If the pNext chain includes a `VkPhysicalDeviceVulkan11Features` structure, then it must not include a `VkPhysicalDevice16BitStorageFeatures`, `VkPhysicalDeviceMultiviewFeatures`, `VkPhysicalDeviceVariablePointersFeatures`, `VkPhysicalDeviceProtectedMemoryFeatures`, `VkPhysicalDeviceSamplerYcbcConversionFeatures`, or `VkPhysicalDeviceShaderDrawParametersFeatures` structure
 - [Handled by API design](#)
6. If the pNext chain includes a `VkPhysicalDeviceVulkan12Features` structure, then it must not include a `VkPhysicalDevice8BitStorageFeatures`, `VkPhysicalDeviceShaderAtomicInt64Features`, `VkPhysicalDeviceShaderFloat16Int8Features`, `VkPhysicalDeviceDescriptorIndexingFeatures`, `VkPhysicalDeviceScalarBlockLayoutFeatures`, `VkPhysicalDeviceImagelessFramebufferFeatures`, `VkPhysicalDeviceUniformBufferStandardLayoutFeatures`, `VkPhysicalDeviceShaderSubgroupExtendedTypesFeatures`, `VkPhysicalDeviceSeparateDepthStencilLayoutsFeatures`, `VkPhysicalDeviceHostQueryResetFeatures`, `VkPhysicalDeviceTimelineSemaphoreFeatures`, `VkPhysicalDeviceBufferDeviceAddressFeatures`, or `VkPhysicalDeviceVulkanMemoryModelFeatures` structure
 - [Handled by API design](#)
7. If ppEnabledExtensions contains "VK_KHR_draw_indirect_count" and the pNext chain includes a `VkPhysicalDeviceVulkan12Features` structure, then `VkPhysicalDeviceVulkan12Features::drawIndirectCount` must be `VK_TRUE`
 - [Handled by API design](#)
8. If ppEnabledExtensions contains "VK_KHR_sampler_mirror_clamp_to_edge" and the pNext chain includes a `VkPhysicalDeviceVulkan12Features` structure, then `VkPhysicalDeviceVulkan12Features::samplerMirrorClampToEdge` must be `VK_TRUE`
 - [Handled by API design](#)
9. If ppEnabledExtensions contains "VK_EXT_descriptor_indexing" and the pNext chain includes a `VkPhysicalDeviceVulkan12Features` structure, then `VkPhysicalDeviceVulkan12Features::descriptorIndexing` must be `VK_TRUE`
 - [Handled by API design](#)
10. If ppEnabledExtensions contains "VK_EXT_sampler_filter_minmax" and the pNext chain includes a `VkPhysicalDeviceVulkan12Features` structure, then `VkPhysicalDeviceVulkan12Features::samplerFilterMinmax` must be `VK_TRUE`
 - [Handled by API design](#)
11. If ppEnabledExtensions contains "VK_EXT_shader_viewport_index_layer" and the pNext chain includes a `VkPhysicalDeviceVulkan12Features` structure, then `VkPhysicalDeviceVulkan12Features::shaderOutputViewportIndex` and `VkPhysicalDeviceVulkan12Features::shaderOutputLayer` must both be `VK_TRUE`
 - [Handled by API design](#)

Queue

Validations for `VkDeviceQueueCreateInfo`:

1. `queueFamilyIndex` must be less than `pQueueFamilyPropertyCount` returned by `vkGetPhysicalDeviceQueueFamilyProperties`
2. `queueCount` must be less than or equal to the `queueCount` member of the `VkQueueFamilyProperties` structure, as returned by `vkGetPhysicalDeviceQueueFamilyProperties` in the `pQueueFamilyProperties[queueFamilyIndex]`
3. Each element of `pQueuePriorities` must be between `0.0` and `1.0` inclusive

- If the protected memory feature is not enabled, the `VK_DEVICE_QUEUE_CREATE_PROTECTED_BIT` bit of `flags` must not be set.
 - Handled by API design

Swapchain

Validations for `VkSwapchainCreateInfoKHR`:

- `surface` must be a surface that is supported by the device as determined using `vkGetPhysicalDeviceSurfaceSupportKHR`
- `minImageCount` must be less than or equal to the value returned in the `maxImageCount` member of the `VkSurfaceCapabilitiesKHR` structure returned by `vkGetPhysicalDeviceSurfaceCapabilitiesKHR` for the surface if the returned `maxImageCount` is not zero
- If `presentMode` is not `VK_PRESENT_MODE_SHARED_DEMAND_REFRESH_KHR` nor `VK_PRESENT_MODE_SHARED_CONTINUOUS_REFRESH_KHR`, then `minImageCount` must be greater than or equal to the value returned in the `minImageCount` member of the `VkSurfaceCapabilitiesKHR` structure returned by `vkGetPhysicalDeviceSurfaceCapabilitiesKHR` for the surface
- `minImageCount` must be 1 if `presentMode` is either `VK_PRESENT_MODE_SHARED_DEMAND_REFRESH_KHR` or `VK_PRESENT_MODE_SHARED_CONTINUOUS_REFRESH_KHR`
- `imageFormat` and `imageColorSpace` must match the `format` and `colorSpace` members, respectively, of one of the `VkSurfaceFormatKHR` structures returned by `vkGetPhysicalDeviceSurfaceFormatsKHR` for the surface
- `imageExtent` must be between `minImageExtent` and `maxImageExtent`, inclusive, where `minImageExtent` and `maxImageExtent` are members of the `VkSurfaceCapabilitiesKHR` structure returned by `vkGetPhysicalDeviceSurfaceCapabilitiesKHR` for the surface
- `imageExtent` members `width` and `height` must both be non-zero
 - Guaranteed by the type system
- `imageArrayLayers` must be greater than 0 and less than or equal to the `maxImageArrayLayers` member of the `VkSurfaceCapabilitiesKHR` structure returned by `vkGetPhysicalDeviceSurfaceCapabilitiesKHR` for the surface
 - Lower bound guaranteed by the type system
- If `presentMode` is `VK_PRESENT_MODE_IMMEDIATE_KHR`, `VK_PRESENT_MODE_MAILBOX_KHR`, `VK_PRESENT_MODE_FIFO_KHR` or `VK_PRESENT_MODE_FIFO_RELAXED_KHR`, `imageUsage` must be a subset of the supported usage flags present in the `supportedUsageFlags` member of the `VkSurfaceCapabilitiesKHR` structure returned by `vkGetPhysicalDeviceSurfaceCapabilitiesKHR` for surface
- If `presentMode` is `VK_PRESENT_MODE_SHARED_DEMAND_REFRESH_KHR` or `VK_PRESENT_MODE_SHARED_CONTINUOUS_REFRESH_KHR`, `imageUsage` must be a subset of the supported usage flags present in the `sharedPresentSupportedUsageFlags` member of the `VkSharedPresentSurfaceCapabilitiesKHR` structure returned by `vkGetPhysicalDeviceSurfaceCapabilities2KHR` for surface
- If `imageSharingMode` is `VK_SHARING_MODE_CONCURRENT`, `pQueueFamilyIndices` must be a valid pointer to an array of `queueFamilyIndexCount` `uint32_t` values
 - Guaranteed by the type system
- If `imageSharingMode` is `VK_SHARING_MODE_CONCURRENT`, `queueFamilyIndexCount` must be greater than 1
 - Guaranteed by the type system
- If `imageSharingMode` is `VK_SHARING_MODE_CONCURRENT`, each element of `pQueueFamilyIndices` must be unique and must be less than `pQueueFamilyPropertyCount`

- returned by either `vkGetPhysicalDeviceQueueFamilyProperties` or `vkGetPhysicalDeviceQueueFamilyProperties2` for the `physicalDevice` that was used to create device
14. `preTransform` must be one of the bits present in the `supportedTransforms` member of the `VkSurfaceCapabilitiesKHR` structure returned by `vkGetPhysicalDeviceSurfaceCapabilitiesKHR` for the surface
 15. `compositeAlpha` must be one of the bits present in the `supportedCompositeAlpha` member of the `VkSurfaceCapabilitiesKHR` structure returned by `vkGetPhysicalDeviceSurfaceCapabilitiesKHR` for the surface
 16. `presentMode` must be one of the `VkPresentModeKHR` values returned by `vkGetPhysicalDeviceSurfacePresentModesKHR` for the surface
 17. If the logical device was created with `VkDeviceGroupDeviceCreateInfo::physicalDeviceCount` equal to 1, `flags` must not contain `VK_SWAPCHAIN_CREATE_SPLIT_INSTANCE_BIND_REGIONS_BIT_KHR`
 - [Handled by API design](#)
 18. If `oldSwapchain` is not `VK_NULL_HANDLE`, `oldSwapchain` must be a non-retired swapchain associated with native window referred to by `surface`
 - [Handled by API design](#)
 19. The implied image creation parameters of the swapchain must be supported as reported by `vkGetPhysicalDeviceImageFormatProperties`
 20. If `flags` contains `VK_SWAPCHAIN_CREATE_MUTABLE_FORMAT_BIT_KHR` then the `pNext` chain must include a `VkImageFormatListCreateInfo` structure with a `viewFormatCount` greater than zero and `pViewFormats` must have an element equal to `imageFormat`
 - [Handled by API design](#)
 21. If `flags` contains `VK_SWAPCHAIN_CREATE_PROTECTED_BIT_KHR`, then `VkSurfaceProtectedCapabilitiesKHR::supportsProtected` must be `VK_TRUE` in the `VkSurfaceProtectedCapabilitiesKHR` structure returned by `vkGetPhysicalDeviceSurfaceCapabilities2KHR` for `surface`
 - [Handled by API design](#)
 22. If the `pNext` chain includes a `VkSurfaceFullScreenExclusiveInfoEXT` structure with its `fullScreenExclusive` member set to `VK_FULL_SCREEN_EXCLUSIVE_APPLICATION_CONTROLLED_EXT`, and `surface` was created using `vkCreateWin32SurfaceKHR`, a `VkSurfaceFullScreenExclusiveWin32InfoEXT` structure must be included in the `pNext` chain
 - [Handled by API design](#)

