

# CS 200

## Lecture 04

### Geometric Graphics

(aka Vector Graphics)

# Miscellaneous Notes

## Abbreviations

aka	Also Known As
dpi	Dots Per Inch
HCGW	How Computer Graphics Works (a book)
NDWB	The Non-Designer's Web Book
ppi	pixels per inch

Please note that although we are not using Adobe Illustrator, Inkscape follows the same model.

## As for Inkscape...

concentrate on *what* we do, not *how* we do it

## Resources you might like to know about if you own a Mac

“Take Control of Fonts in Mac OS X” by Sharon Aker (\$20 eBook)

<http://www.takecontrolbooks.com/fonts-macosx.html>

Also available as “Real World Mac OS X Fonts” from Peachpit Press (ISBN 0-321-47401-5, \$40 US)

— and contains “Take Control of Font Problems in Mac OS X,” another eBook by Sharon Aker

Moving fonts back and forth between Windows and Macintosh PCs

TransType, from [www.fontlab.com](http://www.fontlab.com)

On either platform: “Real World Adobe Illustrator” by Morty Golding, from [www.PeachPit.com](http://www.PeachPit.com) (CS2/e, CS3/e or CS4/e).

# Administrivia

**BEFORE lab this week, please read and high-light**

- Assignment 4
- This week's slides

**Major topics this week**

- Geometric Graphics
- Bézier Curves
- The Toy Pearl

**Visit Learn / Week 4: Geometric Graphics / Files for Geometric Graphics**

- for this week's lecture demo files (Bézier curves), including some short QuickTime movies

Note: the movies created are from a different application (CorelDraw) but the model of Bézier curves is the same.

**Please ask questions!**

# The Toy Pearl

## Toy application documents

- experiment with one feature in a small (ie. simple) document
  - so you don't mess up a "production" document
  - so the feature of interest isn't confused with other features
- save these documents
  - so you can come back to them later



# Assumptions

**You have now used a pixel graphics program: Gimp or Photoshop**

**You understand:**

- basic geometry
- coordinates of a figure

# Things to Think About

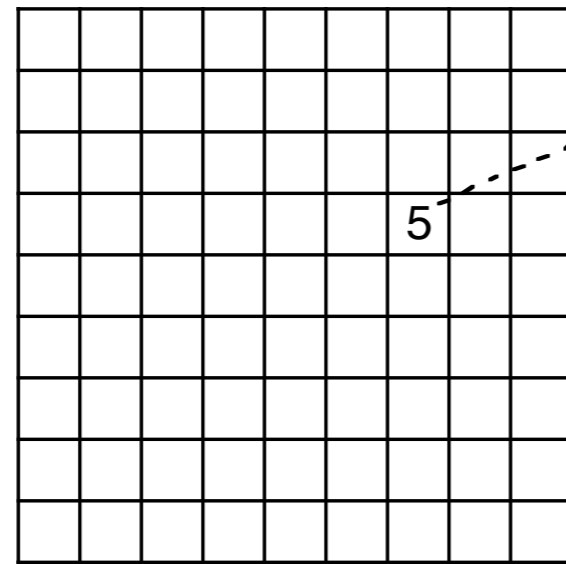
**How do the data objects differ in pixel and geometric graphics?**

**Is there more than one way to do a task?**

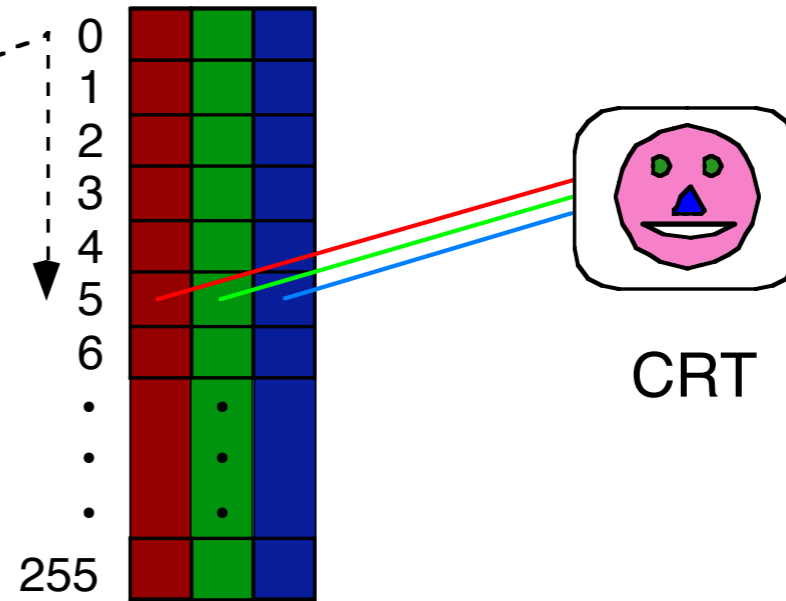
**What are deficiencies/inefficiencies of the interface?**

**What are efficiencies of the interface?**

# A Typical 2-d Geometric Graphics Drawing



Video Memory  
8 bits (1 byte) / pixel  
“Indexed Colour”  
(used by GIFs)



Colour Lookup Table  
(3 bytes / entry)

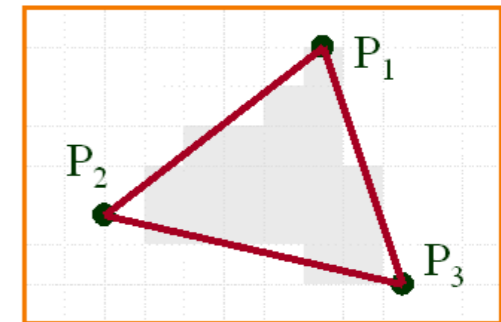
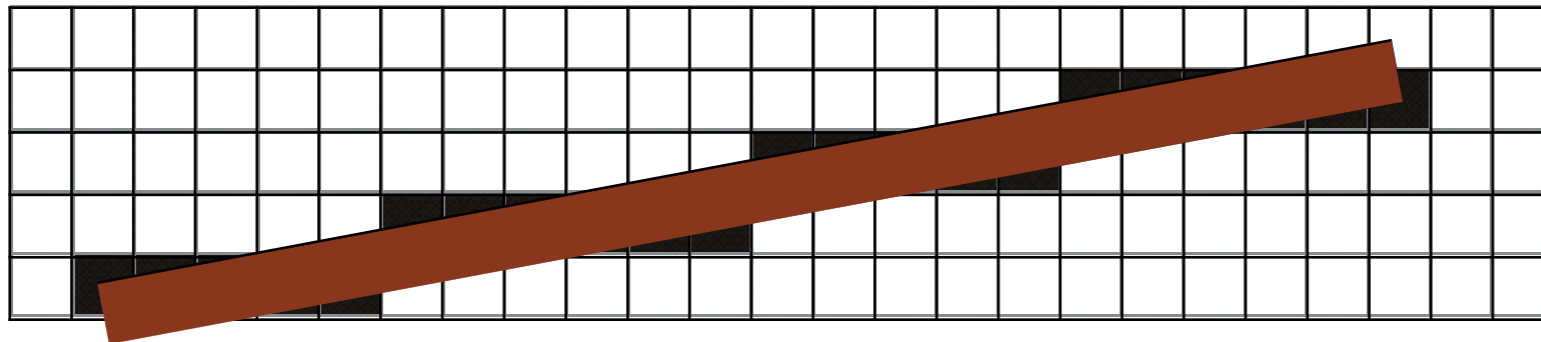
# “A (geometric graphics) drawing is a collection of geometric objects”

## To a pixel-graphics program

- a line is just pixels
- once drawn, the fact that these approximate a line is forgotten — all the program remembers is the pixels

## To a “drawing program”

- a line is a pair of end-point locations
  - eg. “line from (1,0) to (22,3)”
- the program determines which pixels must be illuminated to represent the line but remembers the geometric definition of the line, and which pixels were drawn to represent which geometric object;



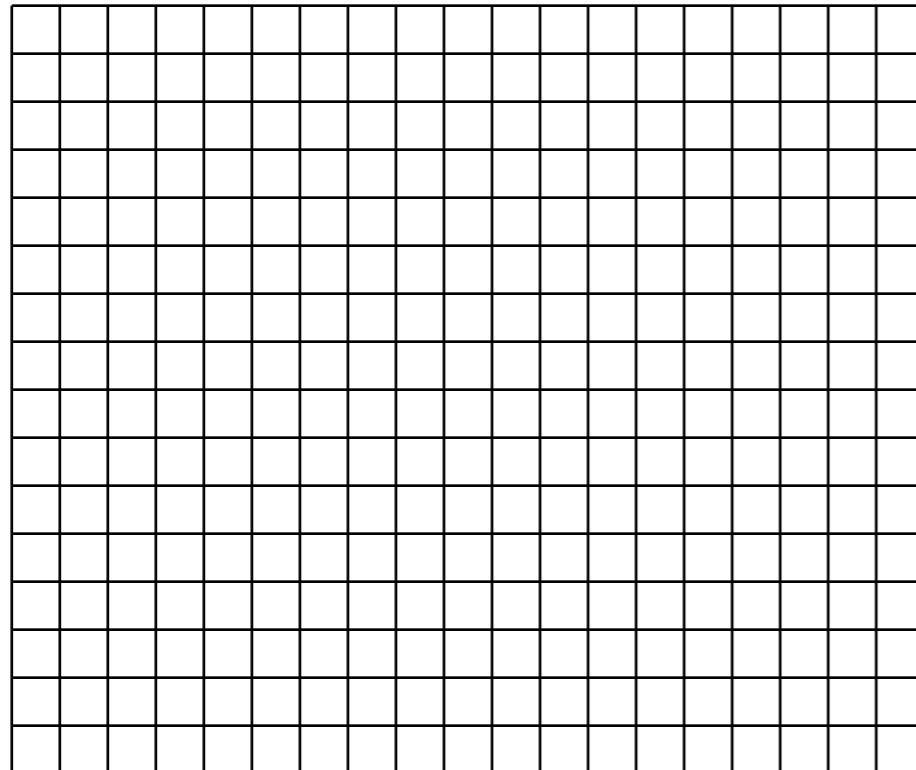
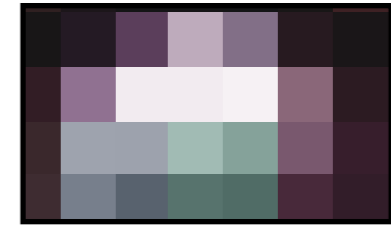
- if you scale the line by  $2x$ , it re-computes which pixels should be illuminated
- if you click on a pixel generated by the line, you can then manipulate the mathematical representation of the line, which is “re-rendered” into pixels periodically as you change it (remember — video memory is re-displayed every 60th of a second or more)



# Pixel vs Geometric Graphics (1)

## Pixel Graphics

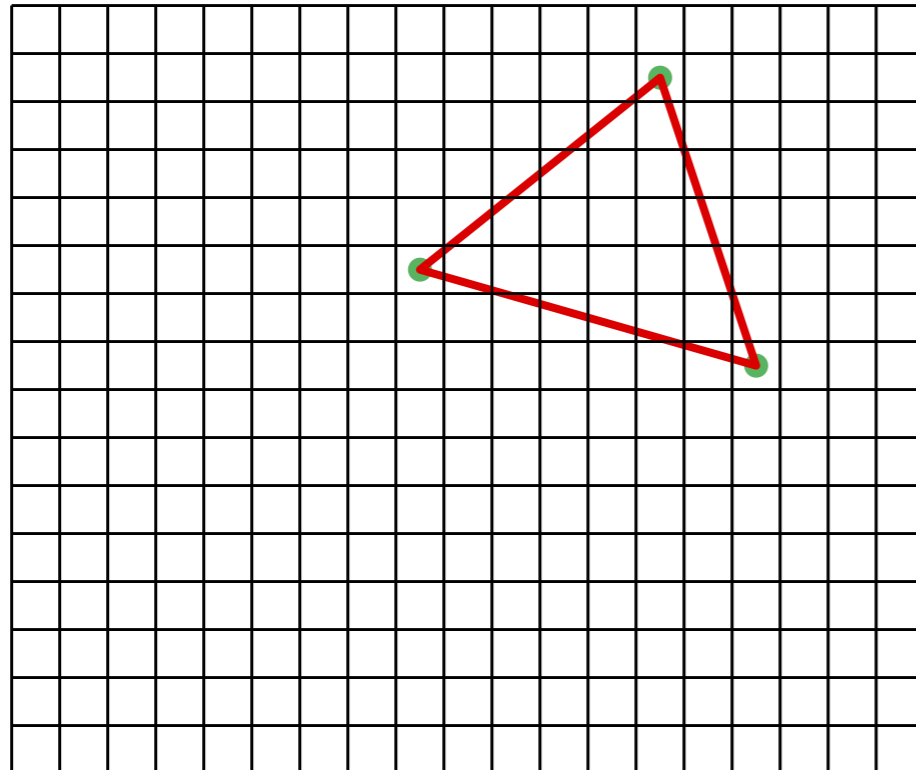
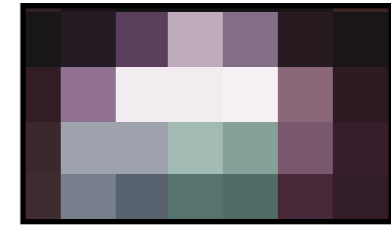
- the program manipulates pixels
- you zoom an image by replicating pixels



