Intro to OpenGL

Rendering Objects

- Object has internal geometry (Model)
- Object relative to other objects (World)
- Object relative to camera (View)
- Object relative to screen (Projection)

Need to transform all geometry then draw…

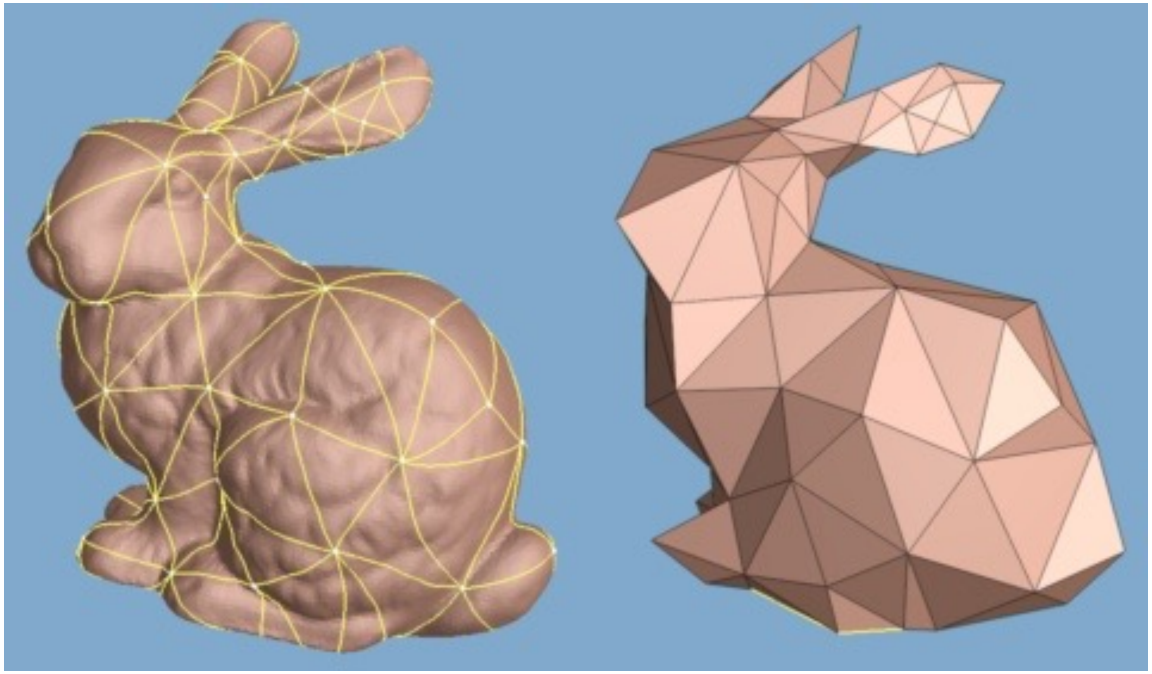
The Graphics Pipeline

- Raytracing pipeline is too slow
  - Raytracers are **irregular applications** (difficult to parallelize)
  - Better-looking ray tracers require numerous samples to converge
- Raster pipeline optimizes local light transport
  - Designed to accelerate rendering process
  - Focused on high throughput and parallelization

Rasterization

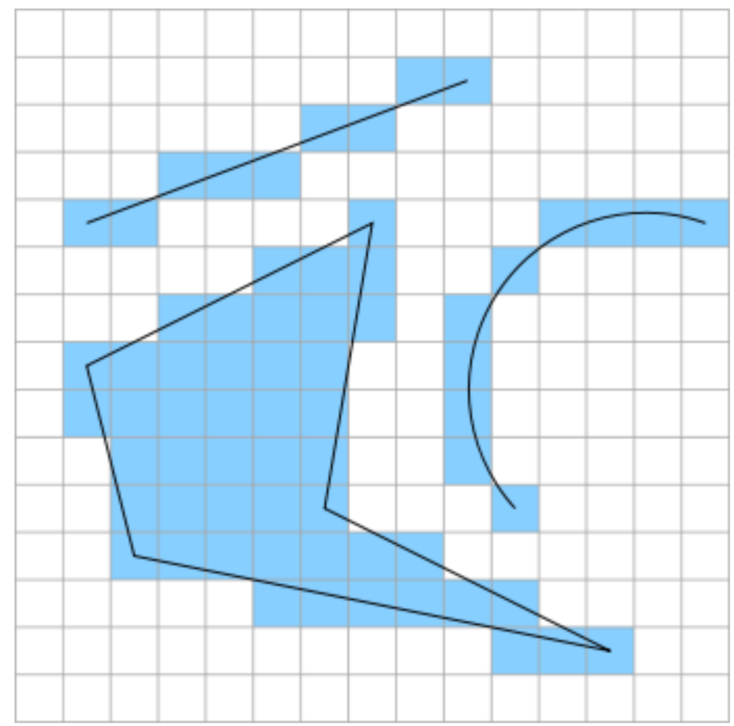
Objects composed of vertex data

Vertex data **tessellated** into primitives



Rasterization

- Primitives have color and position
- Color pixels on screen based on primitive projections
- Embarrassingly parallel with great hardware support!



