Lecture 3:
Computers and Color

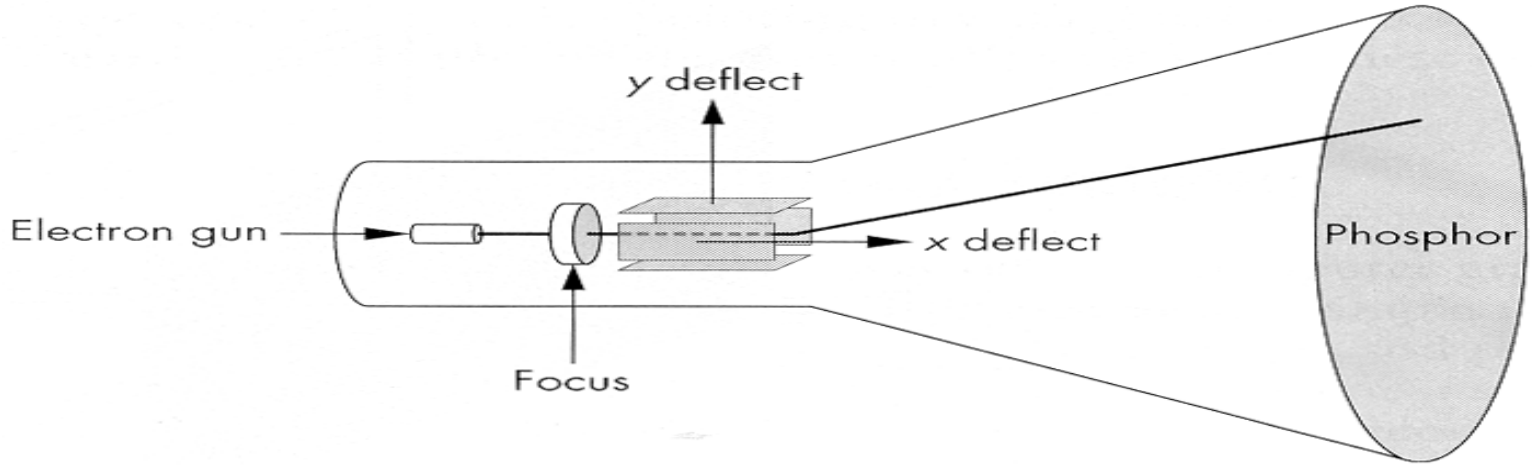
Reading

- Hearn & Baker, sections 2.1-2.2, 4.3

Optional

- I.E. Sutherland. Sketchpad: a man-machine graphics communication system. *Proceedings of the Spring Join Computer Conference*, p. 329-346, 1963.
- T.H. Myer & I.E. Sutherland. On the design of display processors. *Communications of the ACM* 11(6): 410-414, 1968.

Cathode ray tubes (CRTs)



Consists of:

- electron gun
- electron focusing lens
- deflection plates/coils
- electron beam
- anode with phosphor coating

CRTs, cont.

Electrons “boil off” the heated cathode and shoot towards the anode.
Electrons striking the phosphors create light through:

- fluorescence (fraction of usec)
- phosphorescence (10 to 60 usec)