# Pixel vs Geometric Graphics (2)

## Pixel Graphics

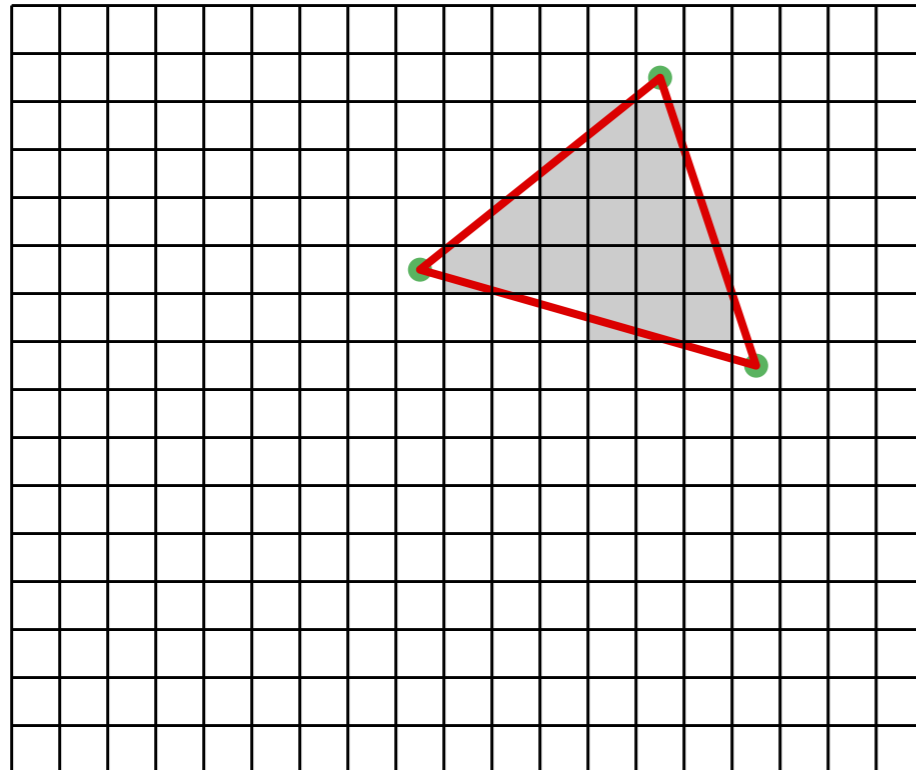
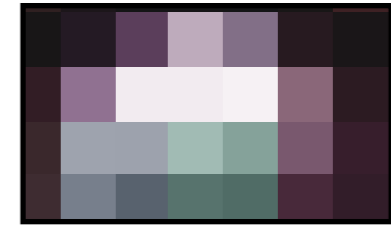
- the program manipulates pixels
- you zoom an image by replicating pixels



# Pixel vs Geometric Graphics (3)

## Pixel Graphics

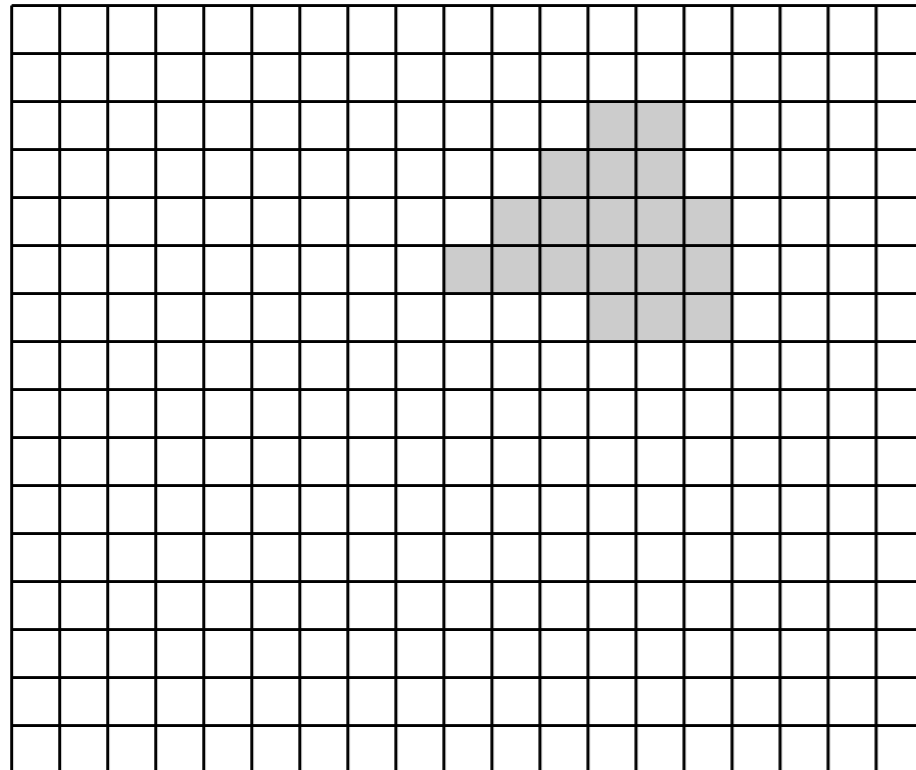
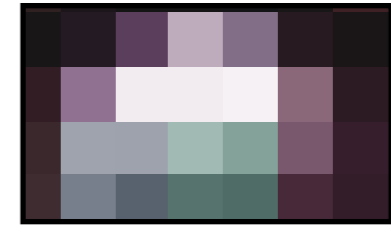
- the program manipulates pixels
- you zoom an image by replicating pixels



# Pixel vs Geometric Graphics (4)

## Pixel Graphics

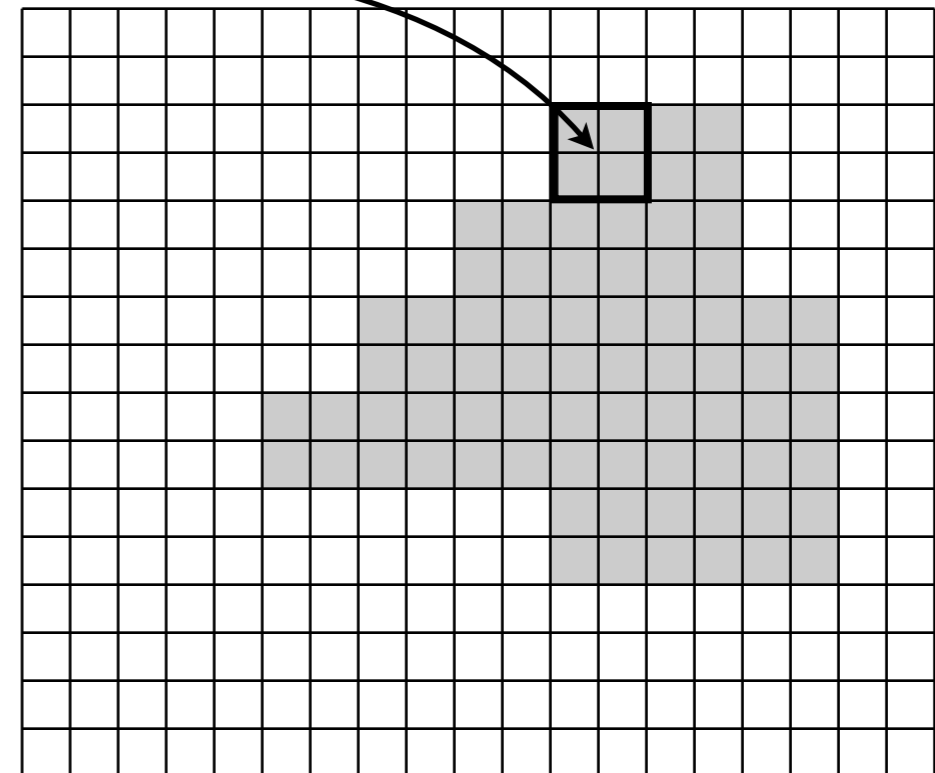
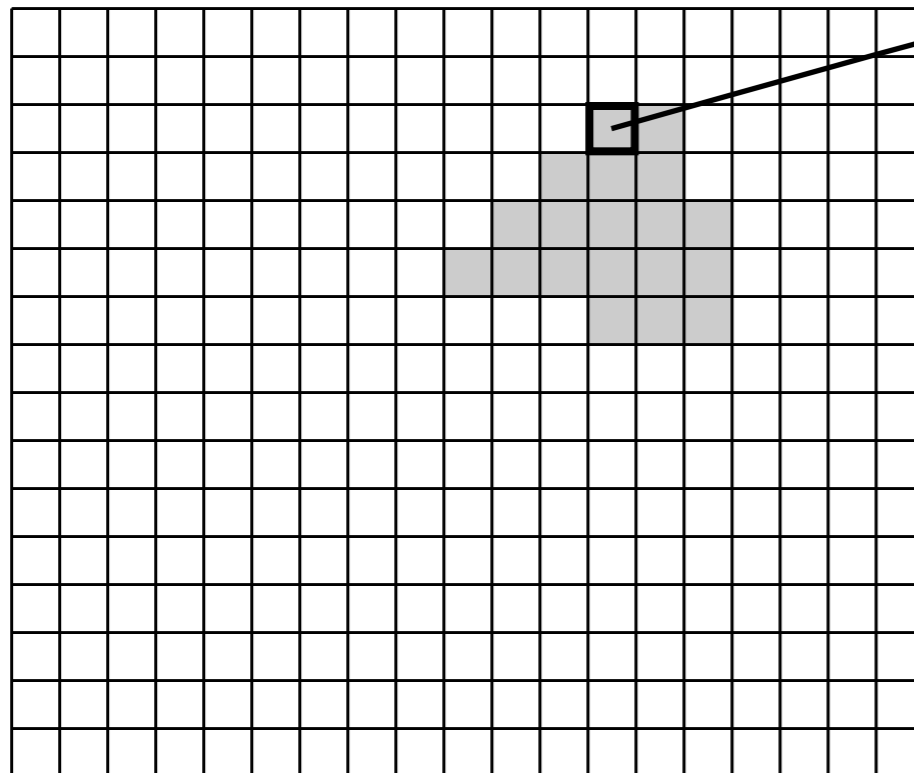
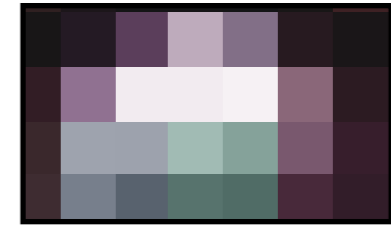
- the program manipulates pixels
- you zoom an image by replicating pixels