OpenGL

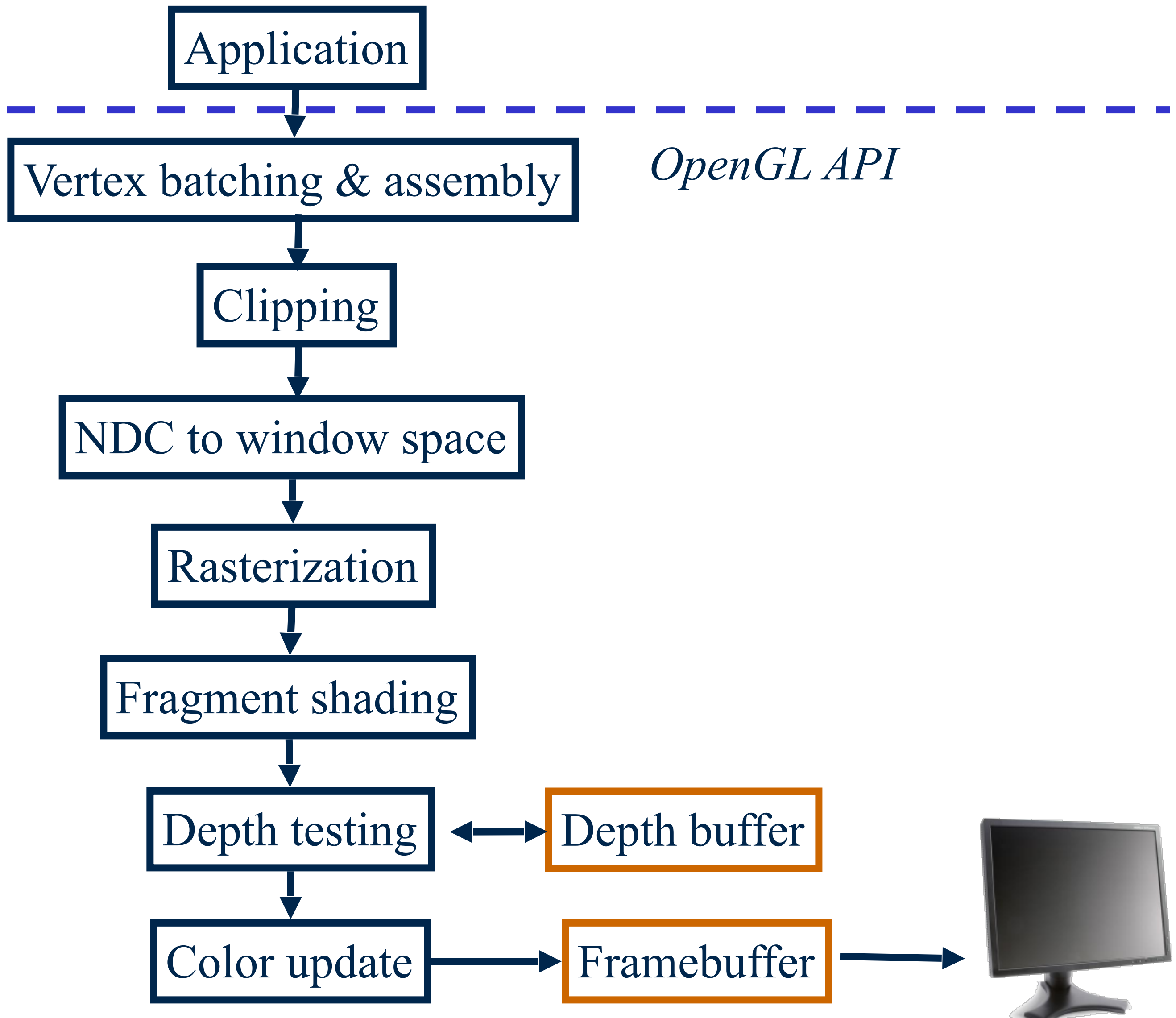
Open Graphics Library

- Standardized in 1992 by Silicon Graphics
- Currently managed by Kronos Group

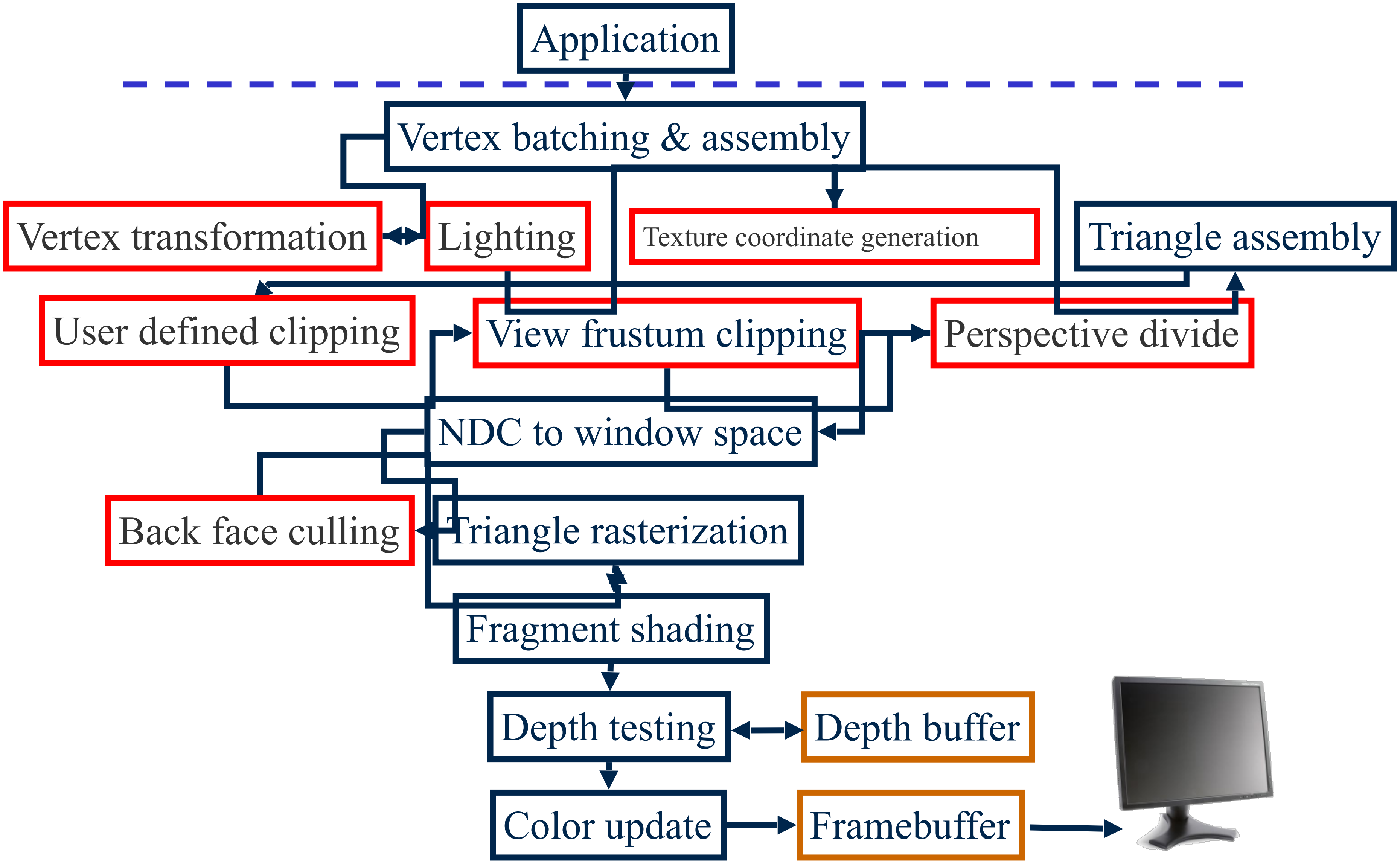
Microsoft equivalent is DirectX

Simplified Graphics Pipeline

NDC = Normalized Device Coordinates, this is a [-1,+1]^3 cube



A Little Expanded…



Old vs Modern OpenGL

Originally OpenGL was a “Fixed Function” Pipeline

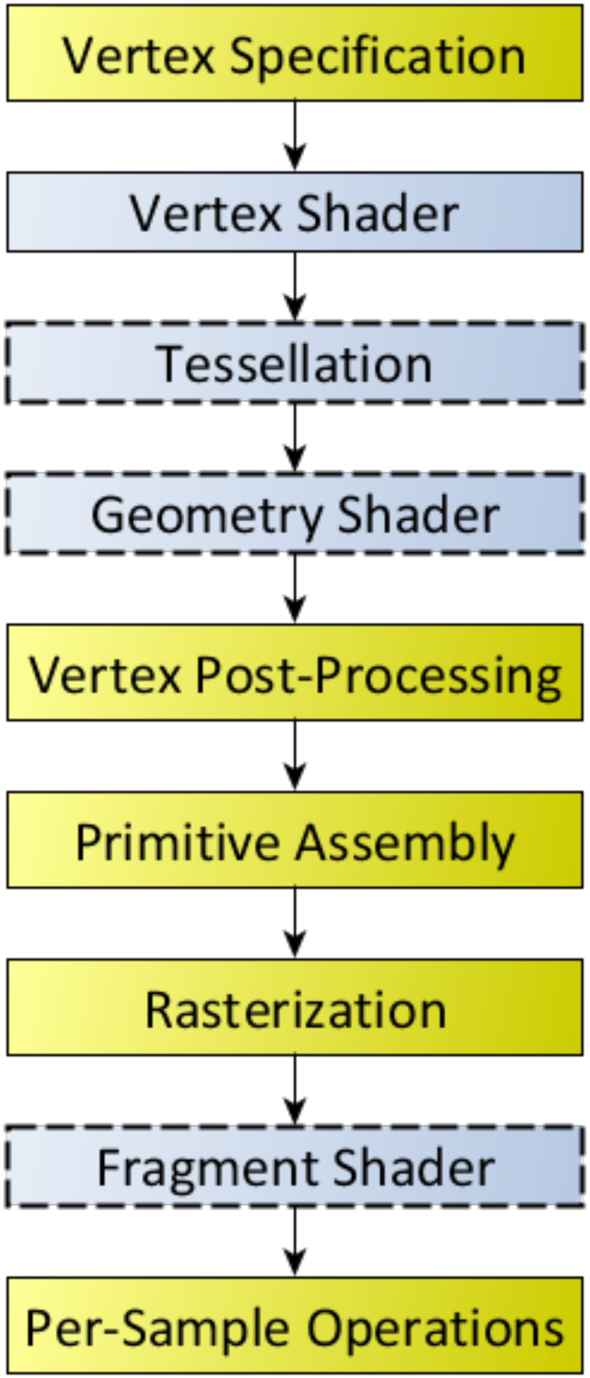
- Exposed graphics hardware through user configurations