Command buffer

Validations for `vkCreateCommandPool`:

1. `pCreateInfo->queueFamilyIndex` must be the index of a queue family available in the logical device `device`.
 - [Handled by API design](#)

Validations for `VkCommandPoolCreateInfo`:

1. If the protected memory feature is not enabled, the `VK_COMMAND_POOL_CREATE_PROTECTED_BIT` bit of `flags` must not be set.
 - [Handled by API design](#)

Validations for `VkCommandBufferAllocateInfo`:

1. commandBufferCount must be greater than 0
 - Guaranteed by the type system

Semaphore

Validations for VkSemaphoreTypeCreateInfo:

1. If the timelineSemaphore feature is not enabled, semaphoreType must not equal VK_SEMAPHORE_TYPE_TIMELINE
2. If semaphoreType is VK_SEMAPHORE_TYPE_BINARY, initialValue must be zero.
 - Handled by API design

Image

Validations for vkCreateImage:

1. If the flags member of pCreateInfo includes VK_IMAGE_CREATE_SPARSE_BINDING_BIT, creating this VkImage must not cause the total required sparse memory for all currently valid sparse resources on the device to exceed VkPhysicalDeviceLimits::sparseAddressSpaceSize

Validations for VkImageCreateInfo:

1. Each of the following values (as described in Image Creation Limits) must not be undefined imageCreateMaxMipLevels, imageCreateMaxArrayLayers, imageCreateMaxExtent, and imageCreateSampleCounts.

2. If `sharingMode` is `VK_SHARING_MODE_CONCURRENT`, `pQueueFamilyIndices` must be a valid pointer to an array of `queueFamilyIndexCount` `uint32_t` values
 - [Handled by API design](#)
3. If `sharingMode` is `VK_SHARING_MODE_CONCURRENT`, `queueFamilyIndexCount` must be greater than 1
 - [Handled by API design](#)
4. If `sharingMode` is `VK_SHARING_MODE_CONCURRENT`, each element of `pQueueFamilyIndices` must be unique and must be less than `pQueueFamilyPropertyCount` returned by either `vkGetPhysicalDeviceQueueFamilyProperties` or `vkGetPhysicalDeviceQueueFamilyProperties2` for the `physicalDevice` that was used to create device
 - [Lower bound handled by API design](#)
5. If the `pNext` chain includes a `VkExternalFormatANDROID` structure, and its `externalFormat` member is non-zero the `format` must be `VK_FORMAT_UNDEFINED`.
 - [Handled by API design](#)
6. If the `pNext` chain does not include a `VkExternalFormatANDROID` structure, or does and its `externalFormat` member is 0, the `format` must not be `VK_FORMAT_UNDEFINED`.
 - [Handled by API design](#)
7. `extent.width` must be greater than 0.
 - [Guaranteed by the type system](#)
8. `extent.height` must be greater than 0.
 - [Guaranteed by the type system](#)
9. `extent.depth` must be greater than 0.
 - [Guaranteed by the type system](#)
10. `mipLevels` must be greater than 0
 - [Guaranteed by the type system](#)
11. `arrayLayers` must be greater than 0
 - [Guaranteed by the type system](#)
12. If `flags` contains `VK_IMAGE_CREATE_CUBE_COMPATIBLE_BIT`, `imageType` must be `VK_IMAGE_TYPE_2D`
 - [Guaranteed by the type system](#)
13. If `flags` contains `VK_IMAGE_USAGE_FRAGMENT_DENSITY_MAP_BIT_EXT`, `imageType` must be `VK_IMAGE_TYPE_2D`
 - [Guaranteed by the type system](#)
14. If `flags` contains `VK_IMAGE_CREATE_2D_ARRAY_COMPATIBLE_BIT`, `imageType` must be `VK_IMAGE_TYPE_3D`
 - [Guaranteed by the type system](#)
15. `extent.width` must be less than or equal to `imageCreateMaxExtent.width` (as defined in Image Creation Limits).
16. `extent.height` must be less than or equal to `imageCreateMaxExtent.height` (as defined in Image Creation Limits).
17. `extent.depth` must be less than or equal to `imageCreateMaxExtent.depth` (as defined in Image Creation Limits).
18. If `imageType` is `VK_IMAGE_TYPE_2D` and `flags` contains `VK_IMAGE_CREATE_CUBE_COMPATIBLE_BIT`, `extent.width` and `extent.height` must be equal and `arrayLayers` must be greater than or equal to 6
 - [Guaranteed by the type system](#)
19. If `imageType` is `VK_IMAGE_TYPE_1D`, both `extent.height` and `extent.depth` must be 1
 - [Guaranteed by the type system](#)
20. If `imageType` is `VK_IMAGE_TYPE_2D`, `extent.depth` must be 1
 - [Guaranteed by the type system](#)
21. `mipLevels` must be less than or equal to the number of levels in the complete mipmap chain based on `extent.width`, `extent.height`, and `extent.depth`.
 - [Guaranteed by the type system](#)

22. `mipLevels` must be less than or equal to `imageCreateMaxMipLevels` (as defined in Image Creation Limits).
23. `arrayLayers` must be less than or equal to `imageCreateMaxArrayLayers` (as defined in Image Creation Limits).
24. If `imageType` is `VK_IMAGE_TYPE_3D`, `arrayLayers` must be 1.
 - [Guaranteed by the type system](#)
25. If `samples` is not `VK_SAMPLE_COUNT_1_BIT`, then `imageType` must be `VK_IMAGE_TYPE_2D`, `flags` must not contain `VK_IMAGE_CREATE_CUBE_COMPATIBLE_BIT`, `mipLevels` must be equal to 1, and `imageCreateMaybeLinear` (as defined in Image Creation Limits) must be `false`,
 - [Guaranteed by the type system](#)
26. If `samples` is not `VK_SAMPLE_COUNT_1_BIT`, `usage` must not contain `VK_IMAGE_USAGE_FRAGMENT_DENSITY_MAP_BIT_EXT`
 - [Guaranteed by the type system](#)
27. If `usage` includes `VK_IMAGE_USAGE_TRANSIENT_ATTACHMENT_BIT`, then bits other than `VK_IMAGE_USAGE_COLOR_ATTACHMENT_BIT`, `VK_IMAGE_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT`, and `VK_IMAGE_USAGE_INPUT_ATTACHMENT_BIT` must not be set
28. If `usage` includes `VK_IMAGE_USAGE_COLOR_ATTACHMENT_BIT`, `VK_IMAGE_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT`, `VK_IMAGE_USAGE_TRANSIENT_ATTACHMENT_BIT`, or `VK_IMAGE_USAGE_INPUT_ATTACHMENT_BIT`, `extent.width` must be less than or equal to `VkPhysicalDeviceLimits::maxFramebufferWidth`
29. If `usage` includes `VK_IMAGE_USAGE_COLOR_ATTACHMENT_BIT`, `VK_IMAGE_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT`, `VK_IMAGE_USAGE_TRANSIENT_ATTACHMENT_BIT`, or `VK_IMAGE_USAGE_INPUT_ATTACHMENT_BIT`, `extent.height` must be less than or equal to `VkPhysicalDeviceLimits::maxFramebufferHeight`
30. If `usage` includes `VK_IMAGE_USAGE_FRAGMENT_DENSITY_MAP_BIT_EXT`, `extent.width` must be less than or equal to $\lceil \frac{\text{maxFramebufferWidth}}{\text{minFragmentDensityTexelSize}_{\text{width}}} \rceil$
31. If `usage` includes `VK_IMAGE_USAGE_FRAGMENT_DENSITY_MAP_BIT_EXT`, `extent.height` must be less than or equal to $\lceil \frac{\text{maxFramebufferHeight}}{\text{minFragmentDensityTexelSize}_{\text{height}}} \rceil$
32. If `usage` includes `VK_IMAGE_USAGE_TRANSIENT_ATTACHMENT_BIT`, `usage` must also contain at least one of `VK_IMAGE_USAGE_COLOR_ATTACHMENT_BIT`, `VK_IMAGE_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT`, or `VK_IMAGE_USAGE_INPUT_ATTACHMENT_BIT`.
33. `samples` must be a bit value that is set in `imageCreateSampleCounts` (as defined in Image Creation Limits).
34. If the multisampled storage images feature is not enabled, and `usage` contains `VK_IMAGE_USAGE_STORAGE_BIT`, `samples` must be `VK_SAMPLE_COUNT_1_BIT`
35. If the sparse bindings feature is not enabled, `flags` must not contain `VK_IMAGE_CREATE_SPARSE_BINDING_BIT`
36. If the sparse aliased residency feature is not enabled, `flags` must not contain `VK_IMAGE_CREATE_SPARSE_ALIASED_BIT`
37. If `imageType` is `VK_IMAGE_TYPE_1D`, `flags` must not contain `VK_IMAGE_CREATE_SPARSE_RESIDENCY_BIT`
38. If the sparse residency for 2D images feature is not enabled, and `imageType` is `VK_IMAGE_TYPE_2D`, `flags` must not contain `VK_IMAGE_CREATE_SPARSE_RESIDENCY_BIT`
39. If the sparse residency for 3D images feature is not enabled, and `imageType` is `VK_IMAGE_TYPE_3D`, `flags` must not contain `VK_IMAGE_CREATE_SPARSE_RESIDENCY_BIT`
40. If the sparse residency for images with 2 samples feature is not enabled, `imageType` is `VK_IMAGE_TYPE_2D`, and `samples` is `VK_SAMPLE_COUNT_2_BIT`, `flags` must not contain `VK_IMAGE_CREATE_SPARSE_RESIDENCY_BIT`