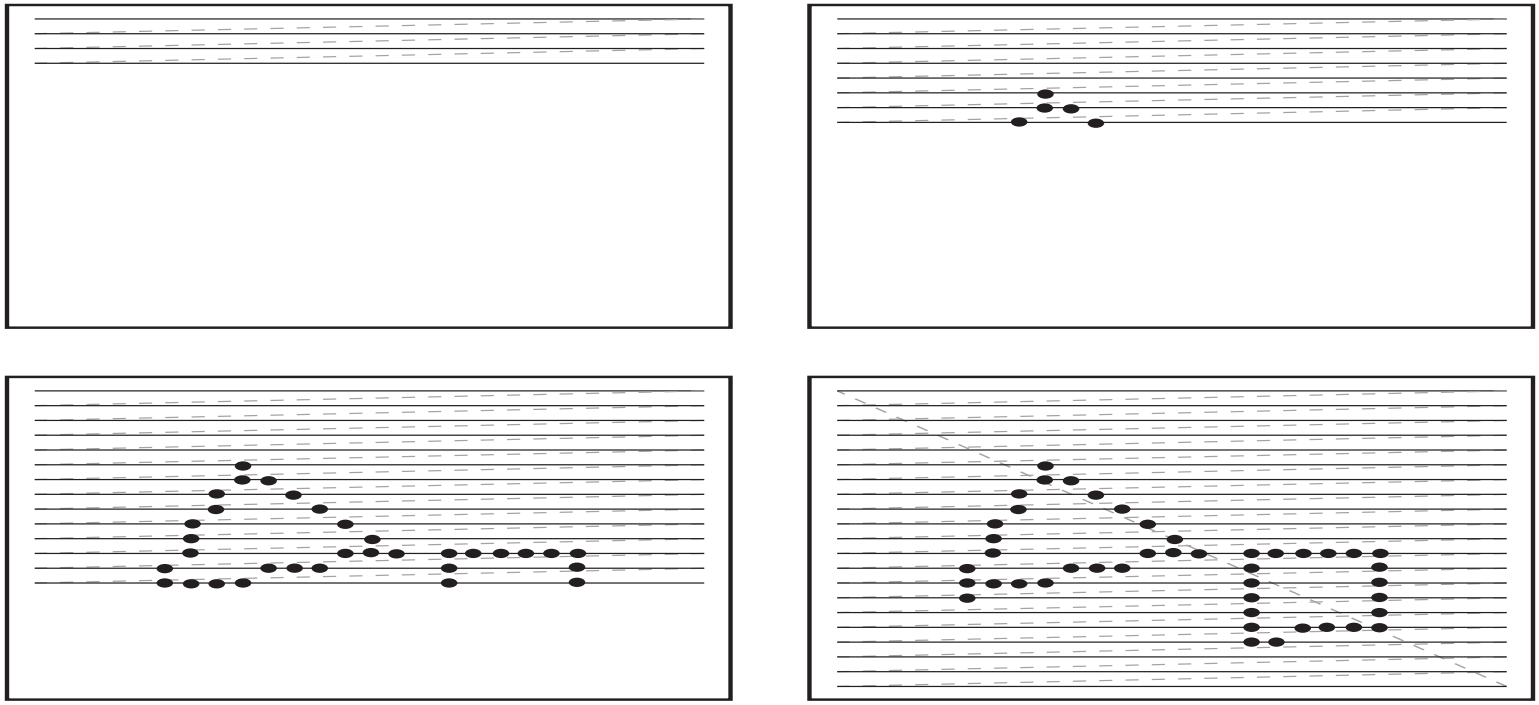
Different phosphors have different:

- color
- persistence (as long as a few seconds)

The image must be **refreshed** to avoid **flicker**:

- typically need at least 60 Hz (why 60 Hz?)
- exact frequency depends on:
  - persistence
  - image intensity
  - ambient lighting
  - wavelength
  - observer

Raster displays



Electron beam traces over screen in **raster scan order**.

- Each left-to-right trace is called a **scan line**.
- Each spot on the screen is a **pixel**.
- When the beam is turned off to sweep back, that is a **retrace**, or a **blanking interval.**

Resolution

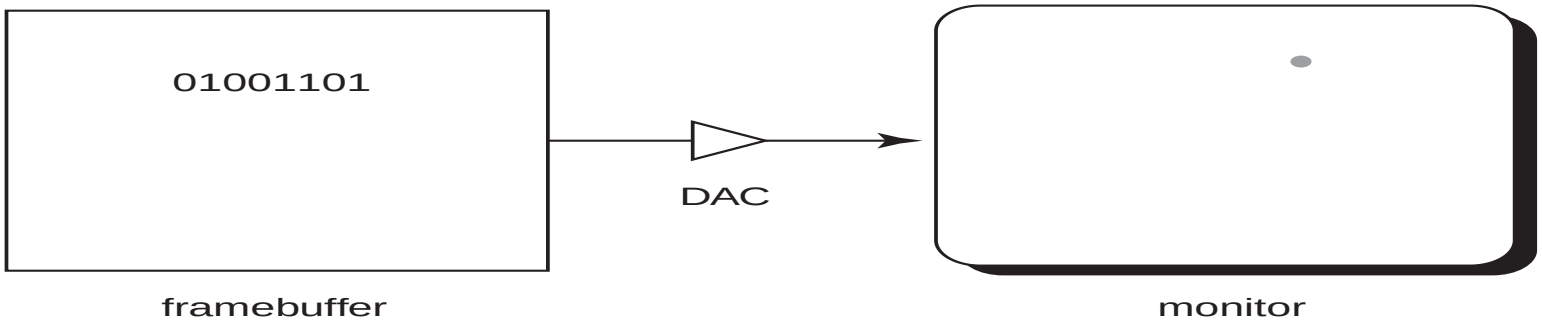
The display's **resolution** is determined by:

- number of scan lines
- number of pixels per scan line
- number of bits per pixel

Examples:

Bitmapped display	960 x 1152 x 1b	1/8 MB
NTSC TV	640 x 480 x 16b	1/2 MB
Color workstation	1280 x 1024 x 24b	4 MB
Laser-printed page		
300 dpi	8.5 x 11 x 300^2 x 1b	1 MB
1200 dpi	8.5 x 11 x 1200^2 x 1b	17 MB
Film	4500 x 3000 x 30b	50 MB

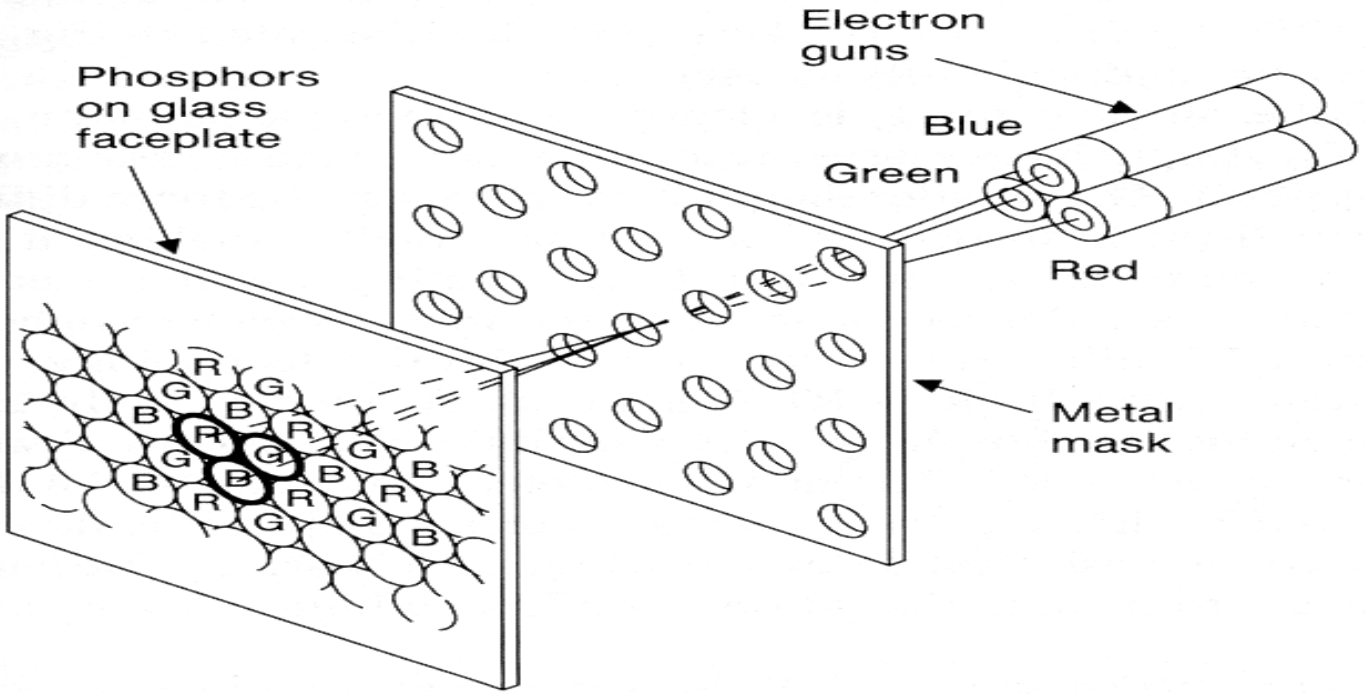
Framebuffers



Intensity of the raster scan beam is modulated according to the contents of a **framebuffer**.

Each element of the framebuffer is associated with a single **pixel** on the screen.