- Built-in math operations manipulate data accordingly

Old vs Modern OpenGL

OpenGL 3.0 is programmable allowing for greater flexibility and control

Also changes hardware pipeline and how a programmer interacts with the GPU

The modern rendering pipeline (blue stages are fully programmable)



Vertex Specification

Specify vertices GPU should process

- One vertex/triangle at a time is slow

Specify how to process

- **Attributes** inform vertex shader what data represents

Vertex Buffer Objects (VBOs)

- Source of data for vertex arrays
- `glBindBuffer` binds given buffer to global target
  - `GL_ARRAY_BUFFER` specifies Buffer Object is vertex attribute data
- `glVertexAttribPointer` specifies attribute data for these vertices
  - i.e. what are the data components and how are they arranged?

VBO Data

Contain data for:

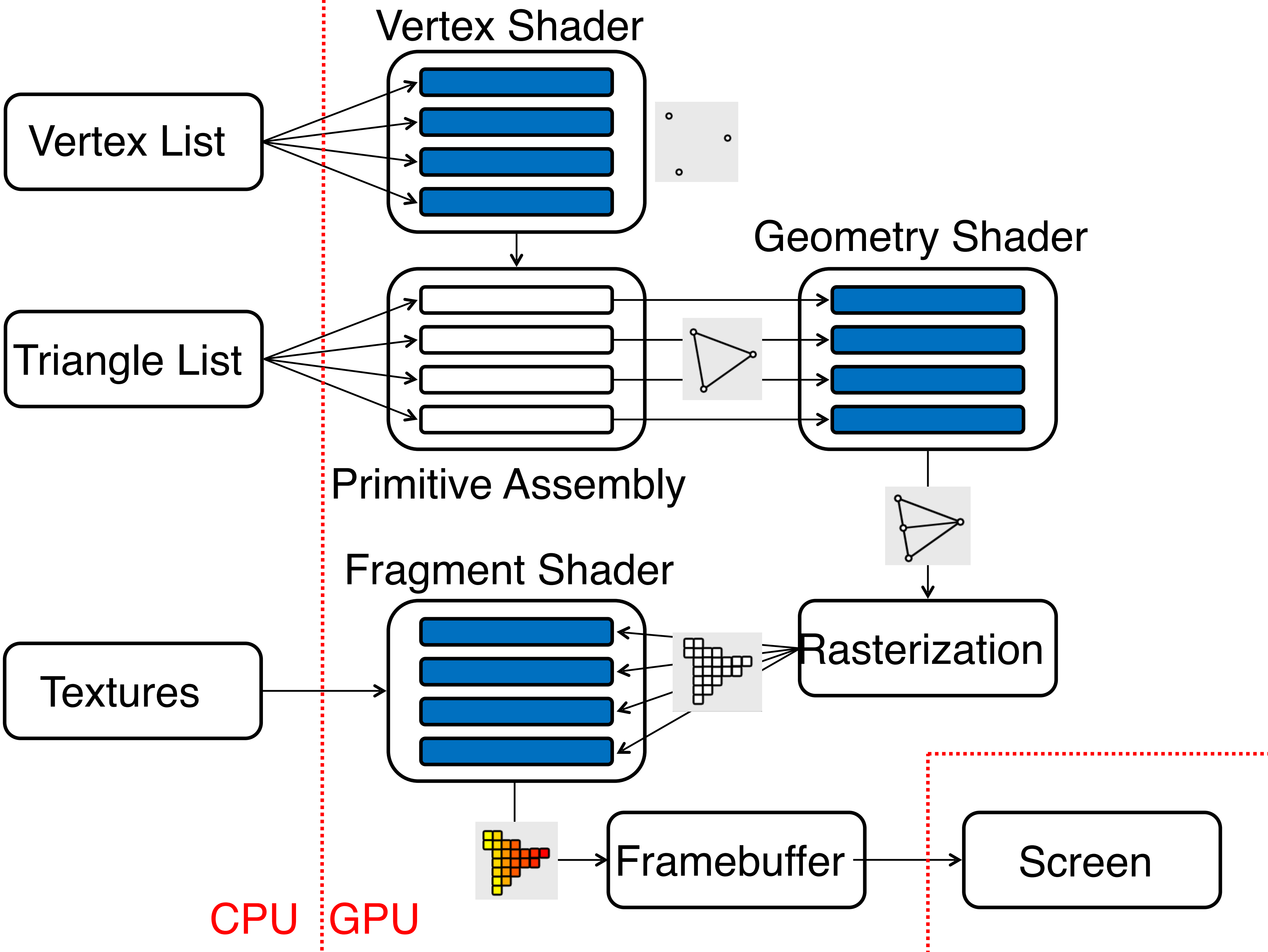
- Vertex position
- Vertex colors
- Texture info
- Normal info
- etc