# Pixel vs Geometric Graphics (5)

## Pixel Graphics

- the program manipulates pixels
- you zoom an image by replicating pixels

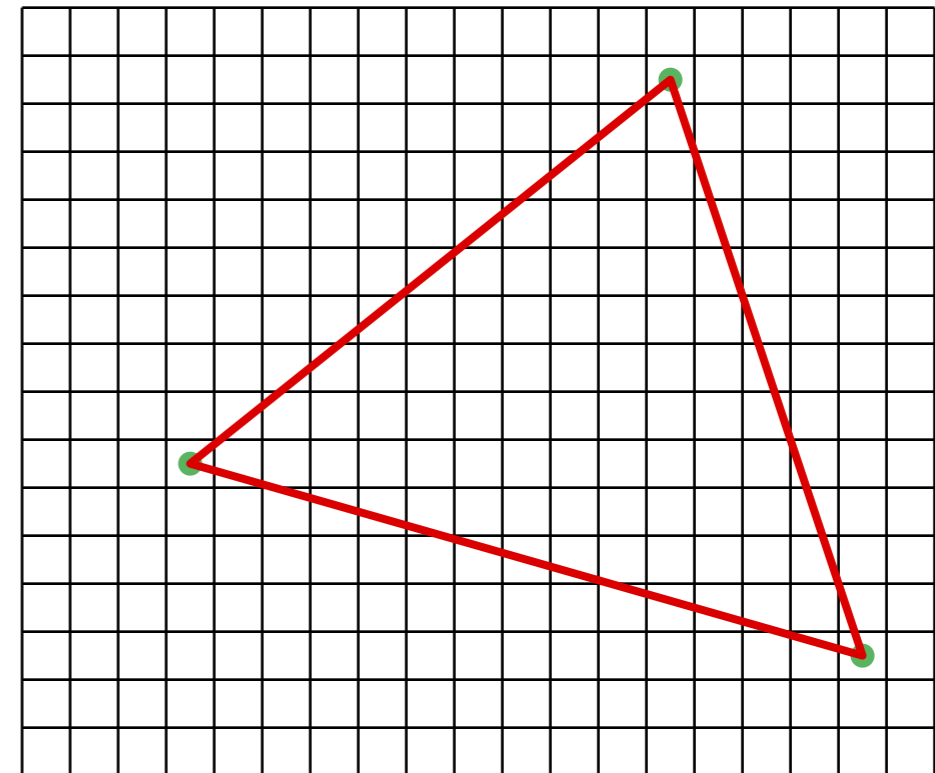
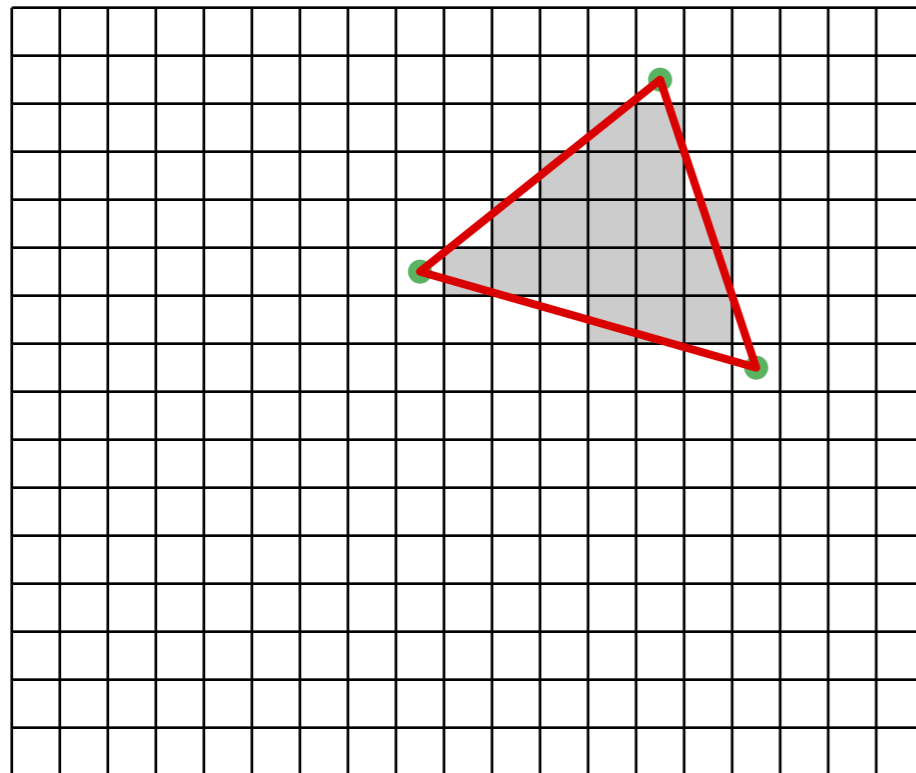


*Our triangle, at 2x zoom  
Notice the increased jaggedness*

# Pixel vs Geometric Graphics (6)

## Geometric Graphics

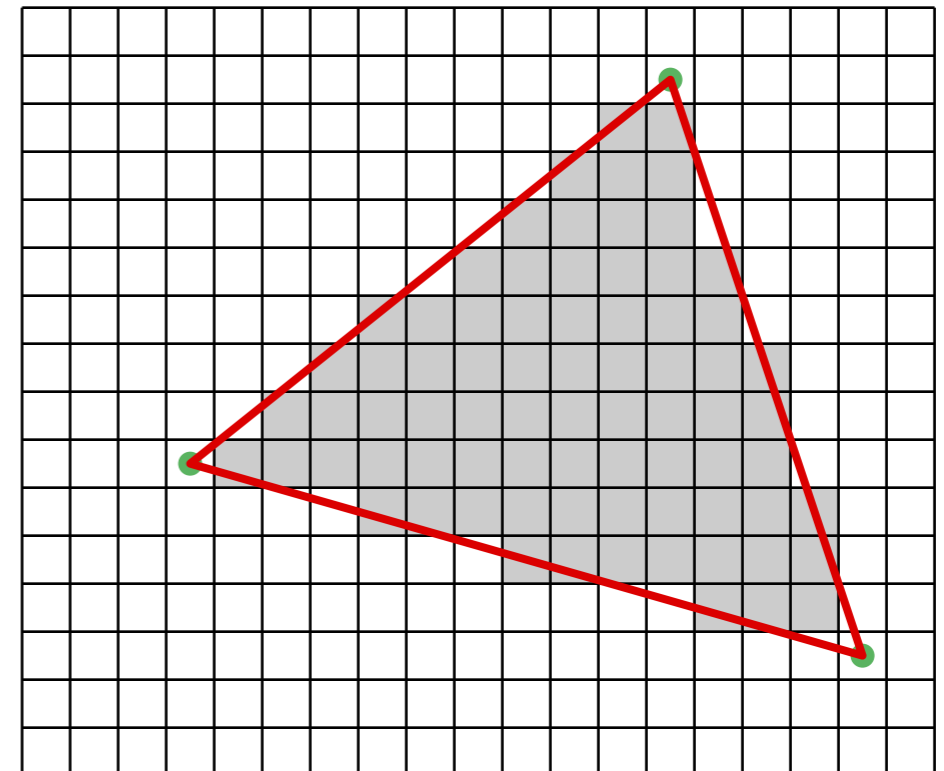
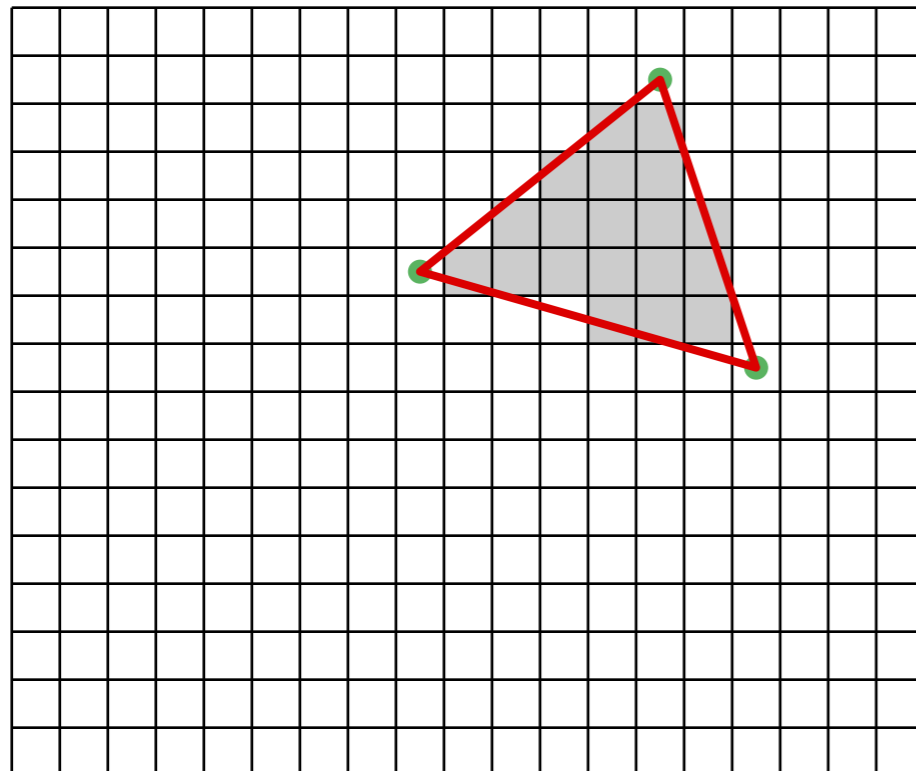
- “sit on top of” pixel graphics
- you define geometric objects (lines, rectangles, circles, etc)
- the program
  - remembers these objects
  - allows you to reshape/edit them
  - re-draws them in video memory whenever they are altered
- so when you zoom in on the triangle, say by 2x
  - first you scale up the triangle



# Pixel vs Geometric Graphics (6)

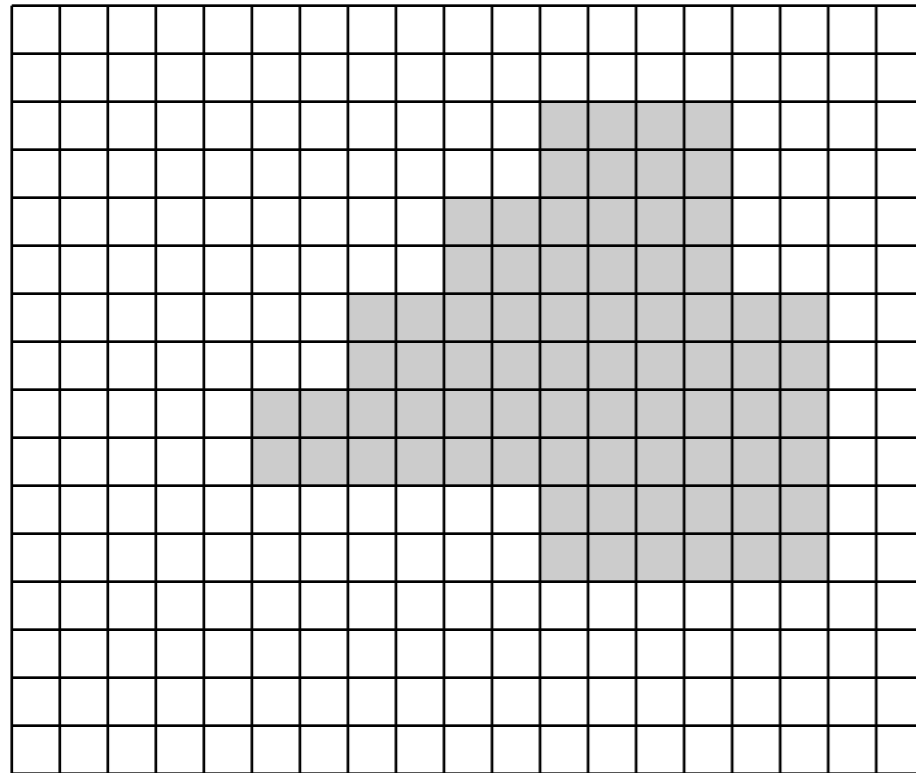
## Geometric Graphics

- “sit on top of” pixel graphics
- you define geometric objects (lines, rectangles, circles, etc)
- the program
  - remembers these objects
  - allows you to reshape/edit them
  - re-draws them in video memory whenever they are altered
- so when you zoom in on the triangle, say by 2x
  - first you scale up the triangle
  - then you determine which pixels are covered by the new & larger triangle