41. If the sparse residency for images with 4 samples feature is not enabled, `imageType` is `VK_IMAGE_TYPE_2D`, and `samples` is `VK_SAMPLE_COUNT_4_BIT`, `flags` must not contain `VK_IMAGE_CREATE_SPARSE_RESIDENCY_BIT`
42. If the sparse residency for images with 8 samples feature is not enabled, `imageType` is `VK_IMAGE_TYPE_2D`, and `samples` is `VK_SAMPLE_COUNT_8_BIT`, `flags` must not contain `VK_IMAGE_CREATE_SPARSE_RESIDENCY_BIT`
43. If the sparse residency for images with 16 samples feature is not enabled, `imageType` is `VK_IMAGE_TYPE_2D`, and `samples` is `VK_SAMPLE_COUNT_16_BIT`, `flags` must not contain `VK_IMAGE_CREATE_SPARSE_RESIDENCY_BIT`
44. If `flags` contains `VK_IMAGE_CREATE_SPARSE_RESIDENCY_BIT` or `VK_IMAGE_CREATE_SPARSE_ALIASED_BIT`, it must also contain `VK_IMAGE_CREATE_SPARSE_BINDING_BIT`
45. If any of the bits `VK_IMAGE_CREATE_SPARSE_BINDING_BIT`, `VK_IMAGE_CREATE_SPARSE_RESIDENCY_BIT`, or `VK_IMAGE_CREATE_SPARSE_ALIASED_BIT` are set, `VK_IMAGE_USAGE_TRANSIENT_ATTACHMENT_BIT` must not also be set
46. If the protected memory feature is not enabled, `flags` must not contain `VK_IMAGE_CREATE_PROTECTED_BIT`.
47. If any of the bits `VK_IMAGE_CREATE_SPARSE_BINDING_BIT`, `VK_IMAGE_CREATE_SPARSE_RESIDENCY_BIT`, or `VK_IMAGE_CREATE_SPARSE_ALIASED_BIT` are set, `VK_IMAGE_CREATE_PROTECTED_BIT` must not also be set.
48. If the `pNext` chain includes a `VkExternalMemoryImageCreateInfoNV` structure, it must not contain a `VkExternalMemoryImageCreateInfo` structure.
 - [Handled by API design](#)
49. If the `pNext` chain includes a `VkExternalMemoryImageCreateInfo` structure, its `handleTypes` member must only contain bits that are also in `VkExternalImageFormatProperties::externalMemoryProperties.compatibleHandleTypes`, as returned by `vkGetPhysicalDeviceImageFormatProperties2` with `format`, `imageType`, `tiling`, `usage`, and `flags` equal to those in this structure, and with a `VkPhysicalDeviceExternalImageFormatInfo` structure included in the `pNext` chain, with a `handleType` equal to any one of the handle types specified in `VkExternalMemoryImageCreateInfo::handleTypes`
 - [Handled by API design](#)
50. If the `pNext` chain includes a `VkExternalMemoryImageCreateInfoNV` structure, its `handleTypes` member must only contain bits that are also in `VkExternalImageFormatPropertiesNV::externalMemoryProperties.compatibleHandleTypes`, as returned by `vkGetPhysicalDeviceExternalImageFormatPropertiesNV` with `format`, `imageType`, `tiling`, `usage`, and `flags` equal to those in this structure, and with `externalHandleType` equal to any one of the handle types specified in `VkExternalMemoryImageCreateInfoNV::handleTypes`
 - [Handled by API design](#)
51. If the logical device was created with `VkDeviceGroupDeviceCreateInfo::physicalDeviceCount` equal to 1, `flags` must not contain `VK_IMAGE_CREATE_SPLIT_INSTANCE_BIND_REGIONS_BIT`
52. If `flags` contains `VK_IMAGE_CREATE_SPLIT_INSTANCE_BIND_REGIONS_BIT`, then `mipLevels` must be one, `arrayLayers` must be one, `imageType` must be `VK_IMAGE_TYPE_2D`, and `imageCreateMaybeLinear` (as defined in Image Creation Limits) must be `false`.
53. If `flags` contains `VK_IMAGE_CREATE_BLOCK_TEXEL_VIEW_COMPATIBLE_BIT`, then `format` must be a block-compressed image format, an ETC compressed image format, or an ASTC compressed image format.
54. If `flags` contains `VK_IMAGE_CREATE_BLOCK_TEXEL_VIEW_COMPATIBLE_BIT`, then `flags` must also contain `VK_IMAGE_CREATE_MUTABLE_FORMAT_BIT`.
55. `initialLayout` must be `VK_IMAGE_LAYOUT_UNDEFINED` or `VK_IMAGE_LAYOUT_PREINITIALIZED`.
 - [Guaranteed by the type system](#)
56. If the `'pNext'` chain includes a `'VkExternalMemoryImageCreateInfo'` or `'VkExternalMemoryImageCreateInfoNV'`
 - [Handled by API design](#)

57. If the image `format` is one of those listed in Formats requiring sampler YCBCRconversion forVK_IMAGE_ASPECT_COLOR_BITimage views, then `mipLevels` must be 1
58. If the image `format` is one of those listed in Formats requiring sampler YCBCRconversion forVK_IMAGE_ASPECT_COLOR_BITimage views, `samples` must be VK_SAMPLE_COUNT_1_BIT
59. If the image `format` is one of those listed in Formats requiring sampler YCBCRconversion forVK_IMAGE_ASPECT_COLOR_BITimage views, `imageType` must be VK_IMAGE_TYPE_2D
60. If the image `format` is one of those listed in Formats requiring sampler YCBCRconversion forVK_IMAGE_ASPECT_COLOR_BITimage views, and the `ycbcrImageArrays` feature is not enabled, `arrayLayers` must be 1
61. If `format` is a *multi-planar* format, and if `imageCreateFormatFeatures` (as defined in Image Creation Limits) does not contain VK_FORMAT_FEATURE_DISJOINT_BIT, then `flags` must not contain VK_IMAGE_CREATE_DISJOINT_BIT
62. If `format` is not a *multi-planar* format, and `flags` does not include VK_IMAGE_CREATE_ALIAS_BIT, `flags` must not contain VK_IMAGE_CREATE_DISJOINT_BIT
63. If `tiling` is VK_IMAGE_TILING_DRM_FORMAT_MODIFIER_EXT, then the `pNext` chain must include exactly one of `VkImageDrmFormatModifierListCreateInfoEXT` or `VkImageDrmFormatModifierExplicitCreateInfoEXT` structures
64. If the `pNext` chain includes a `VkImageDrmFormatModifierListCreateInfoEXT` or `VkImageDrmFormatModifierExplicitCreateInfoEXT` structure, then `tiling` must be VK_IMAGE_TILING_DRM_FORMAT_MODIFIER_EXT
 - [Handled by API design](#)
65. If `tiling` is VK_IMAGE_TILING_DRM_FORMAT_MODIFIER_EXT and `flags` contains VK_IMAGE_CREATE_MUTABLE_FORMAT_BIT, then the `pNext` chain must include a `VkImageFormatListCreateInfo` structure with non-zero `viewFormatCount`.
66. If `flags` contains VK_IMAGE_CREATE_SAMPLE_LOCATIONS_COMPATIBLE_DEPTH_BIT_EXT `format` must be a depth or depth/stencil format
67. If the `pNext` chain includes a `VkExternalMemoryImageCreateInfo` structure whose `handleTypes` member includes VK_EXTERNAL_MEMORY_HANDLE_TYPE_ANDROID_HARDWARE_BUFFER_BIT_ANDROID, `imageType` must be VK_IMAGE_TYPE_2D.
 - [Handled by API design](#)
68. If the `pNext` chain includes a `VkExternalMemoryImageCreateInfo` structure whose `handleTypes` member includes VK_EXTERNAL_MEMORY_HANDLE_TYPE_ANDROID_HARDWARE_BUFFER_BIT_ANDROID, `mipLevels` must either be 1 or equal to the number of levels in the complete mipmap chain based on `extent.width`, `extent.height`, and `extent.depth`.
 - [Handled by API design](#)
69. If the `pNext` chain includes a `VkExternalFormatANDROID` structure whose `externalFormat` member is not 0, `flags` must not include VK_IMAGE_CREATE_MUTABLE_FORMAT_BIT.
 - [Handled by API design](#)
70. If the `pNext` chain includes a `VkExternalFormatANDROID` structure whose `externalFormat` member is not 0, `usage` must not include any usages except VK_IMAGE_USAGE_SAMPLED_BIT.
 - [Handled by API design](#)
71. If the `pNext` chain includes a `VkExternalFormatANDROID` structure whose `externalFormat` member is not 0, `tiling` must be VK_IMAGE_TILING_OPTIMAL.
 - [Handled by API design](#)
72. If `format` is a depth-stencil format, `usage` includes VK_IMAGE_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT, and the `pNext` chain includes a `VkImageStencilUsageCreateInfo` structure, then its `VkImageStencilUsageCreateInfo::stencilUsage` member must also include VK_IMAGE_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT
73. If `format` is a depth-stencil format, `usage` does not include VK_IMAGE_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT, and the `pNext` chain includes a

