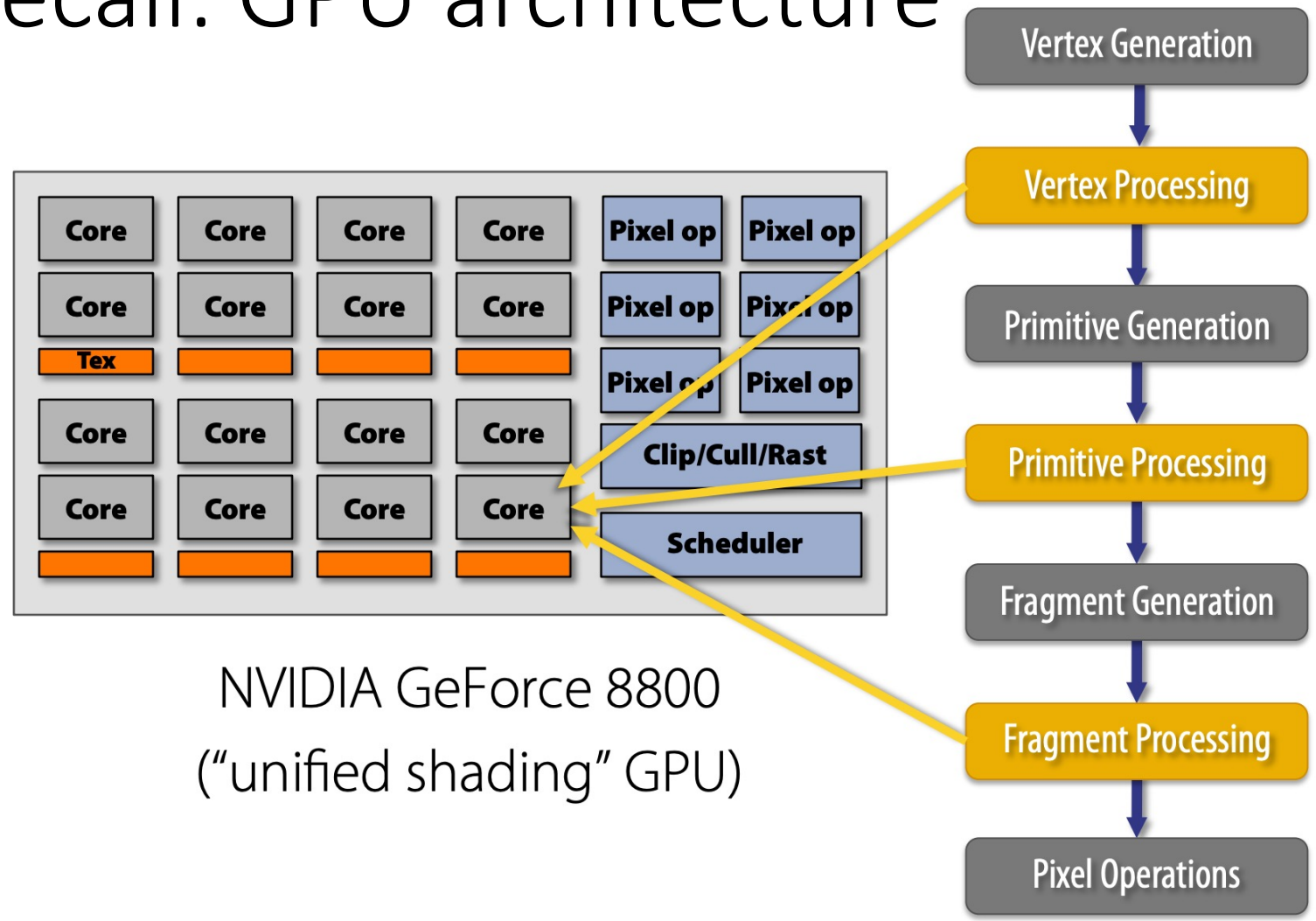
18 –glsl

Recall: GPU architecture



NVIDIA GeForce 8800
("unified shading" GPU)

https://www.cs.cmu.edu/afs/cs/academic/class/15462-f11/www/lec_slides/lec19.pdf

Aside: WebGL vs WebGL2 vs WEbGPU vs … Slightly different GLSL versions …

- WebGL ~= OpenGL ES2, WebGL2 ~= OpenGL ES3

- https://webgl2fundamentals.org/webgl/lessons/webgl1-to-webgl2.html

- https://www.khronos.org/webgl/
- https://www.khronos.org/files/webgl/webgl-reference-card-1_0.pdf
- https://www.khronos.org/files/webgl20-reference-guide.pdf
- https://www.w3.org/community/gpu/

GLSL
(GL Shader Language)

- Vertex shader + fragment shader
- C-like language (akin to C++, C#, Java, etc)

Types [4.1]

A shader can aggregate these using arrays and structures to build more complex types. There are no pointer types.