Color CRT monitors

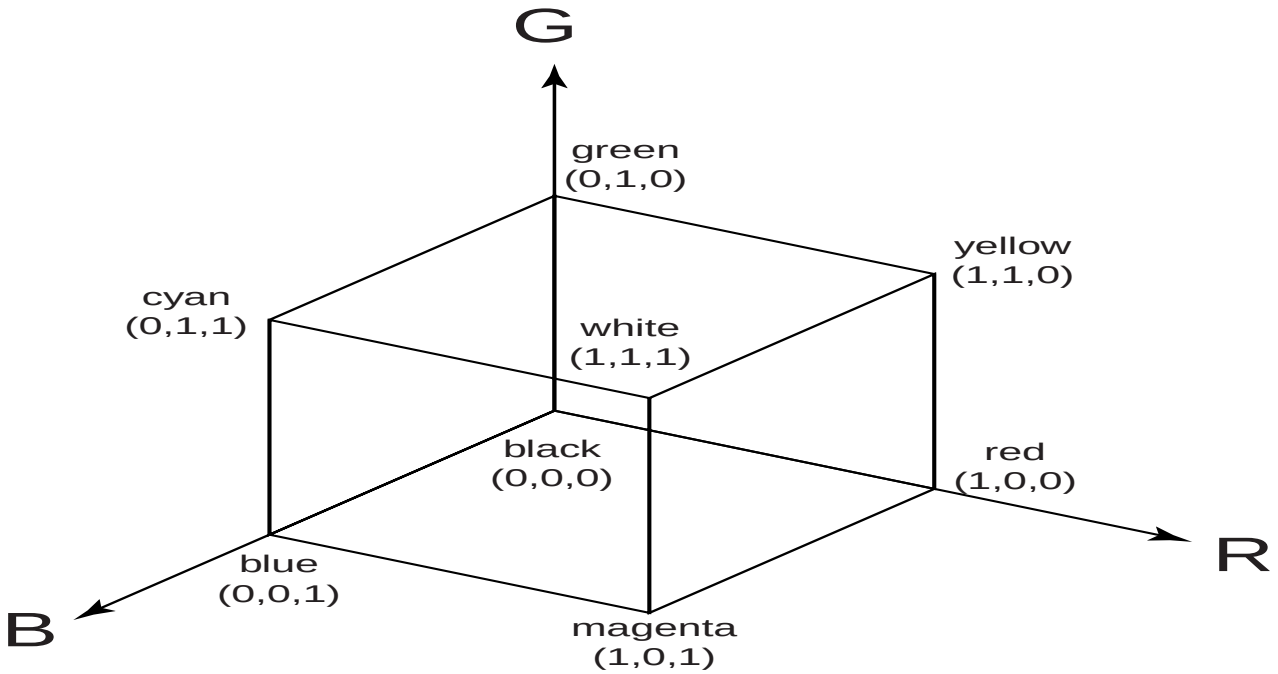


Most color monitors employ **shadow mask** technology:

- uses **triads** of red, green, and blue phosphors at each pixel
- uses three electron guns, one per color
- **shadow mask** used to make each kind of phosphor only "visible" from one gun

These are also known as **RGB monitors**.

Additive color mixing



All colors on a monitor are produced using combinations of red, green, and blue.

A monitor that allows 256 voltage settings for each of R, G, and B is known as a **full-color system**.

The description of each color in framebuffer memory is known as a **channel**.

Specifying colors

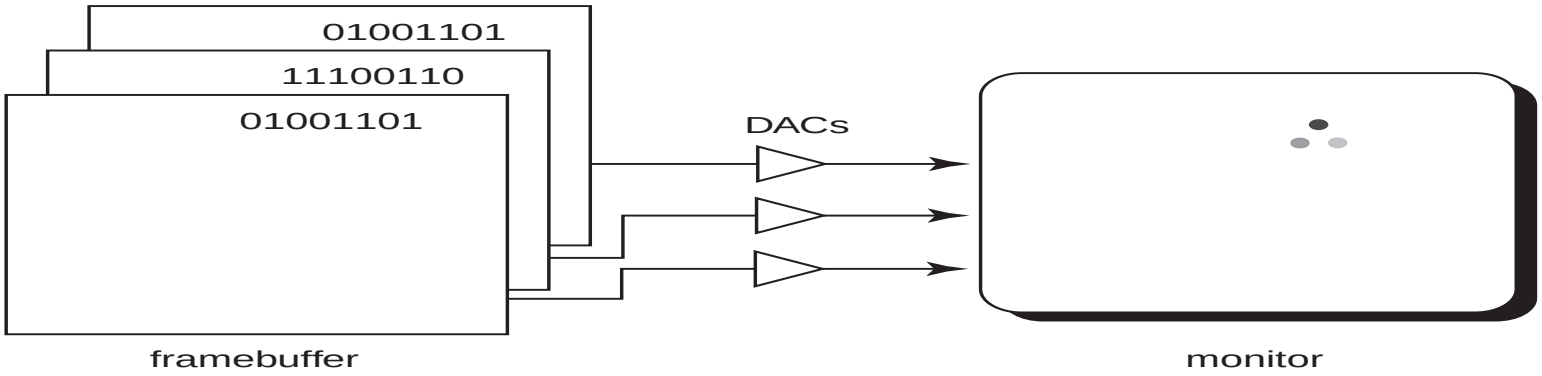
The number of color choices depends on the amount of framebuffer storage allocated per pixel.