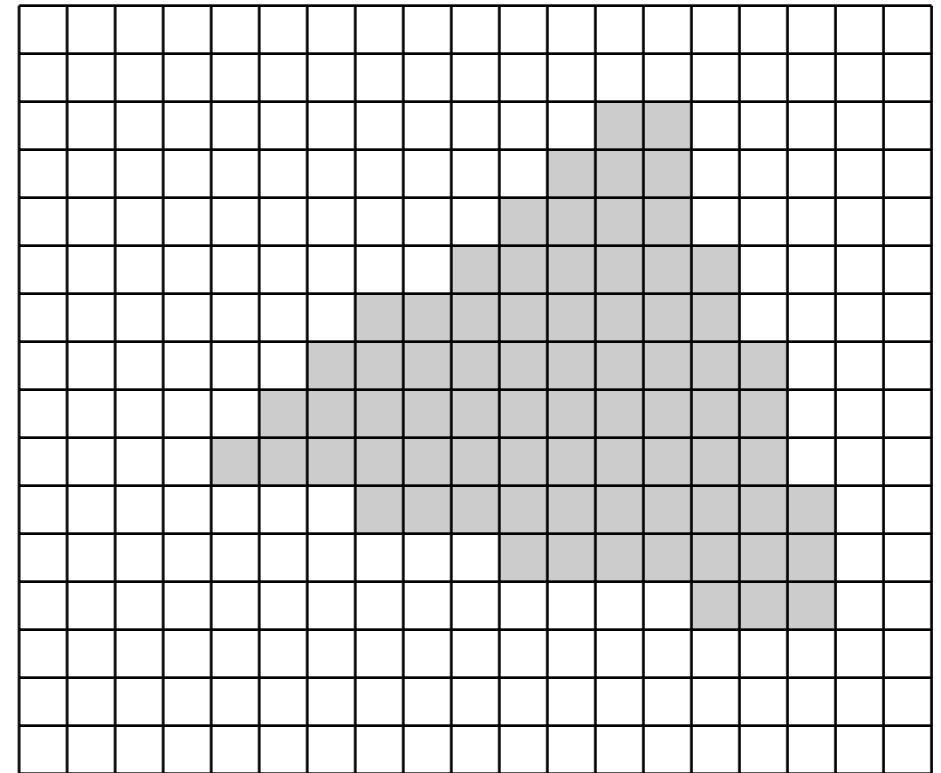


# Pixel vs Geometric Graphics (7)

**Pixel Graphics**  
— pixel replication



**Geometric Graphics**  
— scale the object  
— then recompute pixels



**A Geometric Graphics program zooms an image by scaling objects mathematically before re-drawing them**

- no pixel replication
- no additional jaggedness



# Drawing Standard Geometric Objects

## Drawing familiar objects

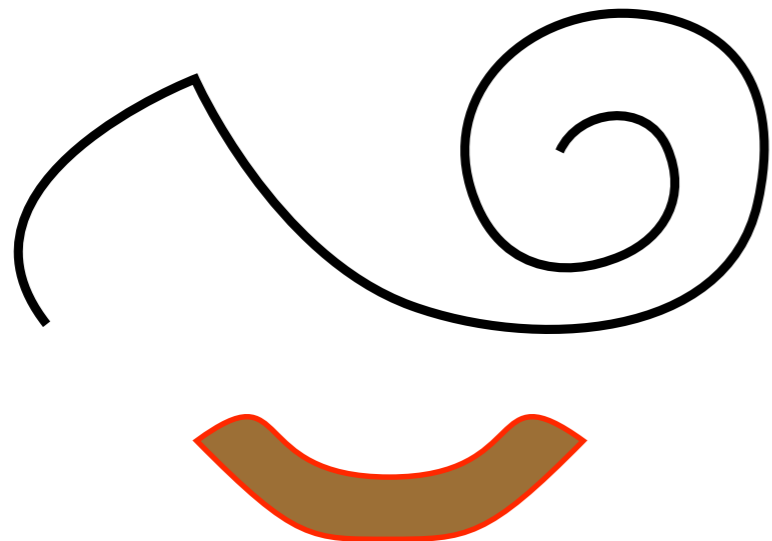
- lines and polygons
- ellipses and circles, rectangles and squares
  - **shift**-click-drag to “constrain” the object to a circle/square/...
  - **option**-click-drag to draw from the center

## Quasi-familiar objects

- text 

## Drawing unfamiliar objects

- Bézier curves & regions



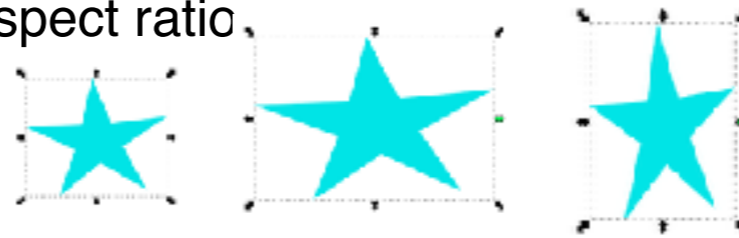
# Manipulating Objects as a Whole

## Select objects with the selection tool


- Click on object

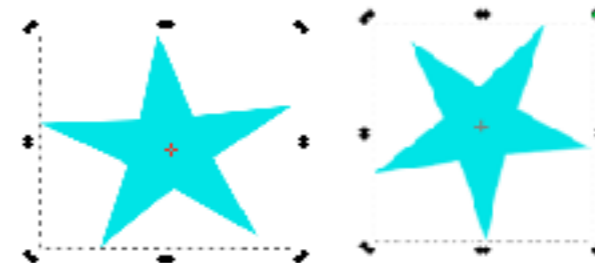
## Selection handles (common to many apps)

- click once on an object to display them
- click-drag a selection handle to scale the image
- shift-click-drag on a handle to preserve the aspect ratio
- click-drag the object itself to move it



## Rotation handles

- Using the selection tool, click on the object again
- Now the selection handles allow you to rotate the object
- You can also use the rotation icons in the toolbar 

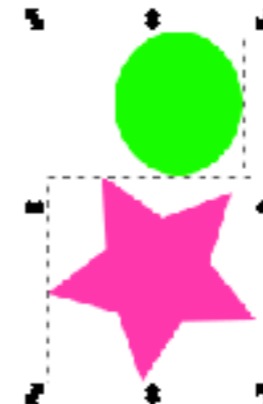


## Selecting multiple objects

- shift-click layers
- click–drag to surround all of them
- — either yields one set of common selection handles

The “opt” Mac key  
= the “alt” Win key

Note that in Inkscape, you use ctrl instead of cmd like in Windows programs.



# Stacking Objects – Who’s on Top?

Objects are drawn (“rendered”) into video memory in some order

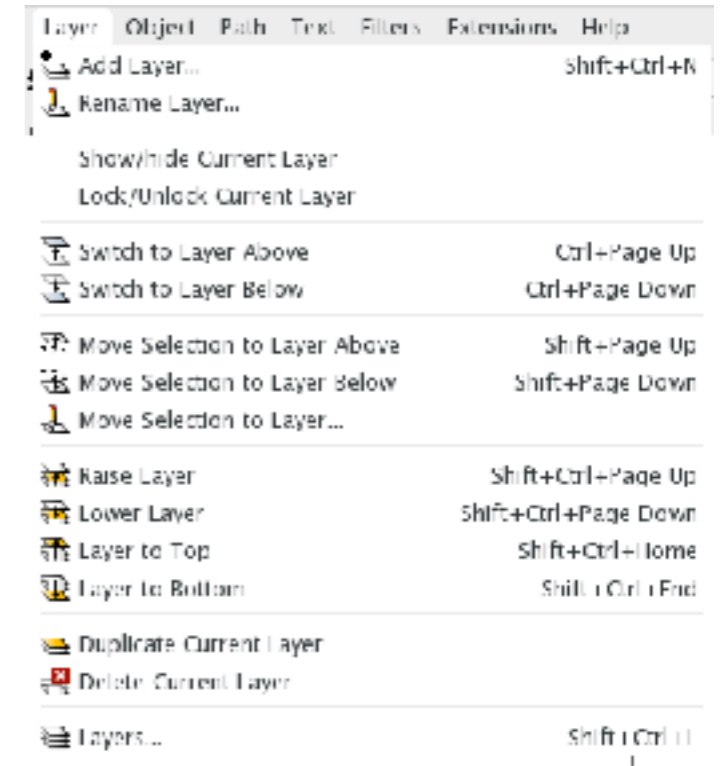
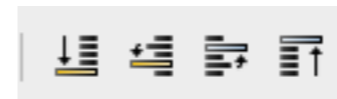
- drawn first ⇒ behind
- drawn last ⇒ in front



You can change the order...

If objects are in the same layer...

- select an object by clicking on it
- use these menu items to move the object up and down



To put objects in different layers (recommended)...

- select an object by clicking on it
- right click on the object and select “Move to layer...”
- select the destination layer
- Alternatively, create a new layer first (Layer > Add Layer...) and make an object in this layer



Changing order of layers...

- Use the arrows in the layers panel (show this panel by Layer > Layers...)
- or use the options in the Layer menu

Layer Icons...

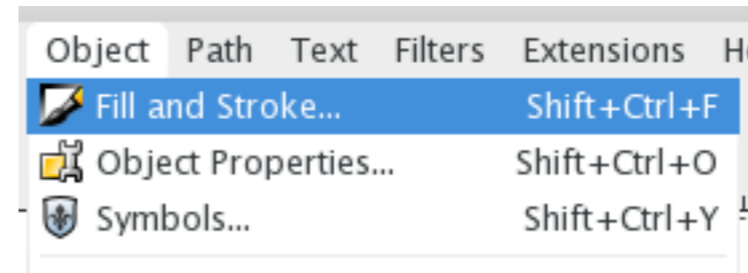
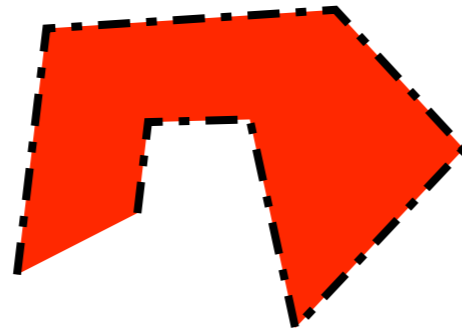
For each layer, click icons to say

- visible / invisible
- write-protected / writable

# Properties

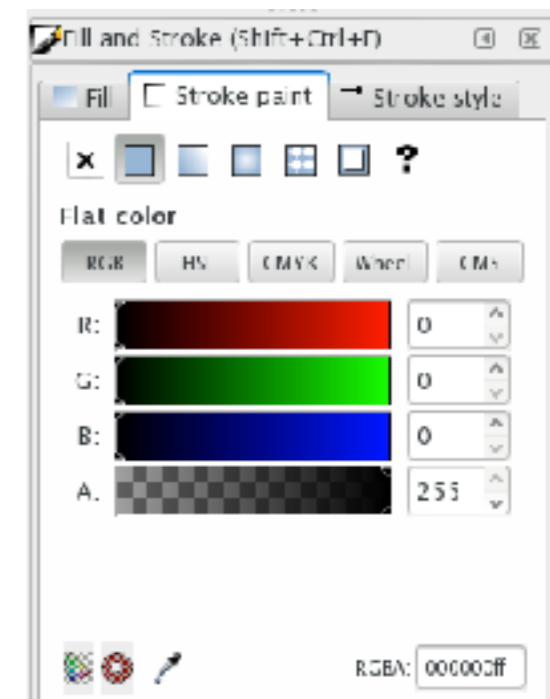
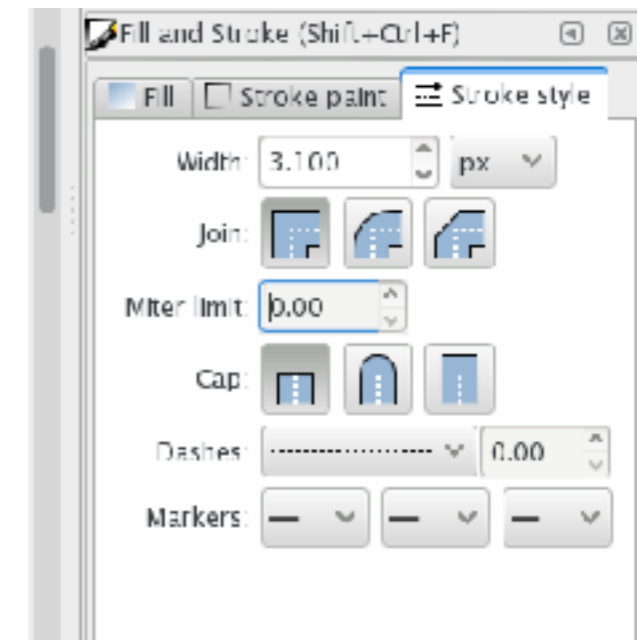
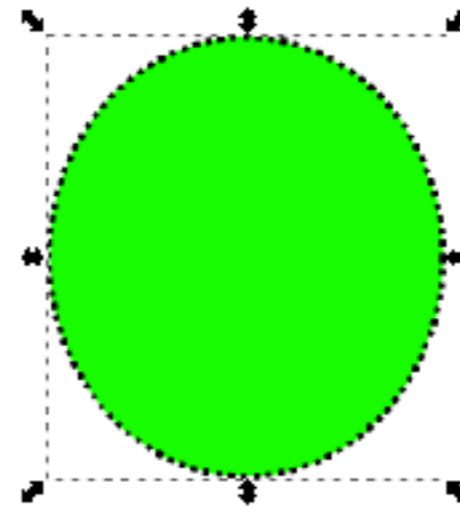
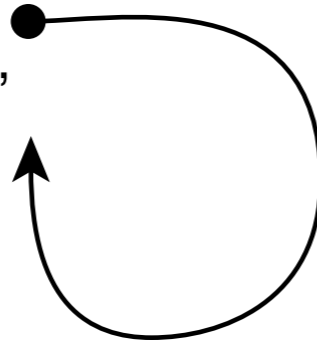
## Stroke

- line thickness
- boundary colour
- fill colour
- dash pattern
- corner and end cap shape
- arrowheads & other “effects”