- VkImageStencilUsageCreateInfo structure, then its `VkImageStencilUsageCreateInfo::stencilUsage` member must also not include `VK_IMAGE_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT`
74. If `format` is a depth-stencil format, usage includes `VK_IMAGE_USAGE_TRANSIENT_ATTACHMENT_BIT`, and the `pNext` chain includes a `VkImageStencilUsageCreateInfo` structure, then its `VkImageStencilUsageCreateInfo::stencilUsage` member must also include `VK_IMAGE_USAGE_TRANSIENT_ATTACHMENT_BIT`
 75. If `format` is a depth-stencil format, usage does not include `VK_IMAGE_USAGE_TRANSIENT_ATTACHMENT_BIT`, and the `pNext` chain includes a `VkImageStencilUsageCreateInfo` structure, then its `VkImageStencilUsageCreateInfo::stencilUsage` member must also not include `VK_IMAGE_USAGE_TRANSIENT_ATTACHMENT_BIT`
 76. If `Format` is a depth-stencil format and the `pNext` chain includes a `VkImageStencilUsageCreateInfo` structure with its `stencilUsage` member including `VK_IMAGE_USAGE_INPUT_ATTACHMENT_BIT`, `extent.width` must be less than or equal to `VkPhysicalDeviceLimits::maxFramebufferWidth`
 77. If `format` is a depth-stencil format and the `pNext` chain includes a `VkImageStencilUsageCreateInfo` structure with its `stencilUsage` member including `VK_IMAGE_USAGE_INPUT_ATTACHMENT_BIT`, `extent.height` must be less than or equal to `VkPhysicalDeviceLimits::maxFramebufferHeight`
 78. If the multisampled storage images feature is not enabled, `format` is a depth-stencil format and the `pNext` chain includes a `VkImageStencilUsageCreateInfo` structure with its `stencilUsage` including `VK_IMAGE_USAGE_STORAGE_BIT`, `samples` must be `VK_SAMPLE_COUNT_1_BIT`
 79. If `flags` contains `VK_IMAGE_CREATE_CORNER_SAMPLED_BIT_NV`, `imageType` must be `VK_IMAGE_TYPE_2D` or `VK_IMAGE_TYPE_3D`
 80. If `flags` contains `VK_IMAGE_CREATE_CORNER_SAMPLED_BIT_NV`, it must not contain `VK_IMAGE_CREATE_CUBE_COMPATIBLE_BIT` and the `format` must not be a depth/stencil format
 81. If `flags` contains `VK_IMAGE_CREATE_CORNER_SAMPLED_BIT_NV` and `imageType` is `VK_IMAGE_TYPE_2D`, `extent.width` and `extent.height` must be greater than 1
 82. If `flags` contains `VK_IMAGE_CREATE_CORNER_SAMPLED_BIT_NV` and `imageType` is `VK_IMAGE_TYPE_3D`, `extent.width`, `extent.height`, and `extent.depth` must be greater than 1
 83. If `usage` includes `VK_IMAGE_USAGE_SHADING_RATE_IMAGE_BIT_NV`, `imageType` must be `VK_IMAGE_TYPE_2D`.
 84. If `usage` includes `VK_IMAGE_USAGE_SHADING_RATE_IMAGE_BIT_NV`, `samples` must be `VK_SAMPLE_COUNT_1_BIT`.
 85. If `usage` includes `VK_IMAGE_USAGE_SHADING_RATE_IMAGE_BIT_NV`, `tiling` must be `VK_IMAGE_TILING_OPTIMAL`.
 86. If `flags` contains `VK_IMAGE_CREATE_SUBSAMPLED_BIT_EXT`, `tiling` must be `VK_IMAGE_TILING_OPTIMAL`
 87. If `flags` contains `VK_IMAGE_CREATE_SUBSAMPLED_BIT_EXT`, `imageType` must be `VK_IMAGE_TYPE_2D`
 88. If `flags` contains `VK_IMAGE_CREATE_SUBSAMPLED_BIT_EXT`, `flags` must not contain `VK_IMAGE_CREATE_CUBE_COMPATIBLE_BIT`
 89. If `flags` contains `VK_IMAGE_CREATE_SUBSAMPLED_BIT_EXT`, `mipLevels` must be 1

Validations for `VkImageViewCreateInfo`:

1. If `image` was not created with `VK_IMAGE_CREATE_CUBE_COMPATIBLE_BIT` then `viewType` must not be `VK_IMAGE_VIEW_TYPE_CUBE` or `VK_IMAGE_VIEW_TYPE_CUBE_ARRAY`
2. If the image cubemap arrays feature is not enabled, `viewType` must not be `VK_IMAGE_VIEW_TYPE_CUBE_ARRAY`
3. If `image` was created with `VK_IMAGE_TYPE_3D` but without

- `VK_IMAGE_CREATE_2D_ARRAY_COMPATIBLE_BIT` set then `viewType` must not be `VK_IMAGE_VIEW_TYPE_2D` or `VK_IMAGE_VIEW_TYPE_2D_ARRAY`
4. `image` must have been created with a `usage` value containing at least one of `VK_IMAGE_USAGE_SAMPLED_BIT`, `VK_IMAGE_USAGE_STORAGE_BIT`, `VK_IMAGE_USAGE_COLOR_ATTACHMENT_BIT`, `VK_IMAGE_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT`, `VK_IMAGE_USAGE_INPUT_ATTACHMENT_BIT`, `VK_IMAGE_USAGE_SHADING_RATE_IMAGE_BIT_NV`, or `VK_IMAGE_USAGE_FRAGMENT_DENSITY_MAP_BIT_EXT`
 5. The format features of the resultant image view must contain at least one bit.
 6. If `usage` contains `VK_IMAGE_USAGE_SAMPLED_BIT`, then the format features of the resultant image view must contain `VK_FORMAT_FEATURE_SAMPLED_IMAGE_BIT`.
 7. If `usage` contains `VK_IMAGE_USAGE_STORAGE_BIT`, then the image view's format features must contain `VK_FORMAT_FEATURE_STORAGE_IMAGE_BIT`.
 8. If `usage` contains `VK_IMAGE_USAGE_COLOR_ATTACHMENT_BIT`, then the image view's format features must contain `VK_FORMAT_FEATURE_COLOR_ATTACHMENT_BIT`.
 9. If `usage` contains `VK_IMAGE_USAGE_DEPTH_STENCIL_ATTACHMENT_BIT`, then the image view's format features must contain `VK_FORMAT_FEATURE_DEPTH_STENCIL_ATTACHMENT_BIT`.
 10. If `usage` contains `VK_IMAGE_USAGE_INPUT_ATTACHMENT_BIT`, then the image view's format features must contain at least one of `VK_FORMAT_FEATURE_COLOR_ATTACHMENT_BIT` or `VK_FORMAT_FEATURE_DEPTH_STENCIL_ATTACHMENT_BIT`.
 11. `subresourceRange.baseMipLevel` must be less than the `mipLevels` specified in `VkImageCreateInfo` when `image` was created
 12. If `subresourceRange.levelCount` is not `VK_REMAINING_MIP_LEVELS`, `subresourceRange.baseMipLevel+subresourceRange.levelCount` must be less than or equal to the `mipLevels` specified in `VkImageCreateInfo` when `image` was created
 13. If `image` was created with `usage` containing `VK_IMAGE_USAGE_FRAGMENT_DENSITY_MAP_BIT_EXT`, `subresourceRange.levelCount` must be 1
 14. If `image` is not a 3D image created with `VK_IMAGE_CREATE_2D_ARRAY_COMPATIBLE_BIT` set, or `viewType` is not `VK_IMAGE_VIEW_TYPE_2D` or `VK_IMAGE_VIEW_TYPE_2D_ARRAY`, `subresourceRange.baseArrayLayer` must be less than the `arrayLayers` specified in `VkImageCreateInfo` when `image` was created
 15. If `subresourceRange.layerCount` is not `VK_REMAINING_ARRAY_LAYERS`, `image` is not a 3D image created with `VK_IMAGE_CREATE_2D_ARRAY_COMPATIBLE_BIT` set, or `viewType` is not `VK_IMAGE_VIEW_TYPE_2D` or `VK_IMAGE_VIEW_TYPE_2D_ARRAY`, `subresourceRange.layerCount` must be non-zero and `subresourceRange.baseArrayLayer+subresourceRange.layerCount` must be less than or equal to the `arrayLayers` specified in `VkImageCreateInfo` when `image` was created
 16. If `image` is a 3D image created with `VK_IMAGE_CREATE_2D_ARRAY_COMPATIBLE_BIT` set, and `viewType` is `VK_IMAGE_VIEW_TYPE_2D` or `VK_IMAGE_VIEW_TYPE_2D_ARRAY`, `subresourceRange.baseArrayLayer` must be less than the depth computed from `baseMipLevel` and `extent.depth` specified in `VkImageCreateInfo` when `image` was created, according to the formula defined in Image Miplevel Sizing.
 17. If `subresourceRange.layerCount` is not `VK_REMAINING_ARRAY_LAYERS`, `image` is a 3D image created with `VK_IMAGE_CREATE_2D_ARRAY_COMPATIBLE_BIT` set, and `viewType` is `VK_IMAGE_VIEW_TYPE_2D` or `VK_IMAGE_VIEW_TYPE_2D_ARRAY`, `subresourceRange.layerCount` must be non-zero and `subresourceRange.baseArrayLayer+subresourceRange.layerCount` must be less than or equal to the depth computed from `baseMipLevel` and `extent.depth` specified in `VkImageCreateInfo` when `image` was created, according to the formula defined in Image Miplevel Sizing.
 18. If `image` was created with the `VK_IMAGE_CREATE_MUTABLE_FORMAT_BIT` flag, but without the `VK_IMAGE_CREATE_BLOCK_TEXEL_VIEW_COMPATIBLE_BIT` flag, and if the `format` of the `image` is not a multi-planar format, `format` must be compatible with the `format` used to create `image`, as defined in Format Compatibility Classes