Basic Types

void	no function return value or empty parameter list
bool	Boolean
int	signed integer
float	floating scalar
vec2, vec3, vec4	n-component floating point vector
bvec2, bvec3, bvec4	Boolean vector
ivec2, ivec3, ivec4	signed integer vector
mat2, mat3, mat4	2x2, 3x3, 4x4 float matrix
sampler2D	access a 2D texture
samplerCube	access cube mapped texture

Structures and Arrays [4.1.8, 4.1.9]

Structures	**struct** *type-name* {
	  members
	} *struct-name*[]; // optional variable declaration,
	// optionally an array

Arrays	**float** foo[3]; * structures and blocks can be arrays * only 1-dimensional arrays supported * structure members can be arrays

Operators and Functions

- Common operators
- Common and unique functions

Built-In Functions

Angle & Trigonometry Functions [8.1]

Component-wise operation. Parameters specified as *angle* are assumed to be in units of radians. T is float, vec2, vec3, vec4.

T **radians**(T *degrees*)	degrees to radians
T **degrees**(T *radians*)	radians to degrees
T **sin**(T *angle*)	sine
T **cos**(T *angle*)	cosine
T **tan**(T *angle*)	tangent
T **asin**(T *x*)	arc sine
T **acos**(T *x*)	arc cosine
T **atan**(T *y*, T *x*) T **atan**(T *y_over_x*)	arc tangent

Exponential Functions [8.2]

Component-wise operation. T is float, vec2, vec3, vec4.

T **pow**(T *x*, T *y*)	x^y
T **exp**(T *x*)	e^x
T **log**(T *x*)	ln
T **exp2**(T *x*)	2^x
T **log2**(T *x*)	$\log_2$
T **sqrt**(T *x*)	square root
T **inversesqrt**(T *x*)	inverse square root

Common Functions [8.3]

Component-wise operation. T is float, vec2, vec3, vec4.

T **abs**(T *x*)	absolute value
T **sign**(T *x*)	returns -1.0, 0.0, or 1.0
T **floor**(T *x*)	nearest integer <= *x*
T **ceil**(T *x*)	nearest integer >= *x*
T **fract**(T *x*)	*x* - **floor**(*x*)
T **mod**(T *x*, T *y*) T **mod**(T *x*, float *y*)	modulus
T **min**(T *x*, T *y*) T **min**(T *x*, float *y*)	minimum value
T **max**(T *x*, T *y*) T **max**(T *x*, float *y*)	maximum value
T **clamp**(T *x*, T *minVal*, T *maxVal*) T **clamp**(T *x*, float *minVal*, float *maxVal*)	**min**(**max**(*x*, **minVal**), **maxVal**)
T **mix**(T *x*, T *y*, T *a*) T **mix**(T *x*, T *y*, float *a*)	linear blend of *x* and *y*
T **step**(T *edge*, T *x*) T **step**(float *edge*, T *x*)	0.0 if *x* < *edge*, else 1.0
T **smoothstep**(T *edge0*, T *edge1*, T *x*) T **smoothstep**(float *edge0*, float *edge1*, T *x*)	clip and smooth

Geometric Functions [8.4]

These functions operate on vectors as vectors, not component-wise. T is float, vec2, vec3, vec4.

float **length**(T *x*)	length of vector
float **distance**(T *p0*, T *p1*)	distance between points
float **dot**(T *x*, T *y*)	dot product
vec3 **cross**(vec3 *x*, vec3 *y*)	cross product
T **normalize**(T *x*)	normalize vector to length 1
T **faceforward**(T *N*, T *I*, T *Nref*)	returns *N* if **dot**(*Nref*, *I*) < 0, else -*N*
T **reflect**(T *I*, T *N*)	reflection direction *I* - 2 * **dot**(*N*,*I*) * *N*
T **refract**(T *I*, T *N*, float *eta*)	refraction vector

Matrix Functions [8.5]

Type mat is any matrix type.

mat **matrixCompMult**(mat *x*, mat *y*)	multiply *x* by *y* component-wise

Vector Relational Functions [8.6]

Compare *x* and *y* component-wise. Sizes of input and return vectors for a particular call must match. Type bvec is bvec*n*; vec is vec*n*; ivec is ivec*n* (where *n* is 2, 3, or 4). T is the union of vec and ivec.

