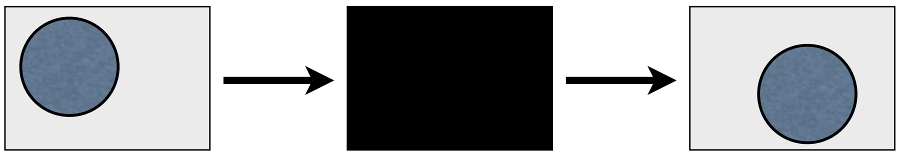
(Modern) Animation Quick Start

- Animation in computer graphics has a long and storied history, but before we go into that, we'll jump right into how it's generally done today, specifically in OpenGL (GLUT)
- Animation today is *full-frame, double-buffered*, and is actually not unlike traditional cel animation: present, in rapid order, a series of still images which the human brain interprets as fluid motion
- As a rule of thumb, we start perceiving "fluid motion" at around 30 frames per second

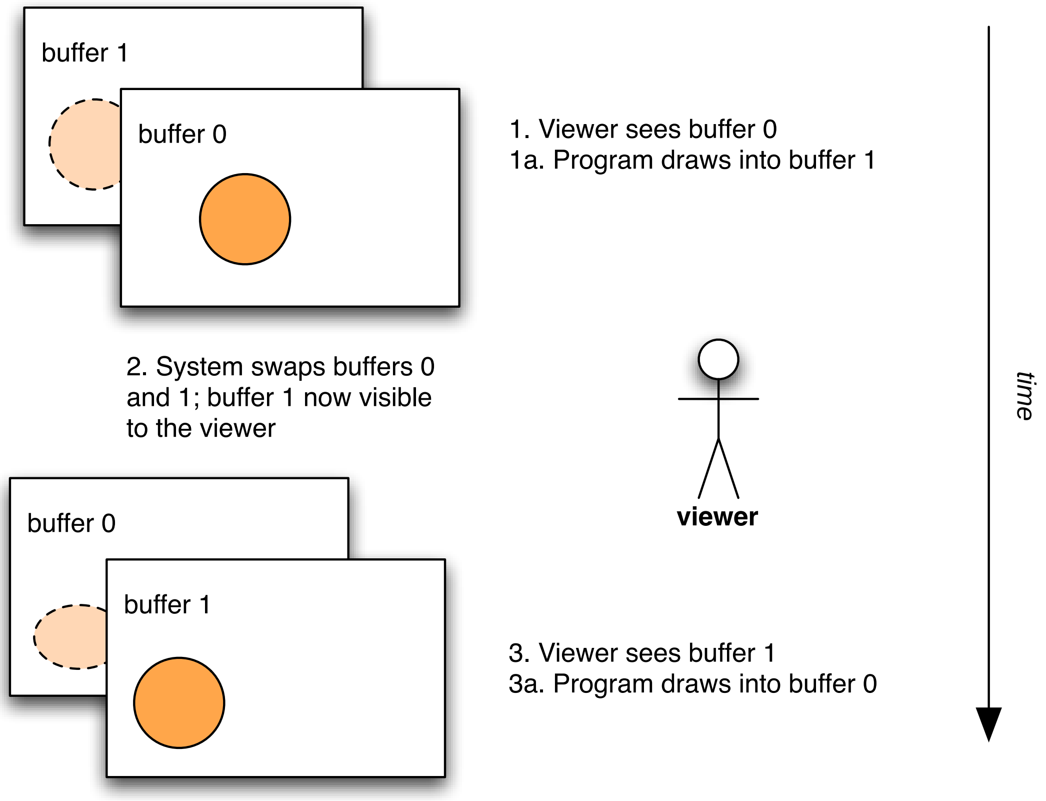
Drawing Full Frames

- You've now seen a single instance of OpenGL drawing, which generally goes like this:
  - Clear the display
  - Draw the objects
- The trick is, *you don't want the user to see the screen clear* — this results in perceived flicker:



Enter Double Buffering

- The solution to the flickering issue is a technique called *double buffering*: with double buffering, the system actually maintains *two* full screens — *buffers* — at any given time; one is on display, and the other is invisible
- Flicker-free animation is achieved by painting on the *offscreen* buffer, then swapping the buffers
- Graphics hardware is set up so that buffers can be swapped really quickly; drawing of the next frame then proceeds on the new offscreen buffer


buffer 1
buffer 0
1. Viewer sees buffer 0
1a. Program draws into buffer 1
2. System swaps buffers 0 and 1; buffer 1 now visible to the viewer
viewer
time
buffer 0
buffer 1
3. Viewer sees buffer 1
3a. Program draws into buffer 0

Frame Rate and Real Time

- During double buffering, the *frame rate* is the frequency at which the buffers swap — conceptually equivalent to the "classic" frame rate of cel animation
- However, remember that we're on a computer system here — the frame rate is *never* absolutely the same, due to the amount of CPU time available, and the scheduling of other processes in the system
- Thus, animation algorithms must be based on *real time*, not frame rate — otherwise, moving objects' velocities will depend on CPU speed and scheduling

- What you *really* want is for a more powerful system to render *more frames per second* than a less powerful system — but to still keep objects "moving" at the same "speed"
- To do this, the classic mechanics equation applies:

distance = rate * time

1. Determine a rate/velocity/speed for moving objects in your program based on real time
2. When the CPU gives you time to display a frame, calculate how much time has passed since the *last* time you displayed a frame
3. Use $d = rt$ to calculate how far to move the object in the new, upcoming frame

GLUT Specifics

- Some specific GLUT calls/constants to remember when doing full-frame, real-time-based animation:

  ```
  glutInitDisplayMode(GLUT_DOUBLE | ... );
  ```

  - ◇ Here, GLUT_DOUBLE sets up double buffering

  ```
  glutSwapBuffers();
  ```

  - ◇ Call this when you're done drawing; GLUT will make the buffer that you were using visible, and prepare the other buffer for the next time you draw a scene

- The function `int glutGet()` returns the current value of various GLUT variables. For animation, we want:

  ```
  int currentTime = glutGet(GLUT_ELAPSED_TIME);
  ```

  - ◇ This will tell you the amount of time since some baseline value; what matters is how much time has passed since the *last* time you drew a frame
  - ◇ Typically, you define a variable, say *lastTime*, and use *currentTime* – *lastTime* to determine the amount by which to move the objects in your program

  ```
  glutPostRedisplay();
  ```

  - ◇ This asks GLUT to repaint your window — you almost never call the display function directly

Other Handy Animation Tricks

With this overall setup for animation, you can perform a few other useful things:

- *Calculate frame rate* — have a counter variable to increment whenever you generate a new frame; at regular intervals, use it to infer the overall frame rate
- *Cap frame rate* — generating a new frame (calculate new state + redisplay) can be expensive; you can give CPU time to other programs by doing nothing until the appropriate amount of time (e.g. at least 1/30th of a second) has passed