Vertex Array Objects (VAOs)

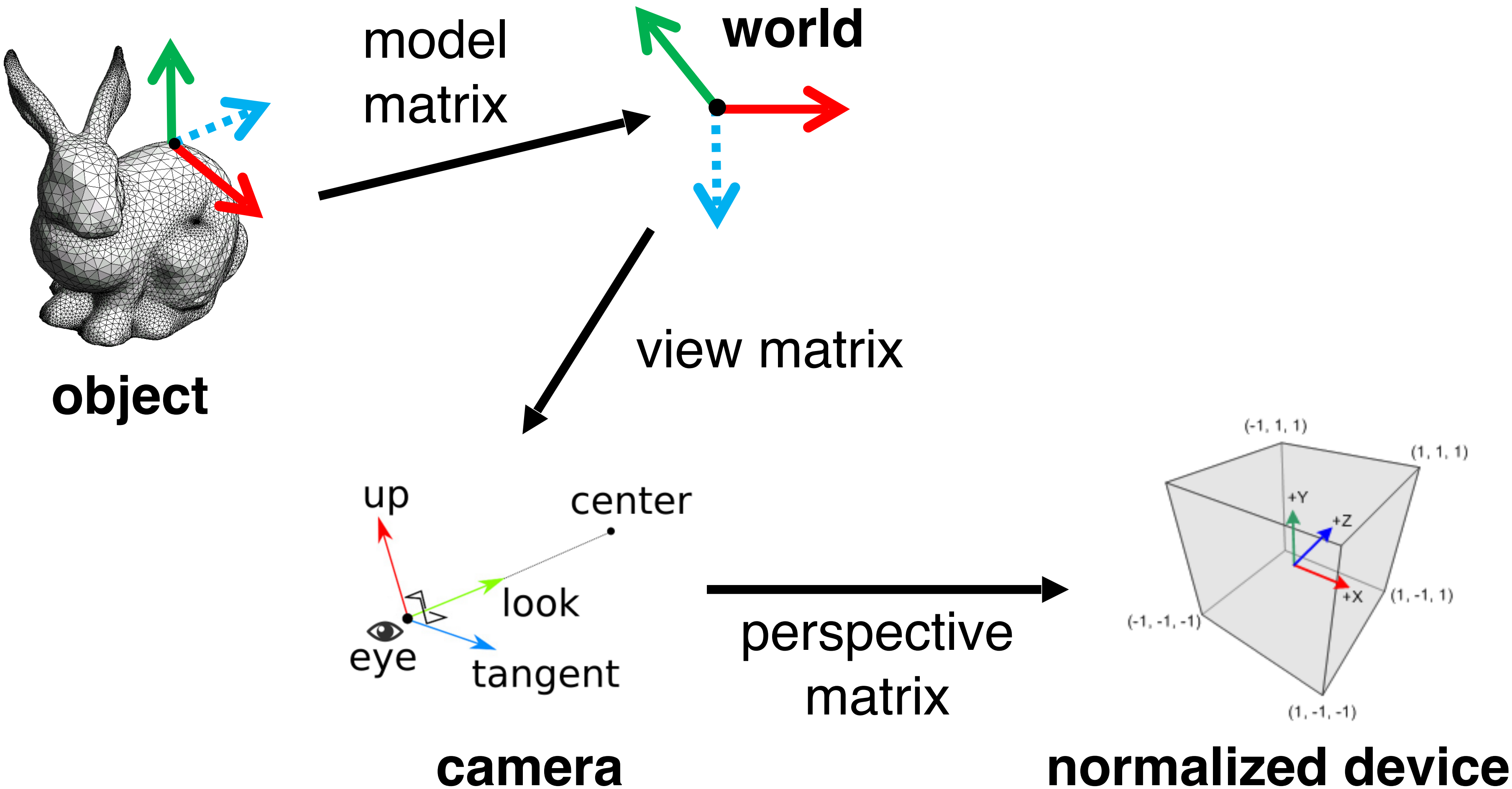
- OpenGL Objects associated with an OpenGL **context** (state of the instance)
- Stores attribute data and Buffer Objects for bussing to GPU
  - Can contain multiple VBOs
- VAOs allow switches between vertex attribute configurations without performance hit
- `glGenVertexArrays` creates VAO
- `glBindVertexArray` binds that VAO to target