**Hmm.**  
**There's not much difference between lines (aka “paths”) and regions (aka “shapes”)**

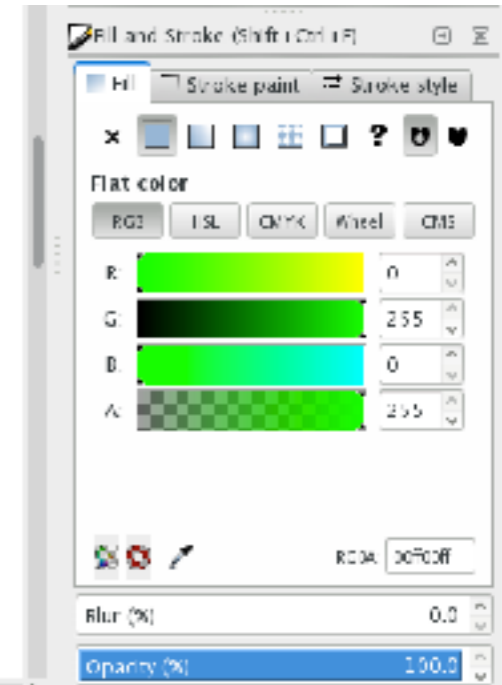
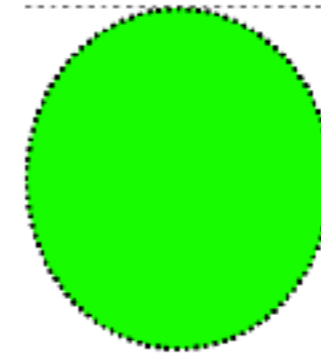
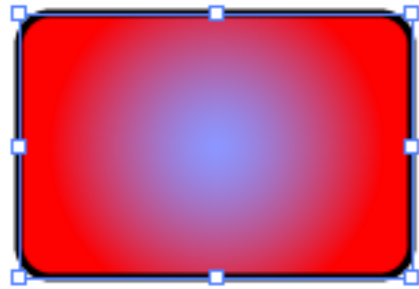
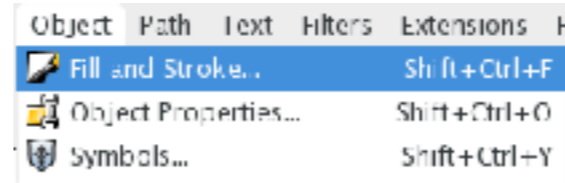
- open vs closed paths
- open paths have an interior... and so can be filled



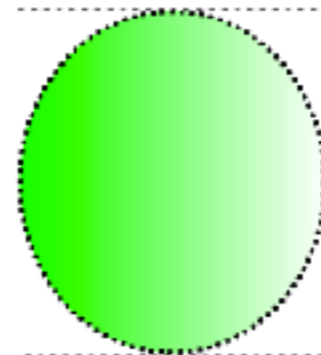
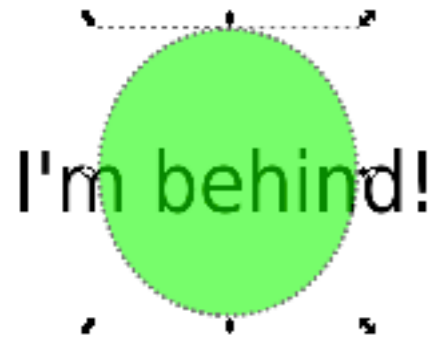
# More Properties

## Fill

- fill the interior of an object in various ways
- (including none)
- For a good time, try gradient fills

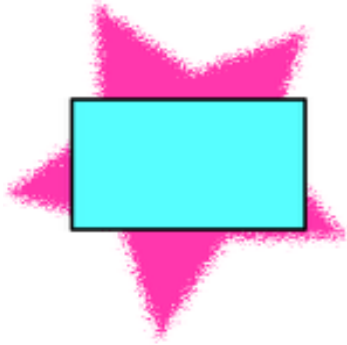


## Transparency (opacity = 100% – transparency)

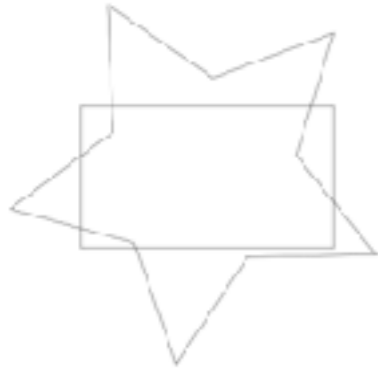


# View Modes

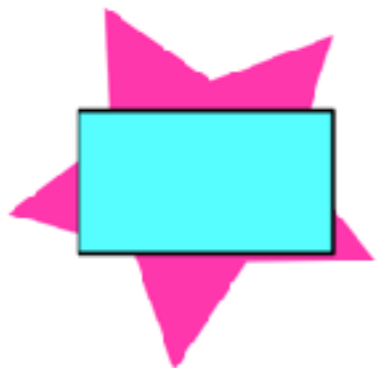
**View > Display Mode > Normal**



**View > Display Mode > Outline**

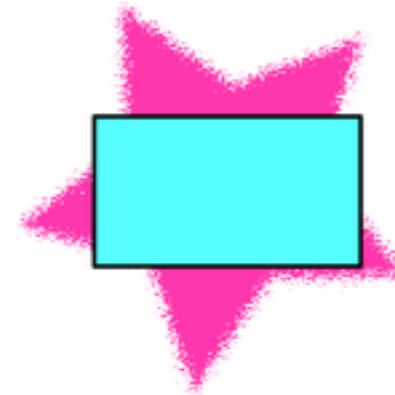


**View > Display Mode > No Filters**

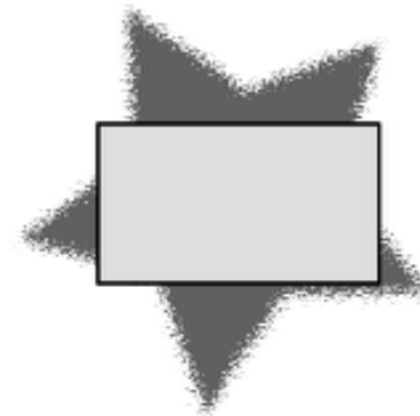


Note that changing the display settings doesn't change how it would appear when saved/exported as an image file, or how it would appear when printed.

**View > Colour Display Mode > Normal**



**View > Colour Display Mode > Grayscale**



# Bézier Curves

“Anchor Points” are where curve “segments” connect (“join”)

- this curve below has 5 segments

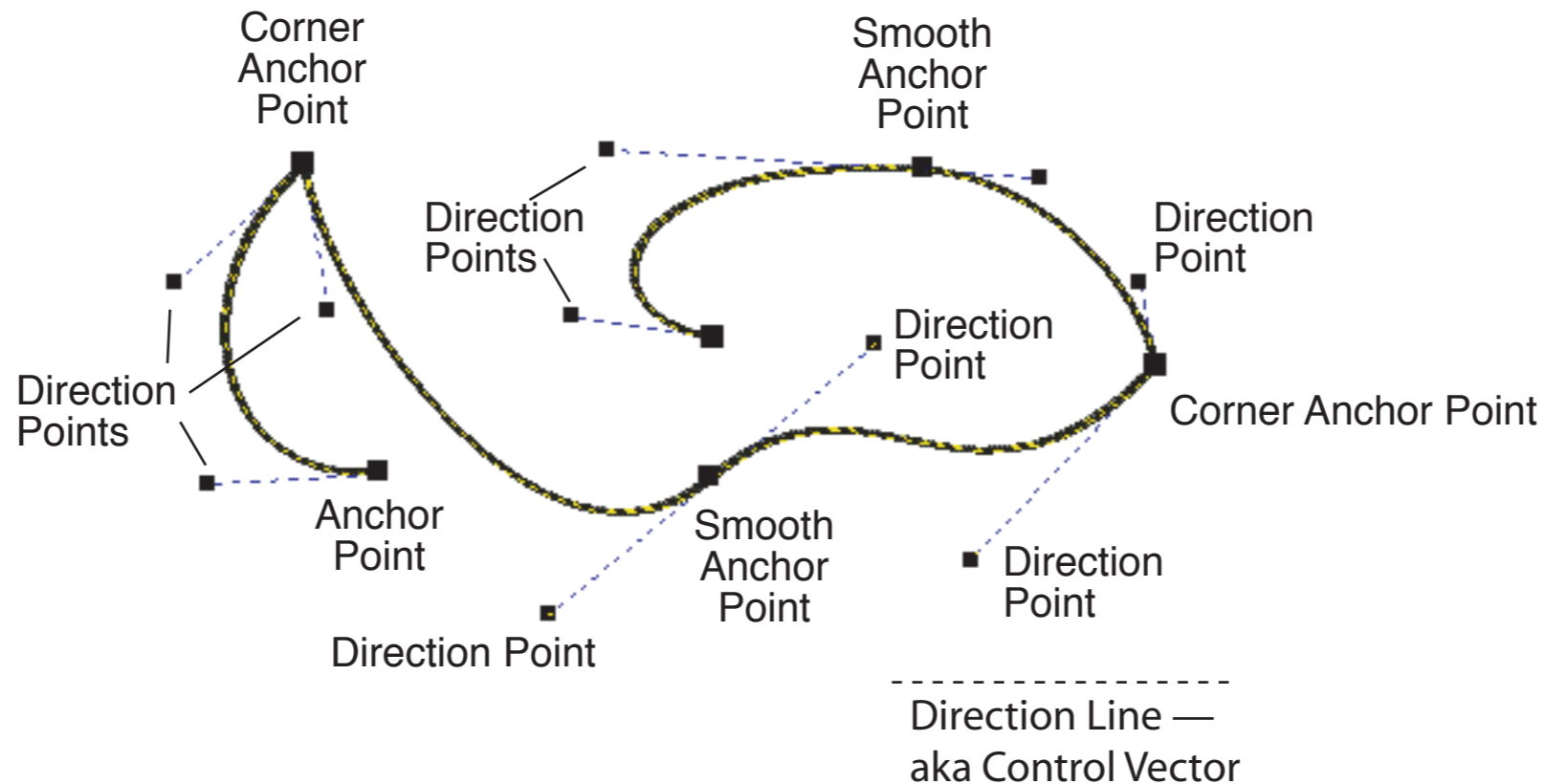
“Direction Lines” (aka “Control Vectors”) determine the curve’s direction at an anchor point

- they extend from an anchor point to a “direction point” (aka “control point”)
- direction lines are tangent to the curve at the anchor point

## Anchor Point types

- “corner” or “cusp” — the incoming & outgoing directions (ie tangents) are different (the corner is sharp)
- “smooth” — the incoming & outgoing directions (ie tangent directions) are the same
- “symmetric” — smooth, and the direction lines are the same length