19. If `image` was created with the `VK_IMAGE_CREATE_BLOCK_TEXEL_VIEW_COMPATIBLE_BIT` flag, `format` must be compatible with, or must be an uncompressed format that is size-compatible with, the `format` used to create `image`.
20. If `image` was created with the `VK_IMAGE_CREATE_BLOCK_TEXEL_VIEW_COMPATIBLE_BIT` flag, the `levelCount` and `layerCount` members of `subresourceRange` must both be 1.
21. If a `VkImageFormatListCreateInfo` structure was included in the `pNext` chain of the `VkImageCreateInfo` structure used when creating `image` and the `viewFormatCount` field of `VkImageFormatListCreateInfo` is not zero then `format` must be one of the formats in `VkImageFormatListCreateInfo::pViewFormats`.
22. If `image` was created with the `VK_IMAGE_CREATE_MUTABLE_FORMAT_BIT` flag, if the `format` of the `image` is a multi-planar format, and if `subresourceRange.aspectMask` is one of `VK_IMAGE_ASPECT_PLANE_0_BIT`, `VK_IMAGE_ASPECT_PLANE_1_BIT`, or `VK_IMAGE_ASPECT_PLANE_2_BIT`, then `format` must be compatible with the `VkFormat` for the plane of the `image` format indicated by `subresourceRange.aspectMask`, as defined in Compatible formats of planes of multi-planar formats
23. If `image` was not created with the `VK_IMAGE_CREATE_MUTABLE_FORMAT_BIT` flag, or if the `format` of the `image` is a multi-planar format and if `subresourceRange.aspectMask` is `VK_IMAGE_ASPECT_COLOR_BIT`, `format` must be identical to the `format` used to create `image`
24. If the `pNext` chain includes a `VkSamplerYcbcrConversionInfo` structure with a `conversion` value other than `VK_NULL_HANDLE`, all members of `components` must have the value `VK_COMPONENT_SWIZZLE_IDENTITY`.
25. If `image` is non-sparse then it must be bound completely and contiguously to a single `VkDeviceMemory` object
26. `subresourceRange` and `viewType` must be compatible with the `image`, as described in the compatibility table
27. If `image` has an external format, `format` must be `VK_FORMAT_UNDEFINED`.
28. If `image` has an external format, the `pNext` chain must include a `VkSamplerYcbcrConversionInfo` structure with a `conversion` object created with the same external format as `image`.
29. If `image` has an external format, all members of `components` must be `VK_COMPONENT_SWIZZLE_IDENTITY`.
30. If `image` was created with `usage` containing `VK_IMAGE_USAGE_SHADING_RATE_IMAGE_BIT_NV`, `viewType` must be `VK_IMAGE_VIEW_TYPE_2D` or `VK_IMAGE_VIEW_TYPE_2D_ARRAY`
31. If `image` was created with `usage` containing `VK_IMAGE_USAGE_SHADING_RATE_IMAGE_BIT_NV`, `format` must be `VK_FORMAT_R8_UINT`
32. If dynamic fragment density map feature is not enabled, `flags` must not contain `VK_IMAGE_VIEW_CREATE_FRAGMENT_DENSITY_MAP_DYNAMIC_BIT_EXT`
33. If dynamic fragment density map feature is not enabled and `image` was created with `usage` containing `VK_IMAGE_USAGE_FRAGMENT_DENSITY_MAP_BIT_EXT`, `flags` must not contain any of `VK_IMAGE_CREATE_PROTECTED_BIT`, `VK_IMAGE_CREATE_SPARSE_BINDING_BIT`, `VK_IMAGE_CREATE_SPARSE_RESIDENCY_BIT`, or `VK_IMAGE_CREATE_SPARSE_ALIASED_BIT`
34. If the `pNext` chain includes a `VkImageViewUsageCreateInfo` structure, and `image` was not created with a `VkImageStencilUsageCreateInfo` structure included in the `pNext` chain of `VkImageCreateInfo`, its `usage` member must not include any bits that were not set in the `usage` member of the `VkImageCreateInfo` structure used to create `image`

35. If the `pNext` chain includes a `VkImageViewUsageCreateInfo` structure, image was created with a `VkImageStencilUsageCreateInfo` structure included in the `pNext` chain of `VkImageCreateInfo`, and `subResourceRange.aspectMask` includes `VK_IMAGE_ASPECT_STENCIL_BIT`, the `usage` member of the `VkImageViewUsageCreateInfo` instance must not include any bits that were not set in the `usage` member of the `VkImageStencilUsageCreateInfo` structure used to create image
 - [Handled by API design](#)
36. If the `pNext` chain includes a `VkImageViewUsageCreateInfo` structure, image was created with a `VkImageStencilUsageCreateInfo` structure included in the `pNext` chain of `VkImageCreateInfo`, and `subResourceRange.aspectMask` includes bits other than `VK_IMAGE_ASPECT_STENCIL_BIT`, the `usage` member of the `VkImageViewUsageCreateInfo` structure must not include any bits that were not set in the `usage` member of the `VkImageCreateInfo` structure used to create image
 - [Handled by API design](#)
37. If `viewType` is `VK_IMAGE_VIEW_TYPE_CUBE` and `subresourceRange.layerCount` is not `VK_REMAINING_ARRAY_LAYERS`, `subresourceRange.layerCount` must be 6
 - [Handled by API design](#)
38. If `viewType` is `VK_IMAGE_VIEW_TYPE_CUBE_ARRAY` and `subresourceRange.layerCount` is not `VK_REMAINING_ARRAY_LAYERS`, `subresourceRange.layerCount` must be a multiple of 6
39. If `viewType` is `VK_IMAGE_VIEW_TYPE_CUBE` and `subresourceRange.layerCount` is `VK_REMAINING_ARRAY_LAYERS`, the remaining number of layers must be 6
40. If `viewType` is `VK_IMAGE_VIEW_TYPE_CUBE_ARRAY` and `subresourceRange.layerCount` is `VK_REMAINING_ARRAY_LAYERS`, the remaining number of layers must be a multiple of 6

Validations for `VkImageSubresourceRange`:

1. If `levelCount` is not `VK_REMAINING_MIP_LEVELS`, it must be greater than 0
 - [Guaranteed by the type system](#)
2. If `layerCount` is not `VK_REMAINING_ARRAY_LAYERS`, it must be greater than 0
 - [Guaranteed by the type system](#)
3. If `aspectMask` includes `VK_IMAGE_ASPECT_COLOR_BIT`, then it must not include any of `VK_IMAGE_ASPECT_PLANE_0_BIT`, `VK_IMAGE_ASPECT_PLANE_1_BIT`, or `VK_IMAGE_ASPECT_PLANE_2_BIT`
4. `aspectMask` must not include `VK_IMAGE_ASPECT_MEMORY_PLANE_i_BIT_EXT` for any index `i`

Buffer

Validations for `vkCreateBuffer`:

1. If the `flags` member of `pCreateInfo` includes `VK_BUFFER_CREATE_SPARSE_BINDING_BIT`, creating this `VkBuffer` must not cause the total required sparse memory for all currently valid sparse resources on the device to exceed `VkPhysicalDeviceLimits::sparseAddressSpaceSize`

Validations for `VkBufferCreateInfo`:

1. size must be greater than 0
 - [Guaranteed by the type system](#)
2. If sharingMode is VK_SHARING_MODE_CONCURRENT, pQueueFamilyIndices must be a valid pointer to an array of queueFamilyIndexCount uint32_t values
 - [Handled by API design](#)
3. If sharingMode is VK_SHARING_MODE_CONCURRENT, queueFamilyIndexCount must be greater than 1
 - [Handled by API design](#)
4. If sharingMode is VK_SHARING_MODE_CONCURRENT, each element of pQueueFamilyIndices must be unique and must be less than pQueueFamilyPropertyCount returned by either vkGetPhysicalDeviceQueueFamilyProperties or vkGetPhysicalDeviceQueueFamilyProperties2 for the physicalDevice that was used to create device
 - [Handled by API design](#)
5. If the sparse bindings feature is not enabled, flags must not contain VK_BUFFER_CREATE_SPARSE_BINDING_BIT
6. If the sparse buffer residency feature is not enabled, flags must not contain VK_BUFFER_CREATE_SPARSE_RESIDENCY_BIT
7. If the sparse aliased residency feature is not enabled, flags must not contain VK_BUFFER_CREATE_SPARSE_ALIASED_BIT
8. If flags contains VK_BUFFER_CREATE_SPARSE_RESIDENCY_BIT or VK_BUFFER_CREATE_SPARSE_ALIASED_BIT, it must also contain VK_BUFFER_CREATE_SPARSE_BINDING_BIT
9. If the pNext chain includes a VkExternalMemoryBufferCreateInfo structure, its handleTypes member must only contain bits that are also in VkExternalBufferProperties::externalMemoryProperties.compatibleHandleTypes, as returned by vkGetPhysicalDeviceExternalBufferProperties with pExternalBufferInfo->handleType equal to any one of the handle types specified in VkExternalMemoryBufferCreateInfo::handleTypes
10. If the protected memory feature is not enabled, flags must not contain VK_BUFFER_CREATE_PROTECTED_BIT
11. If any of the bits VK_BUFFER_CREATE_SPARSE_BINDING_BIT, VK_BUFFER_CREATE_SPARSE_RESIDENCY_BIT, or VK_BUFFER_CREATE_SPARSE_ALIASED_BIT are set, VK_BUFFER_CREATE_PROTECTED_BIT must not also be set
12. If the pNext chain includes a VkDedicatedAllocationBufferCreateInfoNV structure, and the dedicatedAllocation member of the chained structure is VK_TRUE, then flags must not include VK_BUFFER_CREATE_SPARSE_BINDING_BIT, VK_BUFFER_CREATE_SPARSE_RESIDENCY_BIT, or VK_BUFFER_CREATE_SPARSE_ALIASED_BIT
13. If VkBufferDeviceAddressCreateInfoEXT::deviceAddress is not zero, flags must include VK_BUFFER_CREATE_DEVICE_ADDRESS_CAPTURE_REPLAY_BIT
14. If VkBufferOpaqueCaptureAddressCreateInfo::opaqueCaptureAddress is not zero, flags must include VK_BUFFER_CREATE_DEVICE_ADDRESS_CAPTURE_REPLAY_BIT
15. If flags includes VK_BUFFER_CREATE_DEVICE_ADDRESS_CAPTURE_REPLAY_BIT, the bufferDeviceAddressCaptureReplay or VkPhysicalDeviceBufferDeviceAddressFeaturesEXT :: bufferDeviceAddressCaptureReplay feature must be enabled

Validations for VkBufferViewCreateInfo:

1. offset must be less than the size of buffer
2. If range is not equal to VK_WHOLE_SIZE, range must be greater than 0
 - [Guaranteed by the type system](#)
3. If range is not equal to VK_WHOLE_SIZE, range must be an integer multiple of the texel block size of format

4. If `range` is not equal to `VK_WHOLE_SIZE`, `range` divided by the texel block size of `format`, multiplied by the number of texels per texel block for that format (as defined in the Compatible Formats table), must be less than or equal to `VkPhysicalDeviceLimits::maxTexelBufferElements`
5. If `range` is not equal to `VK_WHOLE_SIZE`, the sum of `offset` and `range` must be less than or equal to the size of `buffer`
6. `buffer` must have been created with a `usage` value containing at least one of `VK_BUFFER_USAGE_UNIFORM_TEXEL_BUFFER_BIT` or `VK_BUFFER_USAGE_STORAGE_TEXEL_BUFFER_BIT`
7. If `buffer` was created with `usage` containing `VK_BUFFER_USAGE_UNIFORM_TEXEL_BUFFER_BIT`, `format` must be supported for uniform texel buffers, as specified by the `VK_FORMAT_FEATURE_UNIFORM_TEXEL_BUFFER_BIT` flag in `VkFormatProperties::bufferFeatures` returned by `vkGetPhysicalDeviceFormatProperties`
8. If `buffer` was created with `usage` containing `VK_BUFFER_USAGE_STORAGE_TEXEL_BUFFER_BIT`, `format` must be supported for storage texel buffers, as specified by the `VK_FORMAT_FEATURE_STORAGE_TEXEL_BUFFER_BIT` flag in `VkFormatProperties::bufferFeatures` returned by `vkGetPhysicalDeviceFormatProperties`
9. If `buffer` is non-sparse then it must be bound completely and contiguously to a single `VkDeviceMemory` object
10. If the `texelBufferAlignment` feature is not enabled, `offset` must be a multiple of `VkPhysicalDeviceLimits::minTexelBufferOffsetAlignment`
11. If the `texelBufferAlignment` feature is enabled and if `buffer` was created with `usage` containing `VK_BUFFER_USAGE_STORAGE_TEXEL_BUFFER_BIT`, `offset` must be a multiple of the lesser of `VkPhysicalDeviceTexelBufferAlignmentPropertiesEXT::storageTexelBufferOffsetAlignmentBytes` or, if `VkPhysicalDeviceTexelBufferAlignmentPropertiesEXT::storageTexelBufferOffsetSingleTexelAlignment` is `VK_TRUE`, the size of a texel of the requested `format`. If the size of a texel is a multiple of three bytes, then the size of a single component of `format` is used instead
12. If the `texelBufferAlignment` feature is enabled and if `buffer` was created with `usage` containing `VK_BUFFER_USAGE_UNIFORM_TEXEL_BUFFER_BIT`, `offset` must be a multiple of the lesser of `VkPhysicalDeviceTexelBufferAlignmentPropertiesEXT::uniformTexelBufferOffsetAlignmentBytes` or, if `VkPhysicalDeviceTexelBufferAlignmentPropertiesEXT::uniformTexelBufferOffsetSingleTexelAlignment` is `VK_TRUE`, the size of a texel of the requested `format`. If the size of a texel is a multiple of three bytes, then the size of a single component of `format` is used instead

Descriptor

Validations for `VkDescriptorSetLayoutCreateInfo`:

1. The `VkDescriptorSetLayoutBinding::binding` members of the elements of the `pBindings` array must each have different values.
 - Handled by API design
2. If `flags` contains `VK_DESCRIPTOR_SET_LAYOUT_CREATE_PUSH_DESCRIPTOR_BIT_KHR`, then all elements of `pBindings` must not have a `descriptorType` of `VK_DESCRIPTOR_TYPE_UNIFORM_BUFFER_DYNAMIC` or `VK_DESCRIPTOR_TYPE_STORAGE_BUFFER_DYNAMIC`
3. If `flags` contains `VK_DESCRIPTOR_SET_LAYOUT_CREATE_PUSH_DESCRIPTOR_BIT_KHR`, then all elements of `pBindings` must not have a `descriptorType` of

- `VK_DESCRIPTOR_TYPE_INLINE_UNIFORM_BLOCK_EXT`
4. If `flags` contains `VK_DESCRIPTOR_SET_LAYOUT_CREATE_PUSH_DESCRIPTOR_BIT_KHR`, then the total number of elements of all bindings must be less than or equal to `VkPhysicalDevicePushDescriptorPropertiesKHR::maxPushDescriptors`
 5. If any binding has the `VK_DESCRIPTOR_BINDING_UPDATE_AFTER_BIND_BIT` bit set, `flags` must include `VK_DESCRIPTOR_SET_LAYOUT_CREATE_UPDATE_AFTER_BIND_POOL_BIT`
 6. If any binding has the `VK_DESCRIPTOR_BINDING_UPDATE_AFTER_BIND_BIT` bit set, then all bindings must not have `descriptorType` of `VK_DESCRIPTOR_TYPE_UNIFORM_BUFFER_DYNAMIC` or `VK_DESCRIPTOR_TYPE_STORAGE_BUFFER_DYNAMIC`

Validations for `VkDescriptorSetLayoutBinding`:

1. If `descriptorType` is `VK_DESCRIPTOR_TYPE_SAMPLER` or `VK_DESCRIPTOR_TYPE_COMBINED_IMAGE_SAMPLER`, and `descriptorCount` is not 0 and `pImmutableSamplers` is not `NULL`, `pImmutableSamplers` must be a valid pointer to an array of `descriptorCount` valid `VkSampler` handles
 - [Handled by API design](#)
2. If `descriptorType` is `VK_DESCRIPTOR_TYPE_INLINE_UNIFORM_BLOCK_EXT` then `descriptorCount` must be a multiple of 4
 - [Handled by API design](#)
3. If `descriptorType` is `VK_DESCRIPTOR_TYPE_INLINE_UNIFORM_BLOCK_EXT` then `descriptorCount` must be less than or equal to `VkPhysicalDeviceInlineUniformBlockPropertiesEXT::maxInlineUniformBlockSize`
4. If `descriptorCount` is not 0, `stageFlags` must be a valid combination of `VkShaderStageFlagBits` values
5. If `descriptorType` is `VK_DESCRIPTOR_TYPE_INPUT_ATTACHMENT` and `descriptorCount` is not 0, then `stageFlags` must be 0 or `VK_SHADER_STAGE_FRAGMENT_BIT`
 - [Handled by API design](#)

Pipeline

Validations for `vkCreatePipelineLayout`:

Usage validations

Validations of correct usage in other functions as dictated by the Vulkan specification.