Q: How many colors can be displayed with:

- 3 bits per pixel?
- 8 bits per pixel?
- 24 bits per pixel?

16 bpp systems often allocate 5 bits to red, 6 to green, and 5 to blue. Why does green get the extra bit?

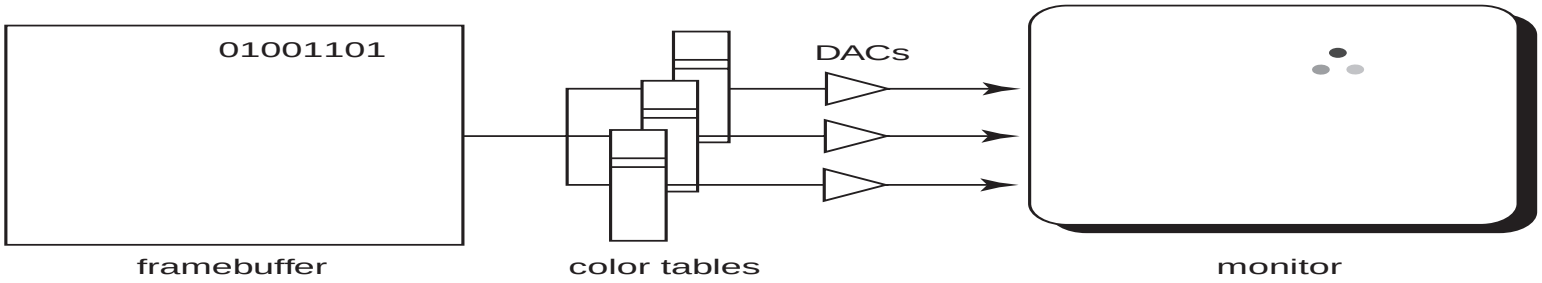
RGB framebuffer



The term **true-color** is sometimes used to refer to systems which the framebuffer directly stores the values of each channel.

Color tables

Color tables allow more color versatility when you only have a few bits per pixel. You get to select a small **palette** of from a large number of available colors.

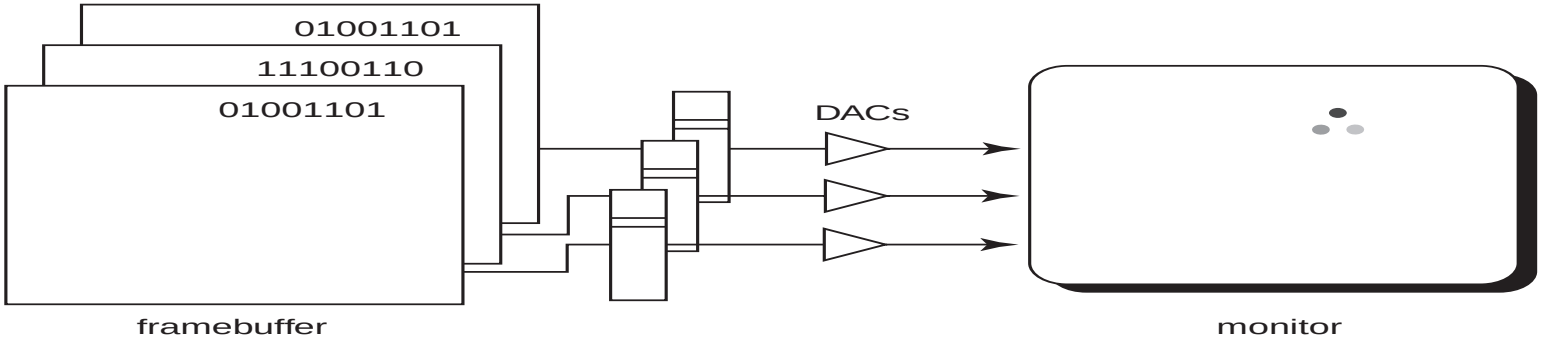


Each framebuffer element is now an index into the color table, where the actual values of each channel are stored.