Using VAOs

1. Create VAO with necessary information:
    1. Create VAO
    2. Bind VAO
    3. Generate and bind VBO
    4. Disable/unbind VAO and VBO
2. Rendering using VAO:
    1. Bind VAO
    2. Draw data in VBO
    3. Unbind VAO

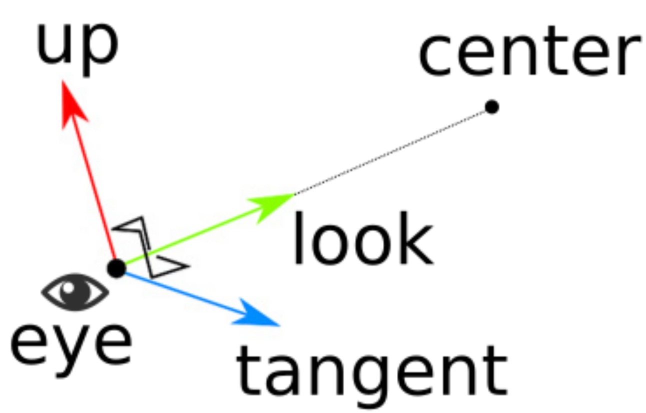

Vertex Shader
Vertex List
Geometry Shader
Triangle List
Primitive Assembly
Fragment Shader
Textures
Rasterization
Framebuffer
Screen
CPU
GPU

Coordinate Systems



Camera Coordinates

Note: Look down negative z direction

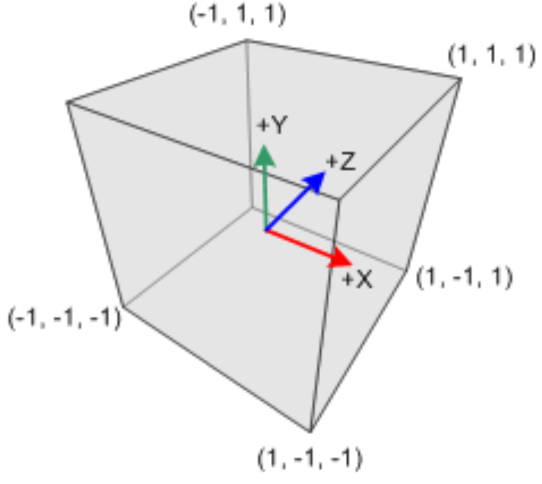


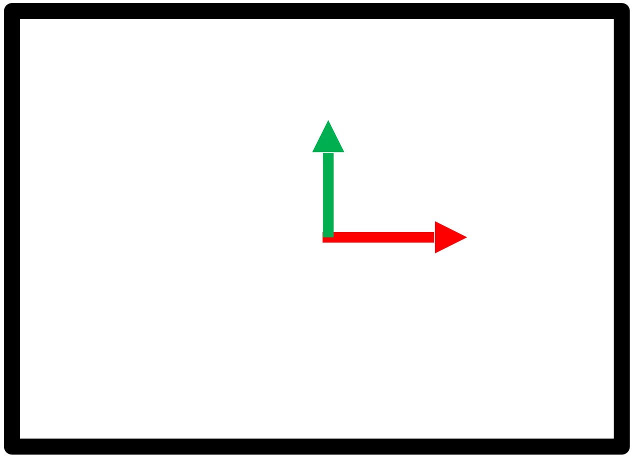
Normalized Device Coordinates

Note:

X and Y map to screen width and height

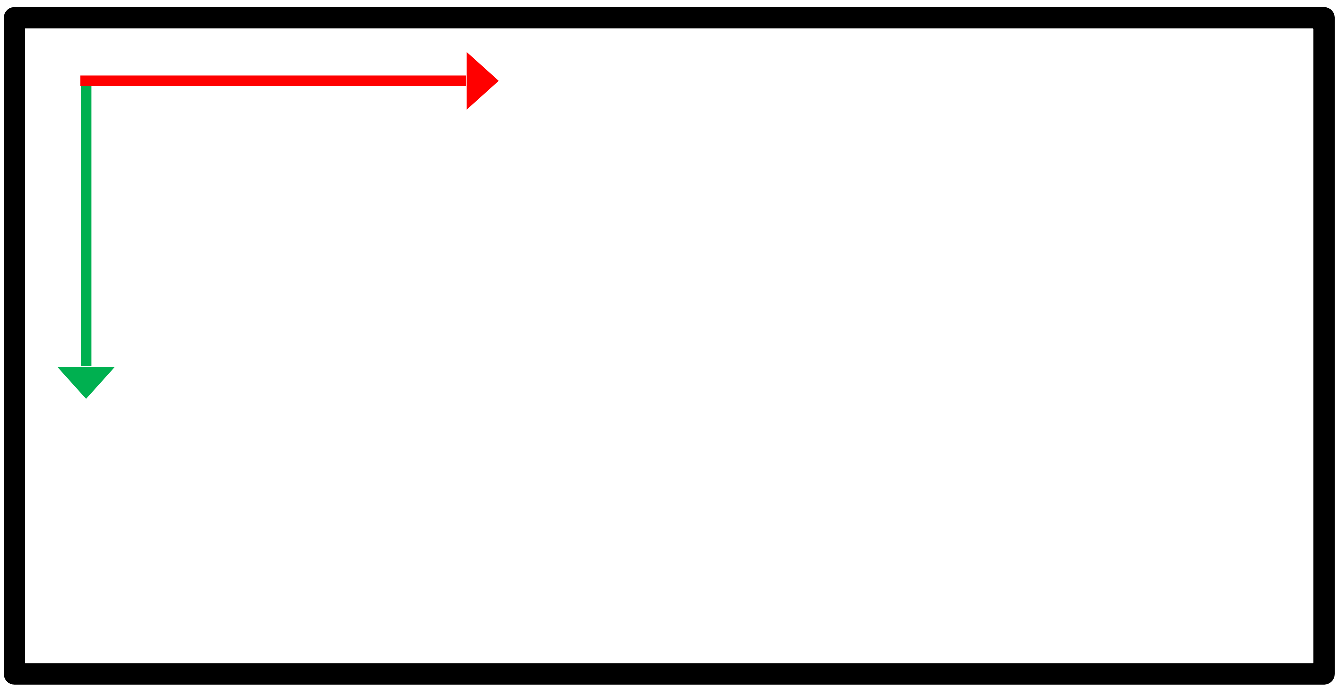
Z used for depth (deeper points are higher)





Except…

Screen coordinates use different system!



Also…

`glViewPort(x, y, width, height)` transforms NDC to window coordinates

Allows for an aspect ratio in final display to screen after being normalized

Incidentally (x, y) specifies the *lower* left corner of the viewport

Framebuffer

Memory region containing pixel data
Controlled by GPU

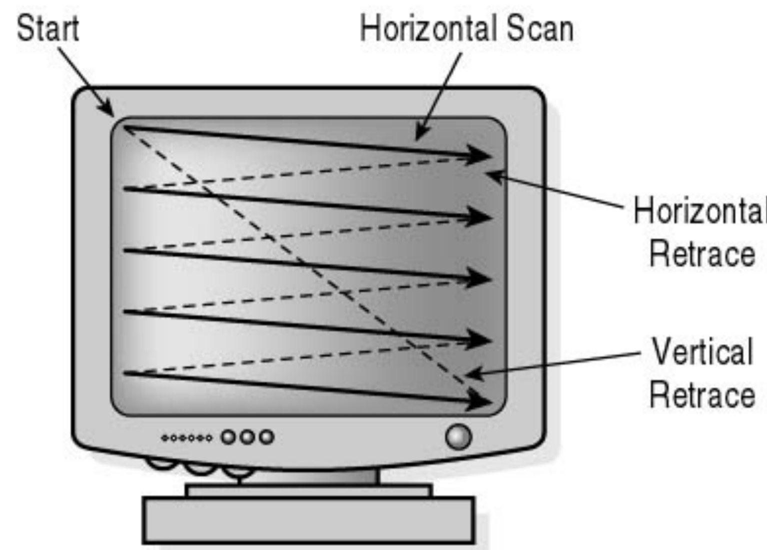
Layers:

- Color buffer (RGB)
- Depth buffer (Z axis position)
- Stencil buffer (extension of depth buffer)