Queue

Validations for `vkGetDeviceQueue`:

1. `queueFamilyIndex` must be one of the queue family indices specified when `device` was created, via the `VkDeviceQueueCreateInfo` structure
 - [Handled by API design](#)
2. `queueIndex` must be less than the number of queues created for the specified queue family index when `device` was created, via the `queueCount` member of the `VkDeviceQueueCreateInfo` structure
 - [Handled by API design](#)
3. `VkDeviceQueueCreateInfo::flags` must have been set to zero when `device` was created
 - [Handled by API design](#)

Validations for `vkGetDeviceQueue2`:

Validations for vkQueueSubmit:

1. If `fence` is not `VK_NULL_HANDLE`, `fence` must be unsigned
2. If `fence` is not `VK_NULL_HANDLE`, `fence` must not be associated with any other queue command that has not yet completed execution on that queue
3. Any calls to `vkCmdSetEvent`, `vkCmdResetEvent` or `vkCmdWaitEvents` that have been recorded into any of the command buffer elements of the `pCommandBuffers` member of any element of `pSubmits`, must not reference any `VkEvent` that is referenced by any of those commands in a command buffer that has been submitted to another queue and is still in the *pending state*
4. Any stage flag included in any element of the `pWaitDstStageMask` member of any element of `pSubmits` must be a pipeline stage supported by one of the capabilities of `queue`, as specified in the table of supported pipeline stages
5. Each element of the `pSignalSemaphores` member of any element of `pSubmits` must be unsignaled when the semaphore signal operation it defines is executed on the device
6. When a semaphore wait operation referring to a binary semaphore defined by any element of the `pWaitSemaphores` member of any element of `pSubmits` executes on `queue`, there must be no other queues waiting on the same semaphore
7. All elements of the `pWaitSemaphores` member of all elements of `pSubmits` created with a `VkSemaphoreType` of `VK_SEMAPHORE_TYPE_BINARY` must reference a semaphore signal operation that has been submitted for execution and any semaphore signal operations on which it depends (if any) must have also been submitted for execution
8. Each element of the `pCommandBuffers` member of each element of `pSubmits` must be in the pending or executable state
9. If any element of the `pCommandBuffers` member of any element of `pSubmits` was not recorded with the `VK_COMMAND_BUFFER_USAGE_SIMULTANEOUS_USE_BIT`, it must not be in the pending state
10. Any secondary command buffers recorded into any element of the `pCommandBuffers` member of any element of `pSubmits` must be in the pending or executable state
11. If any secondary command buffers recorded into any element of the `pCommandBuffers` member of any element of `pSubmits` was not recorded with the `VK_COMMAND_BUFFER_USAGE_SIMULTANEOUS_USE_BIT`, it must not be in the pending state
12. Each element of the `pCommandBuffers` member of each element of `pSubmits` must have been allocated from a `VkCommandPool` that was created for the same queue family `queue` belongs to
 - Returns error
13. If any element of `pSubmits`→`pCommandBuffers` includes a Queue Family Transfer Acquire Operation, there must exist a previously submitted Queue Family Transfer Release Operation on a queue in the queue family identified by the acquire operation, with parameters matching the acquire operation as defined in the definition of such acquire operations, and which happens-before the acquire operation
14. If a command recorded into any element of `pCommandBuffers` was a `vkCmdBeginQuery` whose `queryPool` was created with a `queryType` of `VK_QUERY_TYPE_PERFORMANCE_QUERY_KHR`, the profiling lock must have been held continuously on the `VkDevice` that `queue` was retrieved from, throughout recording of those command buffers
15. Any resource created with `VK_SHARING_MODE_EXCLUSIVE` that is read by an operation specified by `pSubmits` must not be owned by any queue family other than the one which `queue` belongs to, at the time it is executed

Validations for VkSubmitInfo:

1. Each element of `pCommandBuffers` must not have been allocated with `VK_COMMAND_BUFFER_LEVEL_SECONDARY`
2. If the geometry shaders feature is not enabled, each element of `pWaitDstStageMask` must not contain `VK_PIPELINE_STAGE_GEOMETRY_SHADER_BIT`
3. If the tessellation shaders feature is not enabled, each element of `pWaitDstStageMask` must not contain `VK_PIPELINE_STAGE_TESSELLATION_CONTROL_SHADER_BIT` or

- `VK_PIPELINE_STAGE_TESSELLATION_EVALUATION_SHADER_BIT`
4. Each element of `pWaitDstStageMask` must not include `VK_PIPELINE_STAGE_HOST_BIT`.
 5. If any element of `pWaitSemaphores` or `pSignalSemaphores` was created with a `VkSemaphoreType` of `VK_SEMAPHORE_TYPE_TIMELINE`, then the `pNext` chain must include a `VkTimelineSemaphoreSubmitInfo` structure
 6. If the `pNext` chain of this structure includes a `VkTimelineSemaphoreSubmitInfo` structure and any element of `pWaitSemaphores` was created with a `VkSemaphoreType` of `VK_SEMAPHORE_TYPE_TIMELINE`, then its `waitSemaphoreValueCount` member must equal `waitSemaphoreCount`
 7. If the `pNext` chain of this structure includes a `VkTimelineSemaphoreSubmitInfo` structure and any element of `pSignalSemaphores` was created with a `VkSemaphoreType` of `VK_SEMAPHORE_TYPE_TIMELINE`, then its `signalSemaphoreValueCount` member must equal `signalSemaphoreCount`
 8. For each element of `pSignalSemaphores` created with a `VkSemaphoreType` of `VK_SEMAPHORE_TYPE_TIMELINE` the corresponding element of `VkTimelineSemaphoreSubmitInfo::pSignalSemaphoreValues` must have a value greater than the current value of the semaphore when the semaphore signal operation is executed
 9. For each element of `pWaitSemaphores` created with a `VkSemaphoreType` of `VK_SEMAPHORE_TYPE_TIMELINE` the corresponding element of `VkTimelineSemaphoreSubmitInfo::pWaitSemaphoreValues` must have a value which does not differ from the current value of the semaphore or the value of any outstanding semaphore wait or signal operation on that semaphore by more than `maxTimelineSemaphoreValueDifference`.
 10. For each element of `pSignalSemaphores` created with a `VkSemaphoreType` of `VK_SEMAPHORE_TYPE_TIMELINE` the corresponding element of `VkTimelineSemaphoreSubmitInfo::pSignalSemaphoreValues` must have a value which does not differ from the current value of the semaphore or the value of any outstanding semaphore wait or signal operation on that semaphore by more than `maxTimelineSemaphoreValueDifference`.
 11. If the mesh shaders feature is not enabled, each element of `pWaitDstStageMask` must not contain `VK_PIPELINE_STAGE_MESH_SHADER_BIT_NV`
 12. If the task shaders feature is not enabled, each element of `pWaitDstStageMask` must not contain `VK_PIPELINE_STAGE_TASK_SHADER_BIT_NV`

Swapchain

Validations for `vkAcquireNextImageKHR`:

1. `swapchain` must not be in the retired state
2. If `semaphore` is not `VK_NULL_HANDLE` it must be unsignaled
3. If `semaphore` is not `VK_NULL_HANDLE` it must not have any uncompleted signal or wait operations pending
4. If `fence` is not `VK_NULL_HANDLE` it must be unsignaled and must not be associated with any other queue command that has not yet completed execution on that queue
5. `semaphore` and `fence` must not both be equal to `VK_NULL_HANDLE`
 - Handled by API design
6. If the number of currently acquired images is greater than the difference between the number of images in `swapchain` and the value of `VkSurfaceCapabilitiesKHR::minImageCount` as returned by a call to `vkGetPhysicalDeviceSurfaceCapabilities2KHR` with the `surface` used to create `swapchain`, `timeout` must not be `UINT64_MAX`
7. `semaphore` must have a `VkSemaphoreType` of `VK_SEMAPHORE_TYPE_BINARY`
 - Guaranteed by the type system

Validations for `vkQueuePresentKHR`:

1. Each element of `pSwapchains` member of `pPresentInfo` must be a swapchain that is created for a surface for which presentation is supported from `queue` as determined using a call to `vkGetPhysicalDeviceSurfaceSupportKHR`
2. If more than one member of `pSwapchains` was created from a display surface, all display surfaces referenced that refer to the same display must use the same display mode
3. When a semaphore wait operation referring to a binary semaphore defined by the elements of the `pWaitSemaphores` member of `pPresentInfo` executes on `queue`, there must be no other queues waiting on the same semaphore.
4. All elements of the `pWaitSemaphores` member of `pPresentInfo` must be semaphores that are signaled, or have semaphore signal operations previously submitted for execution.
5. All elements of the `pWaitSemaphores` member of `pPresentInfo` must be created with a `VkSemaphoreType` of `VK_SEMAPHORE_TYPE_BINARY`.
 - [Handled by API design](#)
6. All elements of the `pWaitSemaphores` member of `pPresentInfo` must reference a semaphore signal operation that has been submitted for execution and any semaphore signal operations on which it depends (if any) must have also been submitted for execution.