Look up “pen tool” and “reshape curve” in Help > Photoshop Help



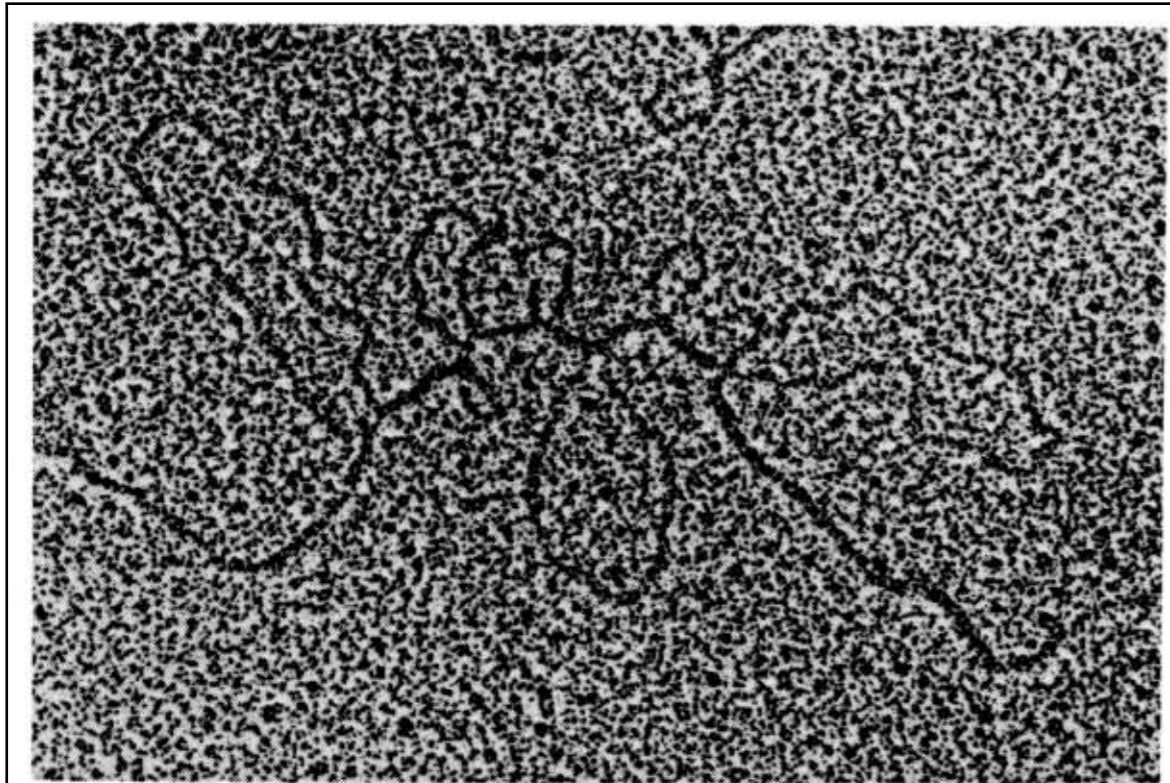
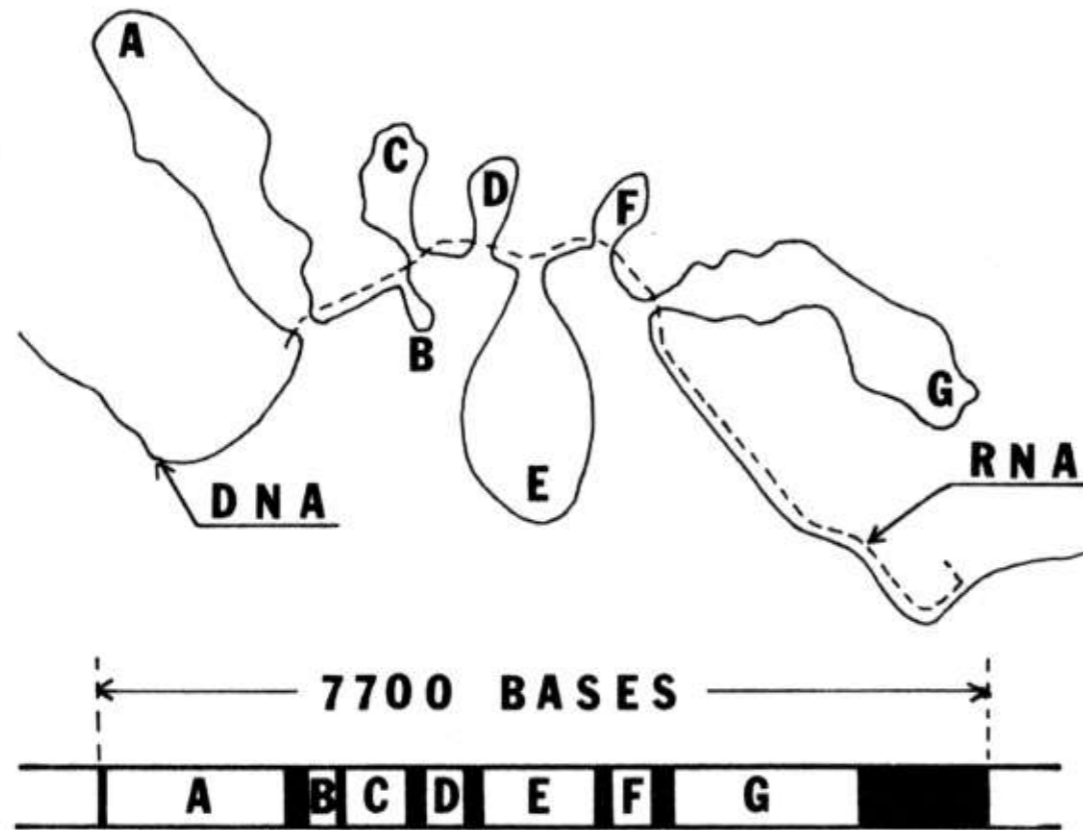
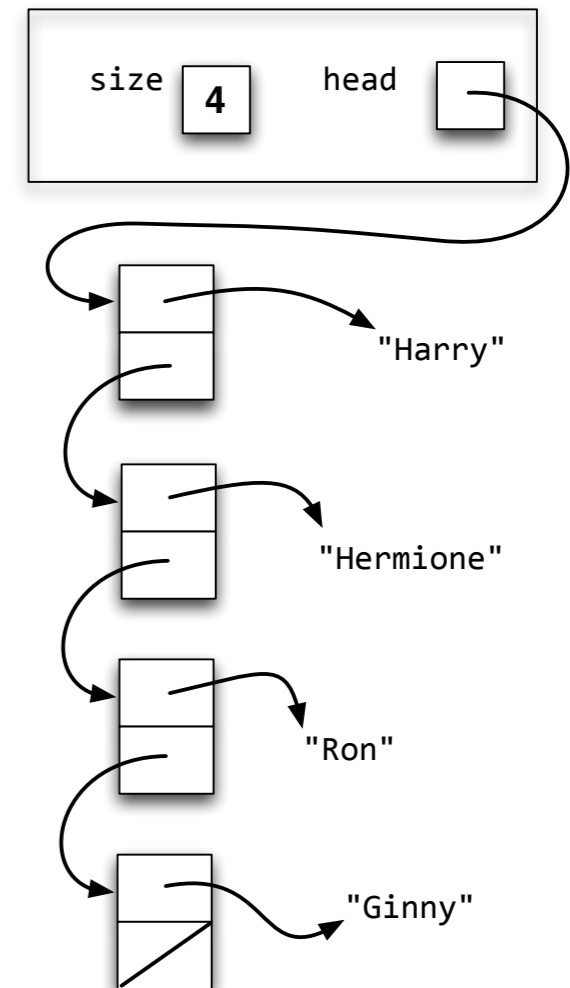


Figure 4.13 on page 85 of "The Design of Life" by Renato Dulbecco (1987).



A fairly typical CS 135 slide.





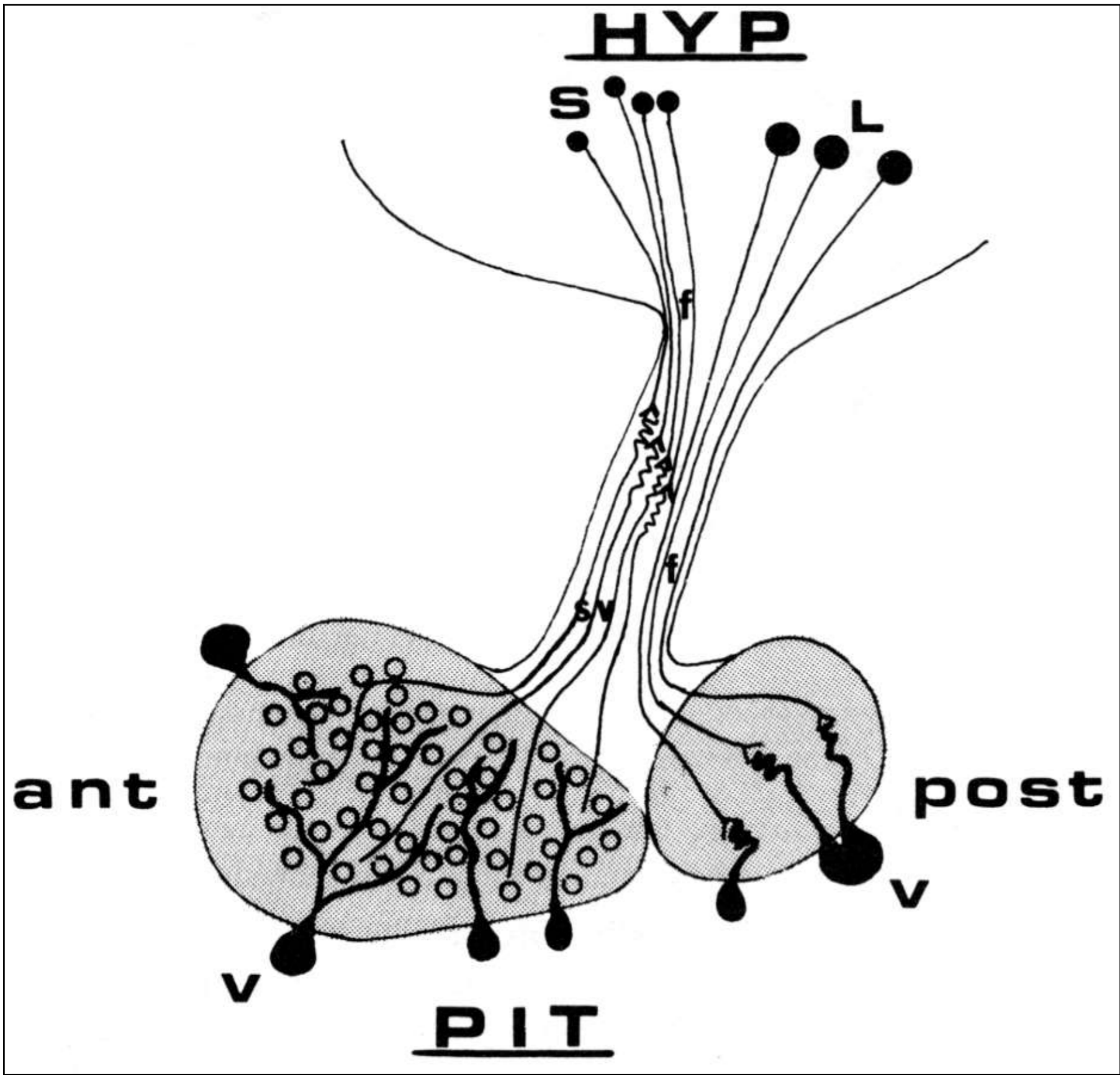
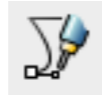


Figure 8.3 on page 152 of "The Design of Life" by Renato Dulbecco (1987).

# Creating a Bézier Curve

Click the Pen tool button



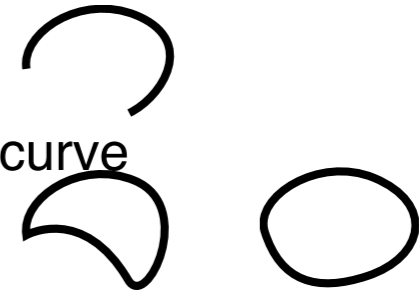
Click–drag–release repeatedly to define each segment

- click to place the next anchor point (node)
- then drag to pull out that anchor point's outgoing direction line




Click-release, click-drag elsewhere to create a corner point with no direction lines

**Open Curve:** double-click or press Enter when you're finished defining an open curve

**Closed Curve:** click-drag on the starting point to finish creating a closed curve



**Important hints!**

- the fewer anchor points, the better — it makes the curve easier to reshape
- don't try to edit the curve as you (initially) draw it
  - you can add (new) intermediate anchor points later (see next slide) 
- to change one direction point without the other, press shift while moving the direction points
- to create a node with only one direction point, press shift before making direction points
- **to extend a Bézier curve created previously**
  - select the existing Bézier curve
  - select the Pen (Bézier) tool and move it over the relevant end point
    - the end node changes from white to red when you're over the end point  
  - click on the end anchor point and
    - drag elsewhere to create a smooth join & another segment, or
    - release and click-drag elsewhere to create a corner join & another segment

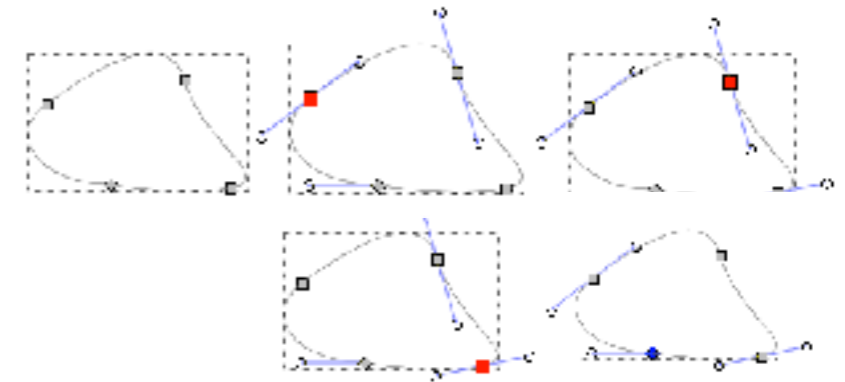
# Editing (Reshaping) a Bézier Curve

Use the **Edit Paths by Nodes Tool**




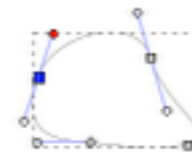
## To move an anchor point

- click on the curve in a segment ending at the anchor point, or click-drag to create a selection box containing the anchor point
- then click-drag the anchor point