Displaying a Framebuffer

CRTs: beam sweeps across screen to draw pixels (one pass every 1/60 secs)

LCDs: grab framebuffer (every 1/60 secs)



CRT Sweeping

Flickering and Tearing

Framebuffer changes while monitor draws

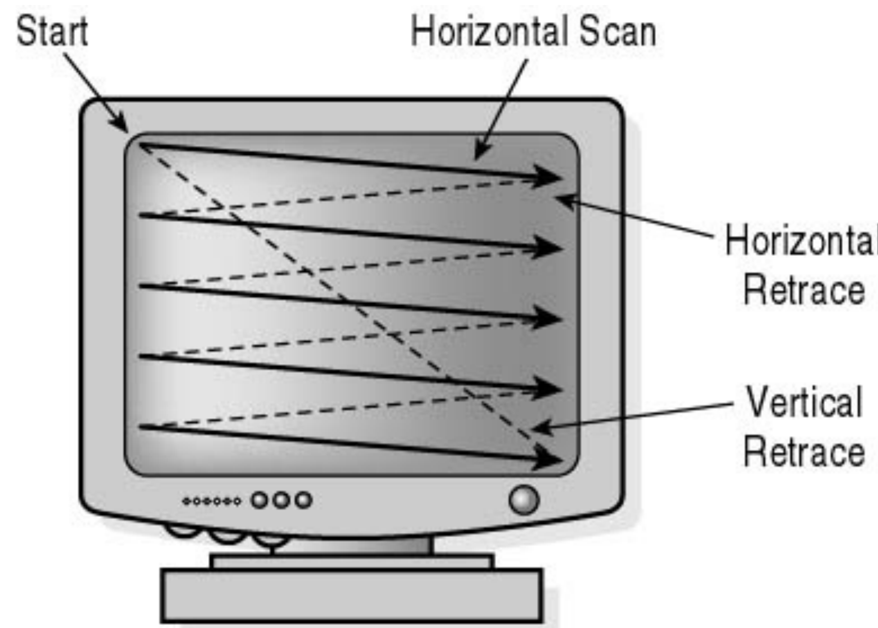
How to solve?

When to Draw

On CRTs: wait for **vertical retrace** to swap

- "VSync"
- Occurs 1/60 sec
- Introduces lag

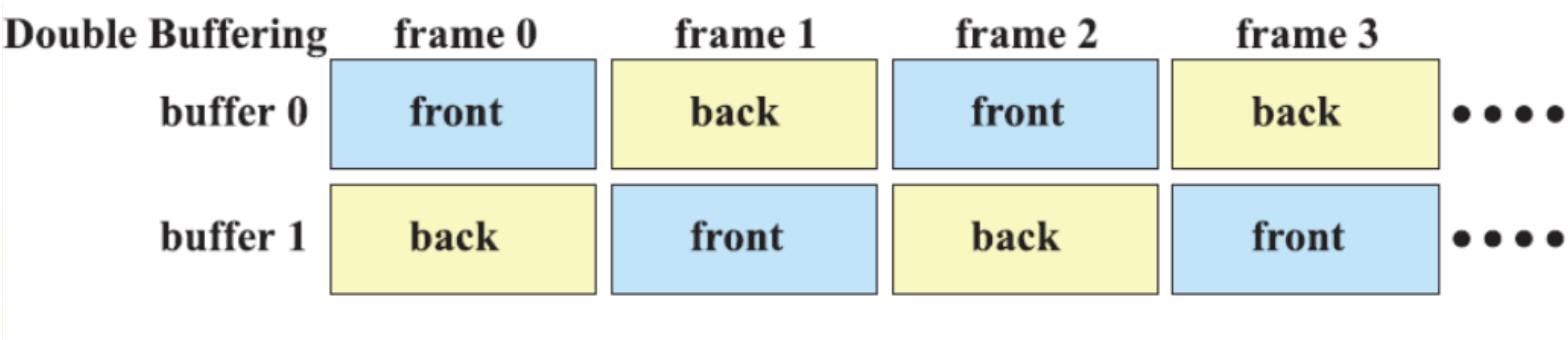
On LCDs: swap when not reading



CRT Sweeping

Double-Buffering

Use two frame buffers



Render to **back buffer** while showing **front buffer**

Then swap

Triple Buffering and Beyond

Triple buffering can be used in conjunction with VSync to reduce double-buffering latency with less tearing than VSync

Can also queue up *n* frames generalizing notion of “double” or “triple” buffering

Side Note: G-Sync and FreeSync

G-Sync (NVidia) and FreeSync (AMD) improve upon VSync by synchronizing refresh rates with frame rate

Solves for VSync issues where fluctuating frame rates creates tearing

OpenGL Tutorial

Work through:

http://www.opengl-tutorial.org/beginners-tutorials/tutorial-2-the-first-triangle/