Validations for `VkPresentInfoKHR`:

1. Each element of `pImageIndices` must be the index of a presentable image acquired from the swapchain specified by the corresponding element of the `pSwapchains` array, and the presented image subresource must be in the `VK_IMAGE_LAYOUT_PRESENT_SRC_KHR` or `VK_IMAGE_LAYOUT_SHARED_PRESENT_KHR` layout at the time the operation is executed on a `VkDevice`
 - [Guaranteed by the type system](#)
2. All elements of the `pWaitSemaphores` must have a `VkSemaphoreType` of `VK_SEMAPHORE_TYPE_BINARY`

Fence

Validations for `vkResetFences`:

1. Each element of `pFences` must not be currently associated with any queue command that has not yet completed execution on that queue

Image

Validations for `vkBindImageMemory`:

1. `image` must not have been created with the `VK_IMAGE_CREATE_DISJOINT_BIT` set.
2. `image` must not already be backed by a memory object
 - [Handled by API design](#)
3. `image` must not have been created with any sparse memory binding flags

4. `memoryOffset` must be less than the size of `memory`
 - [Handled by API design](#)
5. `memory` must have been allocated using one of the memory types allowed in the `memoryTypeBits` member of the `VkMemoryRequirements` structure returned from a call to `vkGetImageMemoryRequirements` with `image`
 - [Handled by API design](#)
6. `memoryOffset` must be an integer multiple of the `alignment` member of the `VkMemoryRequirements` structure returned from a call to `vkGetImageMemoryRequirements` with `image`
 - [Handled by API design](#)
7. The difference of the size of `memory` and `memoryOffset` must be greater than or equal to the `size` member of the `VkMemoryRequirements` structure returned from a call to `vkGetImageMemoryRequirements` with the same `image`
 - [Handled by API design](#)
8. If `image` requires a dedicated allocation (as reported by `vkGetImageMemoryRequirements2` in `VkMemoryDedicatedRequirements::requiresDedicatedAllocation` for `image`), `memory` must have been created with `VkMemoryDedicatedAllocateInfo::image` equal to `image`
9. If the dedicated allocation image aliasing feature is not enabled, and the `VkMemoryAllocateInfo` provided when `memory` was allocated included a `VkMemoryDedicatedAllocateInfo` structure in its `pNext` chain, and `VkMemoryDedicatedAllocateInfo::image` was not `VK_NULL_HANDLE`, then `image` must equal `VkMemoryDedicatedAllocateInfo::image` and `memoryOffset` must be zero.
10. If the dedicated allocation image aliasing feature is enabled, and the `VkMemoryAllocateInfo` provided when `memory` was allocated included a `VkMemoryDedicatedAllocateInfo` structure in its `pNext` chain, and `VkMemoryDedicatedAllocateInfo::image` was not `VK_NULL_HANDLE`, then `memoryOffset` must be zero, and `image` must be either equal to `VkMemoryDedicatedAllocateInfo::image` or an image that was created using the same parameters in `VkImageCreateInfo`, with the exception that `extent` and `arrayLayers` may differ subject to the following restrictions: every dimension in the `extent` parameter of the image being bound must be equal to or smaller than the original image for which the allocation was created; and the `arrayLayers` parameter of the image being bound must be equal to or smaller than the original image for which the allocation was created.
11. If `image` was created with the `VK_IMAGE_CREATE_PROTECTED_BIT` bit set, the image must be bound to a memory object allocated with a memory type that reports `VK_MEMORY_PROPERTY_PROTECTED_BIT`
12. If `image` was created with the `VK_IMAGE_CREATE_PROTECTED_BIT` bit not set, the image must not be bound to a memory object created with a memory type that reports `VK_MEMORY_PROPERTY_PROTECTED_BIT`
13. If `image` was created with `VkDedicatedAllocationImageCreateInfoNV::dedicatedAllocation` equal to `VK_TRUE`, `memory` must have been created with `VkDedicatedAllocationMemoryAllocateInfoNV::image` equal to an image handle created with identical creation parameters to `image` and `memoryOffset` must be zero
14. If the value of `VkExportMemoryAllocateInfo::handleTypes` used to allocate `memory` is not `0`, it must include at least one of the handles set in `VkExternalMemoryImageCreateInfo::handleTypes` when `image` was created
15. If `memory` was created by a memory import operation, the external handle type of the imported memory must also have been set in `VkExternalMemoryImageCreateInfo::handleTypes` when `image` was created

Buffer

Validations for `vkBindBufferMemory`:

1. buffer must not already be backed by a memory object
 - Handled by API design
2. buffer must not have been created with any sparse memory binding flags
3. memoryOffset must be less than the size of memory
 - Handled by API design
4. memory must have been allocated using one of the memory types allowed in the memoryTypeBits member of the `VkMemoryRequirements` structure returned from a call to `vkGetBufferMemoryRequirements` with buffer
 - Handled by API design
5. memoryOffset must be an integer multiple of the alignment member of the `VkMemoryRequirements` structure returned from a call to `vkGetBufferMemoryRequirements` with buffer
 - Handled by API design
6. The size member of the `VkMemoryRequirements` structure returned from a call to `vkGetBufferMemoryRequirements` with buffer must be less than or equal to the size of memory minus memoryOffset
 - Handled by API design
7. If buffer requires a dedicated allocation(as reported by `vkGetBufferMemoryRequirements2` in `VkMemoryDedicatedRequirements::requiresDedicatedAllocation` for buffer), memory must have been created with `VkMemoryDedicatedAllocateInfo::buffer` equal to buffer
8. If the `VkMemoryAllocateInfo` provided when memory was allocated included a `VkMemoryDedicatedAllocateInfo` structure in its pNext chain, and `VkMemoryDedicatedAllocateInfo::buffer` was not `VK_NULL_HANDLE`, then buffer must equal `VkMemoryDedicatedAllocateInfo::buffer`, and `memoryOffset` must be zero.
9. If buffer was created with the `VK_BUFFER_CREATE_PROTECTED_BIT` bit set, the buffer must be bound to a memory object allocated with a memory type that reports `VK_MEMORY_PROPERTY_PROTECTED_BIT`
10. If buffer was created with the `VK_BUFFER_CREATE_PROTECTED_BIT` bit not set, the buffer must not be bound to a memory object created with a memory type that reports `VK_MEMORY_PROPERTY_PROTECTED_BIT`
11. If buffer was created with `VkDedicatedAllocationBufferCreateInfoNV::dedicatedAllocation` equal to `VK_TRUE`, memory must have been created with `VkDedicatedAllocationMemoryAllocateInfoNV::buffer` equal to a buffer handle created with identical creation parameters to buffer and `memoryOffset` must be zero
12. If the value of `VkExportMemoryAllocateInfo::handleTypes` used to allocate memory is not `0`, it must include at least one of the handles set in `VkExternalMemoryBufferCreateInfo::handleTypes` when buffer was created
13. If memory was created by a memory import operation, the external handle type of the imported memory must also have been set in `VkExternalMemoryBufferCreateInfo::handleTypes` when buffer was created
14. If the `VkPhysicalDeviceBufferDeviceAddressFeatures::bufferDeviceAddress` feature is enabled and buffer was created with the `VK_BUFFER_USAGE_SHADER_DEVICE_ADDRESS_BIT` bit set, memory must have been allocated with the `VK_MEMORY_ALLOCATE_DEVICE_ADDRESS_BIT` bit set

Validations for `vkMapMemory`:

1. memory must not be currently host mapped
 - Handled by API design
2. offset must be less than the size of memory

- 3. If `size` is not equal to `VK_WHOLE_SIZE`, `size` must be greater than 0
 - [Guaranteed by the type system](#)
- 4. If `size` is not equal to `VK_WHOLE_SIZE`, `size` must be less than or equal to the size of the `memory` minus `offset`
- 5. `memory` must have been created with a memory type that reports `VK_MEMORY_PROPERTY_HOST_VISIBLE_BIT`
- 6. `memory` must not have been allocated with multiple instances.

Validations for `VkMappedMemoryRange`:

- 1. `memory` must be currently host mapped
 - [Handled by API design](#)
- 2. If `size` is not equal to `VK_WHOLE_SIZE`, `offset` and `size` must specify a range contained within the currently mapped range of `memory`
 - [Handled by API design](#)
- 3. If `size` is equal to `VK_WHOLE_SIZE`, `offset` must be within the currently mapped range of `memory`
 - [Handled by API design](#)
- 4. If `size` is equal to `VK_WHOLE_SIZE`, the end of the current mapping of `memory` must be a multiple of `VkPhysicalDeviceLimits::nonCoherentAtomSize` bytes from the beginning of the `memory` object.
- 5. `offset` must be a multiple of `VkPhysicalDeviceLimits::nonCoherentAtomSize`
- 6. If `size` is not equal to `VK_WHOLE_SIZE`, `size` must either be a multiple of `VkPhysicalDeviceLimits::nonCoherentAtomSize`, or `offset` plus `size` must equal the size of `memory`.

Statistics

Category	Statically solved	Dynamically solved	Left to user	Total
Implicit	198	17	0	215
Creation	62	0	141	203
Usage	22	1	64	87
Total	282	18	205	505