## To change the direction of a curve at an anchor point

- click on a curve segment ending at that anchor point, or drag a selection box around the anchor point to select it thus making its direction lines visible
- then click-drag one of the anchor point's direction points
- to move a direction point individually, click on the node and then click  in the toolbar to make the selected nodes a corner



**See online help for more detail (& stay away from the pencil tool...)**

**There are movies illustrating the above on oscar in**

Learn / Week 4: Geometric Graphics / Files for Geometric Graphics / Bézier Movies

**You can also click-drag on the curve itself**

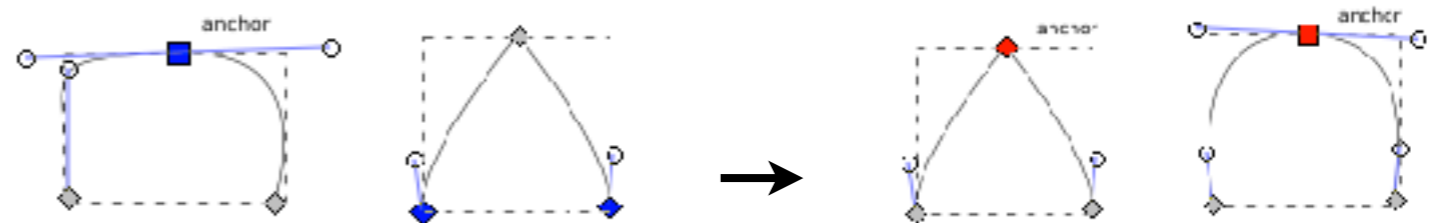
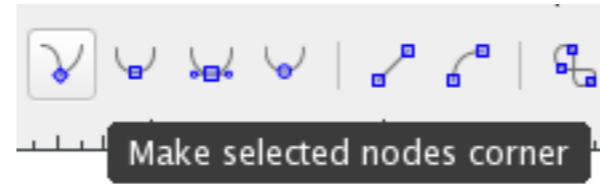
- but that usually isn't very useful;
- somewhat better: click drag to select & move one or more segments

# Other things you can do to a Bézier curve

You can also



- add an anchor point
- delete an anchor point
- change a smooth join to a corner join; this allows you to edit the direction vectors independently
- change a corner join to a smooth join
- join two end anchor points
- cut a curve into pieces
- continue an existing curve
- and other stuff...
  - poke around (try control-clicking)
  - see Inkscape’s online help



**Suggestion: learn how Bézier curves work by playing with toy curves before you do the assignment**

- serious geometric graphics programs now all have Bézier curves, though the terminology & interaction techniques vary
- also, they’re usually just called “curves” or “paths”

**Fill, stroke, transparency & other properties just as for rectangles, etc**

# Text – Outline Fonts

Letter forms are represented by curved outlines

Guess how that's done 😊 *Yup, you guessed right — Bézier curves!*

## Adobe Type 1 “Postscript fonts” (Type 1)

- an adjunct of the postscript page description language that made laser printers so attractive in the mid-eighties
- underlay the Macintosh's early success
- comprised of two files
  - one containing “bit-mapped” screen fonts at particular sizes
  - one containing outline font definitions, for use when printing

*Text*  
*Text*

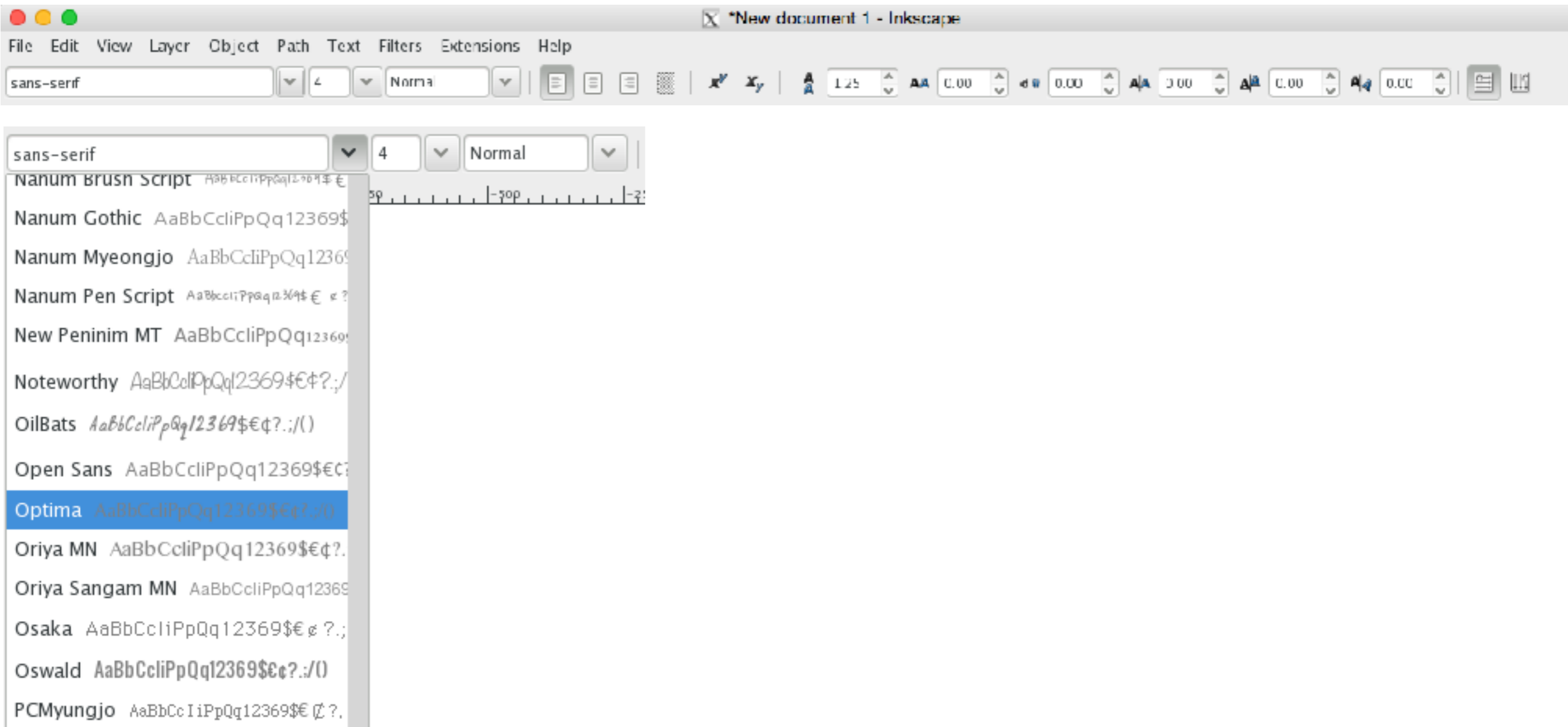
## TrueType (TT)

- created by Apple in the 80's because Adobe charged so much for licensing Type 1 technology
- subsequently adopted by Microsoft
- not as flexible as Type 1 format & harder for designers to work with
- Apple & Microsoft TT font files have different formats; Macs support both formats.

## OpenType (OT)

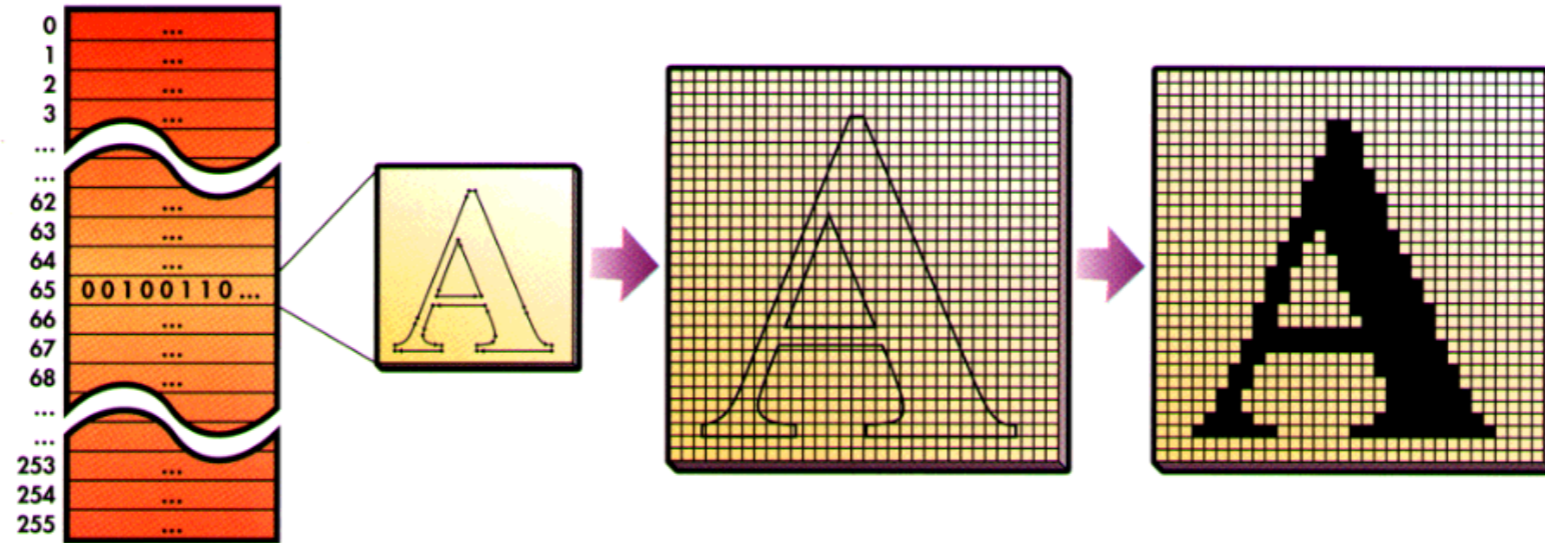
- created by Microsoft (1996–2000), later adopted by Adobe
- wraps & extends both Type 1 and TrueType font formats; works on both Macs and Windows PCs

# The Fonts Menu in Inkscape



This is the text menu icon

# How Text is Displayed

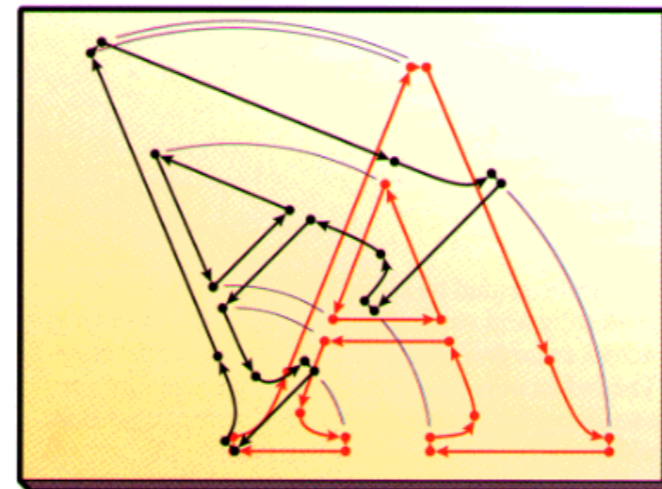


**1** Characters that belong to an outline font are arranged in tables like bitmapped fonts, but the table entries do not contain bitmapped images of the characters. Instead, they contain mathematical descriptions of the character outlines that permit characters to be scaled to any size. A character description is essentially a set of statements that tells the computer how to draw a series of connecting lines and curves that form the character outline.

**2** To draw a character, a piece of software called an *interpreter* reads and executes the statements. The result is a character outline scaled to the desired size. On systems that run Windows and use TrueType fonts, the interpreter is built into the operating system. On computers that utilize third-party font managers such as Adobe Type Manager, the interpreter is part of the font manager.

**3** After scaling is complete, a component of the interpreter called the *rasterizer* or *scan converter* decides which pixels to illuminate based on the shape described by the font outline. The scan conversion process can be as simple as illuminating all the pixels whose centers fall on or inside the character outline. Sometimes special considerations must be made, such as ensuring that all three legs of a lowercase *m* are the same width even if the character outline falls in such a way that one leg covers more pixel centers than the others. Font instructions to eliminate these irregularities, which are more pronounced at smaller scales, are called *hints*.