bvec **lessThan**(T *x*, T *y*)	x < y
bvec **lessThanEqual**(T *x*, T *y*)	x <= y
bvec **greaterThan**(T *x*, T *y*)	x > y
bvec **greaterThanEqual**(T *x*, T *y*)	x >= y
bvec **equal**(T *x*, T *y*) bvec **equal**(bvec *x*, bvec *y*)	x == y
bvec **notEqual**(T *x*, T *y*) bvec **notEqual**(bvec *x*, bvec *y*)	x!= y
bool **any**(bvec *x*)	true if any component of *x* is true
bool **all**(bvec *x*)	true if all components of *x* are true
bvec **not**(bvec *x*)	logical complement of *x*

Texture Lookup Functions [8.7]

Available only in vertex shaders.

vec4 **texture2DLod**(sampler2D *sampler*, vec2 *coord*, float *lod*)
vec4 **texture2DProjLod**(sampler2D *sampler*, vec3 *coord*, float *lod*)
vec4 **texture2DProjLod**(sampler2D *sampler*, vec4 *coord*, float *lod*)
vec4 **textureCubeLod**(samplerCube *sampler*, vec3 *coord*, float *lod*)

Available only in fragment shaders.

vec4 **texture2D**(sampler2D *sampler*, vec2 *coord*, float *bias*)
vec4 **texture2DProj**(sampler2D *sampler*, vec3 *coord*, float *bias*)
vec4 **texture2DProj**(sampler2D *sampler*, vec4 *coord*, float *bias*)
vec4 **textureCube**(samplerCube *sampler*, vec3 *coord*, float *bias*)

Available in vertex and fragment shaders.

vec4 **texture2D**(sampler2D *sampler*, vec2 *coord*)
vec4 **texture2DProj**(sampler2D *sampler*, vec3 *coord*)
vec4 **texture2DProj**(sampler2D *sampler*, vec4 *coord*)
vec4 **textureCube**(samplerCube *sampler*, vec3 *coord*)

Swizzling

- Address components of vectors

Built-In Inputs, Outputs, and Constants [7]

Shader programs use Special Variables to communicate with fixed-function parts of the pipeline. Output Special Variables may be read back after writing. Input Special Variables are read-only. All Special Variables have global scope.

Vertex Shader Special Variables [7.1]

Outputs:

Variable	Description	Units or coordinate system
highp vec4 gl_Position;	transformed vertex position	clip coordinates
mediump float gl_PointSize;	transformed point size (point rasterization only)	pixels

Fragment Shader Special Variables [7.2]

Fragment shaders may write to **gl_FragColor** or to one or more elements of **gl_FragData[]**, but not both.
The size of the **gl_FragData** array is given by the built-in constant **gl_MaxDrawBuffers**.

Inputs:

Variable	Description	Units or coordinate system
mediump vec4 gl_FragCoord;	fragment position within frame buffer	window coordinates
bool gl_FrontFacing;	fragment belongs to a front-facing primitive	Boolean
mediump vec2 gl_PointCoord;	fragment position within a point (point rasterization only)	0.0 to 1.0 for each component

Outputs:

Variable	Description	Units or coordinate system
mediump vec4 gl_FragColor;	fragment color	RGBA color
mediump vec4 gl_FragData[*n*]	fragment color for color attachment *n*	RGBA color

Information Flow

Step through an Example

- https://webglfundamentals.org/webgl/lessons/resources/webgl-state-diagram.html#no-help

Simple Vertex Shader

```
attribute vec4 position;
attribute vec3 normal;
attribute vec2 texcoord;
uniform mat4 projection;
uniform mat4 modelView;
varying vec3 v_normal;
varying vec2 v_texcoord;
void main() {
    gl_Position = projection * modelView * position;
    v_normal = mat3(modelView) * normal;
    v_texcoord = texcoord;
}
```

Simple Fragment Shader

```
precision highp float;
varying vec3 v_normal;
varying vec2 v_texcoord;
uniform sampler2D diffuse;
uniform sampler2D decal;
uniform vec4 diffuseMult;
uniform vec3 lightDir;
void main() {
    vec3 normal = normalize(v_normal);
    float light = dot(normal, lightDir) * 0.5 + 0.5;
    vec4 color = texture2D(diffuse, v_texcoord) * diffuseMult;
    vec4 decalColor = texture2D(decal, v_texcoord);
    decalColor.rgb *= decalColor.a;
    color = color * (1.0 - decalColor.a) + decalColor;
    gl_FragColor = vec4(color.rgb * light, color.a);
}
```

A bit more …

https://developer.mozilla.org/en-US/docs/Web/API/WebGL_API

https://webglfundamentals.org/webgl/lessons/webgl-how-it-works.html

https://webglfundamentals.org/webgl/lessons/resources/webgl-state-diagram.html#no-help

https://threejs.org/docs/#api/en/materials/ShaderMaterial