- Color table entries can be changed in software.

Color tables on 24-bit systems

Even full-color systems often use color tables. In this case, there is a separate color table for each 8 bit channel.



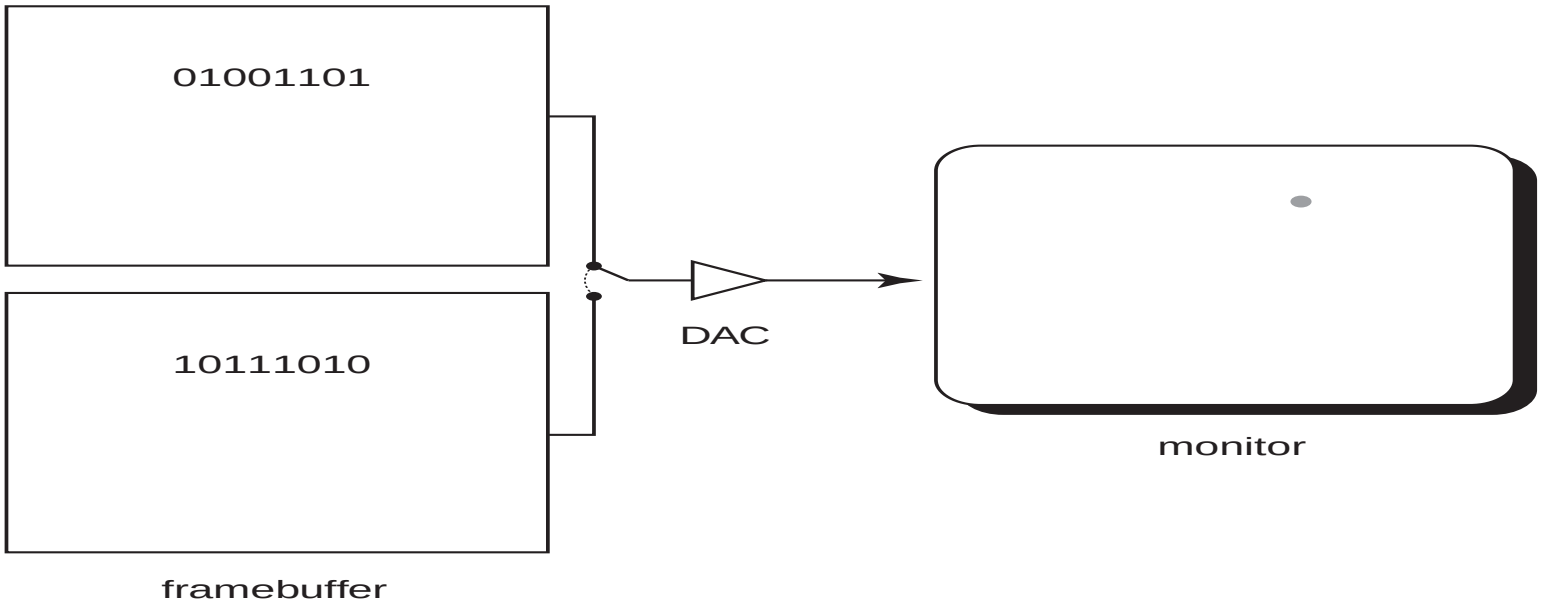
Most SGI workstations are like this.

Q: Why would you want this capability?

Double-buffering

Q: What happens when you write to the framebuffer while it is being displayed on the monitor?

Double-buffering provides a solution.



Summary

Here's what you should take home from this lecture:

- The basic components of black-and-white and color CRTs
- All of the **boldfaced terms**
- Computing screen resolution & framebuffer size
- The correspondence between elements of framebuffer memory and pixels on-screen
- How color tables work
- How double-buffering works