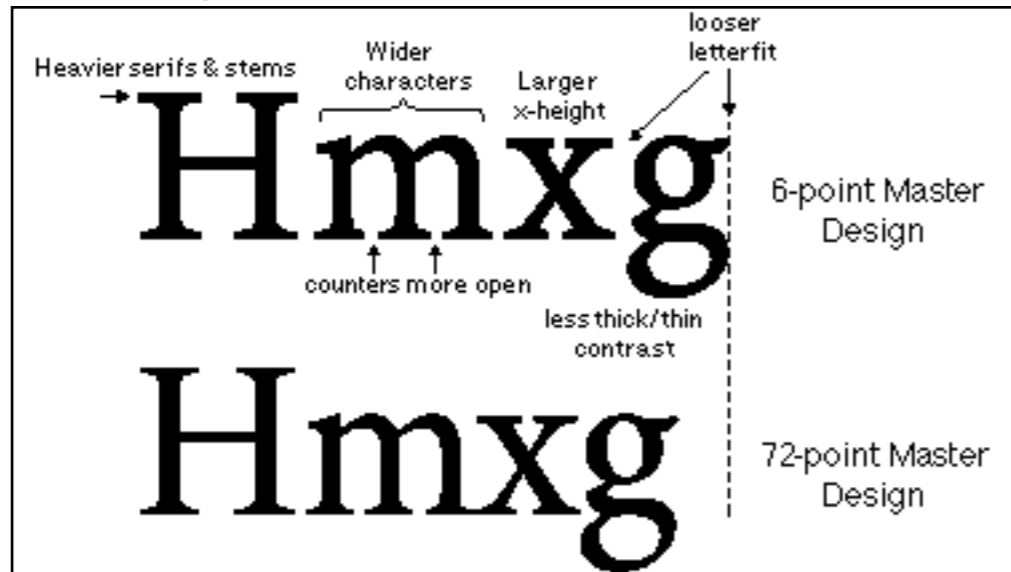
**4** Simple geometric transforms allow outline fonts to be rotated to any angle. To rotate an *A* counterclockwise 45 degrees, the interpreter recomputes the positions and orientations of the lines and curves before drawing the outline. Then it performs a routine scan conversion to fill in the dots.



# What's So Great About Outline Fonts (esp TT Fonts)?

Because they are “geometry-based” they scale w/o increased jaggedness

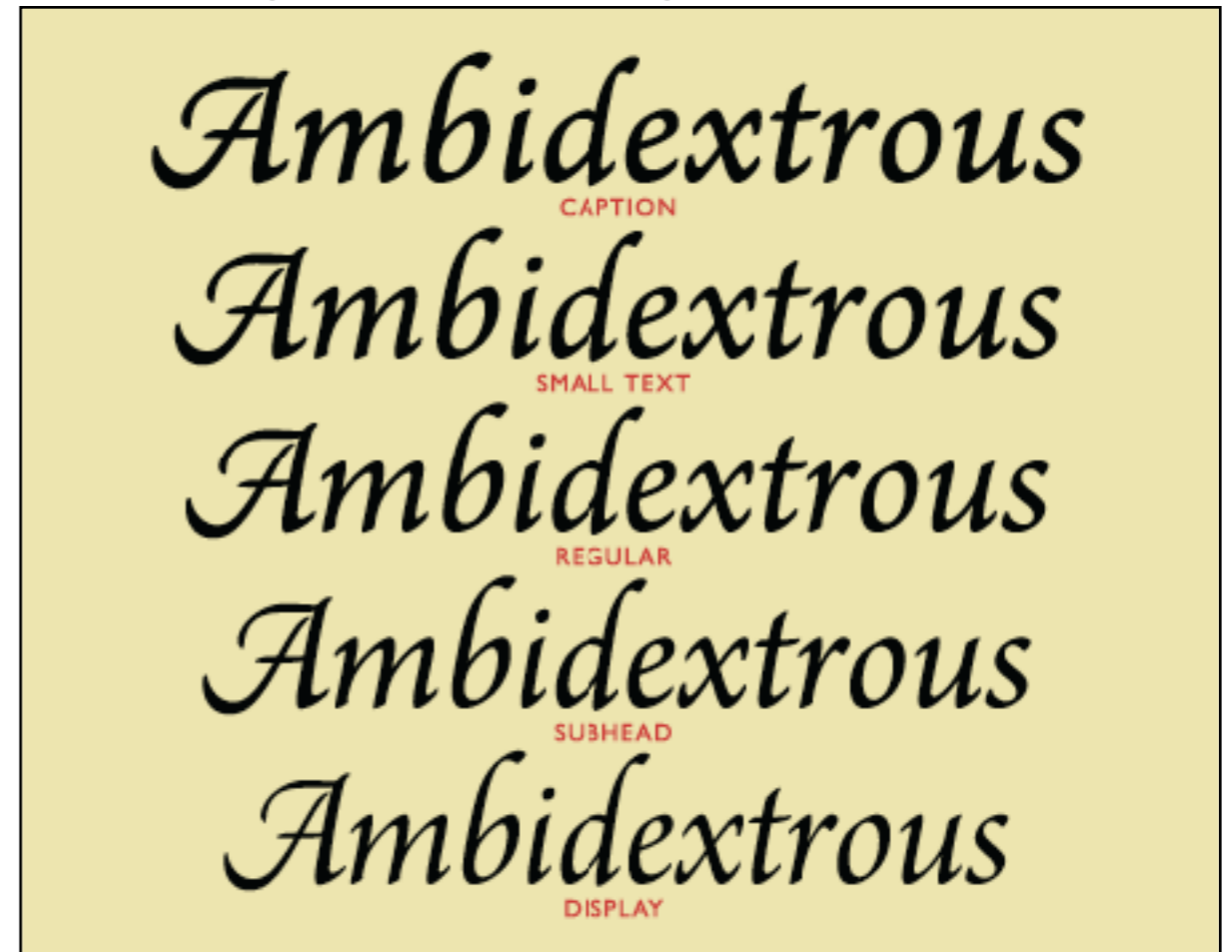
- although “optical” adjustments are needed for large scale changes



Adobe Minion MultiMaster

Adobe Arne Pro Italic  
—intended point size ranges

Caption:	5 to 8.5 point
SmText:	8.6 to 11 point
Regular:	11.1 to 14 point
Subhead:	14.1 to 21.5 point
Display:	21.5 point or larger

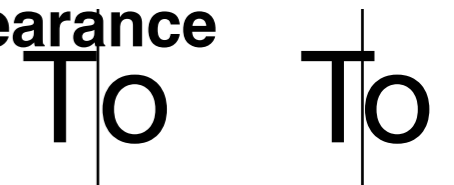
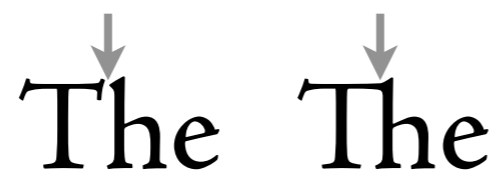


The point is that these examples are **designed** for use at different sizes, but are displayed here **scaled to the same size** so you can compare the designs.

The individual font names suggest roughly what range of sizes each font is intended for.

Contain lots of advanced typographic information for better visual appearance

- eg for “**kerning**”





# Text in Inkscape

## “Point text” (aka “label text”)

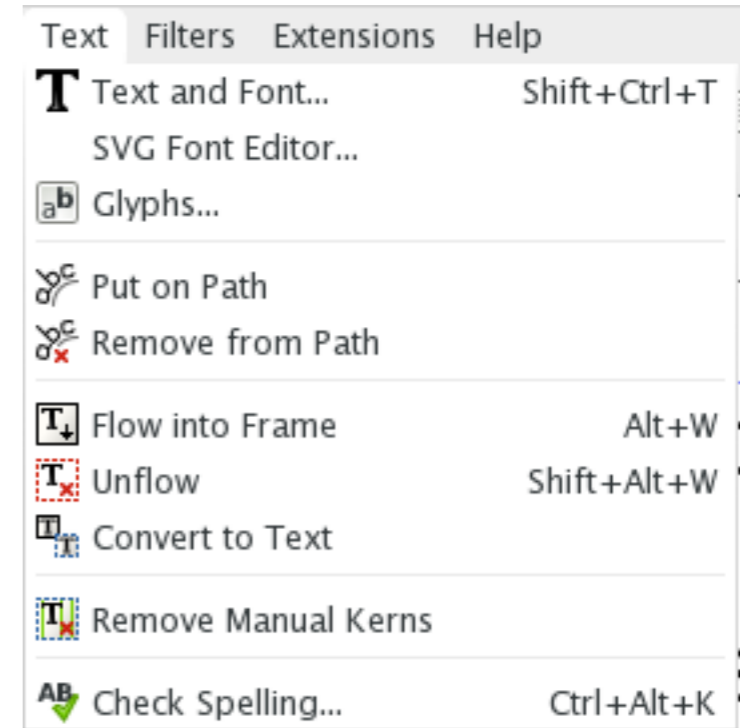
- just click and start typing 



Toolbar Icon

## “Area text” (aka “paragraph text”)

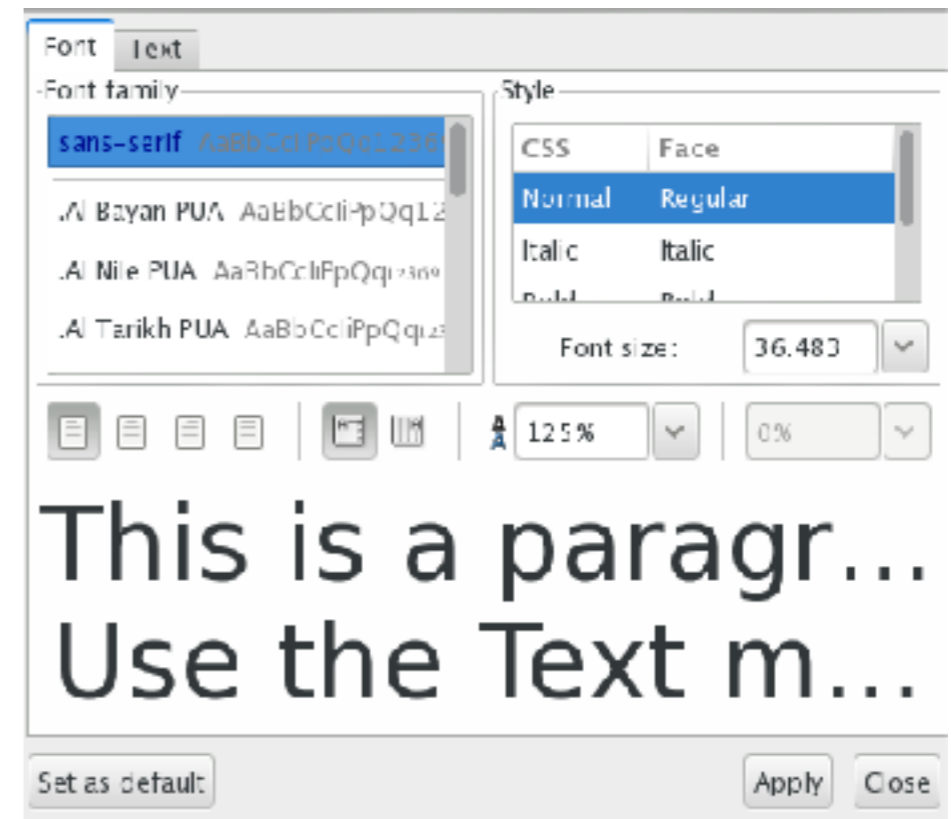
This is a paragraph of text because I dragged out a "text frame" before starting to type.  
Use the Text menu to control different attributes of the type area.



Text Menu

## “Path Text”

- An example of text “wrapped” along a path.



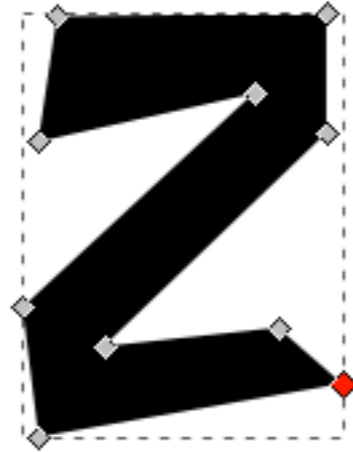
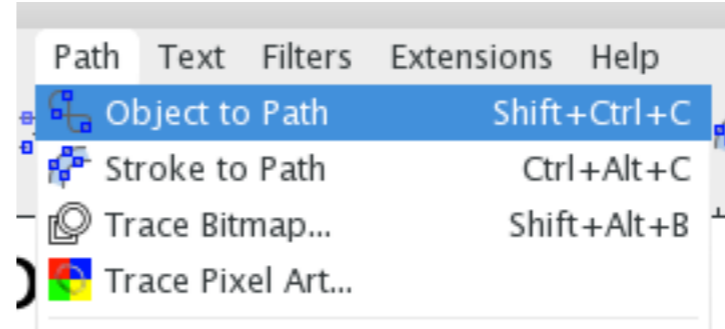
Text Options Panel

Explore the Type menu, Type tool, and online help

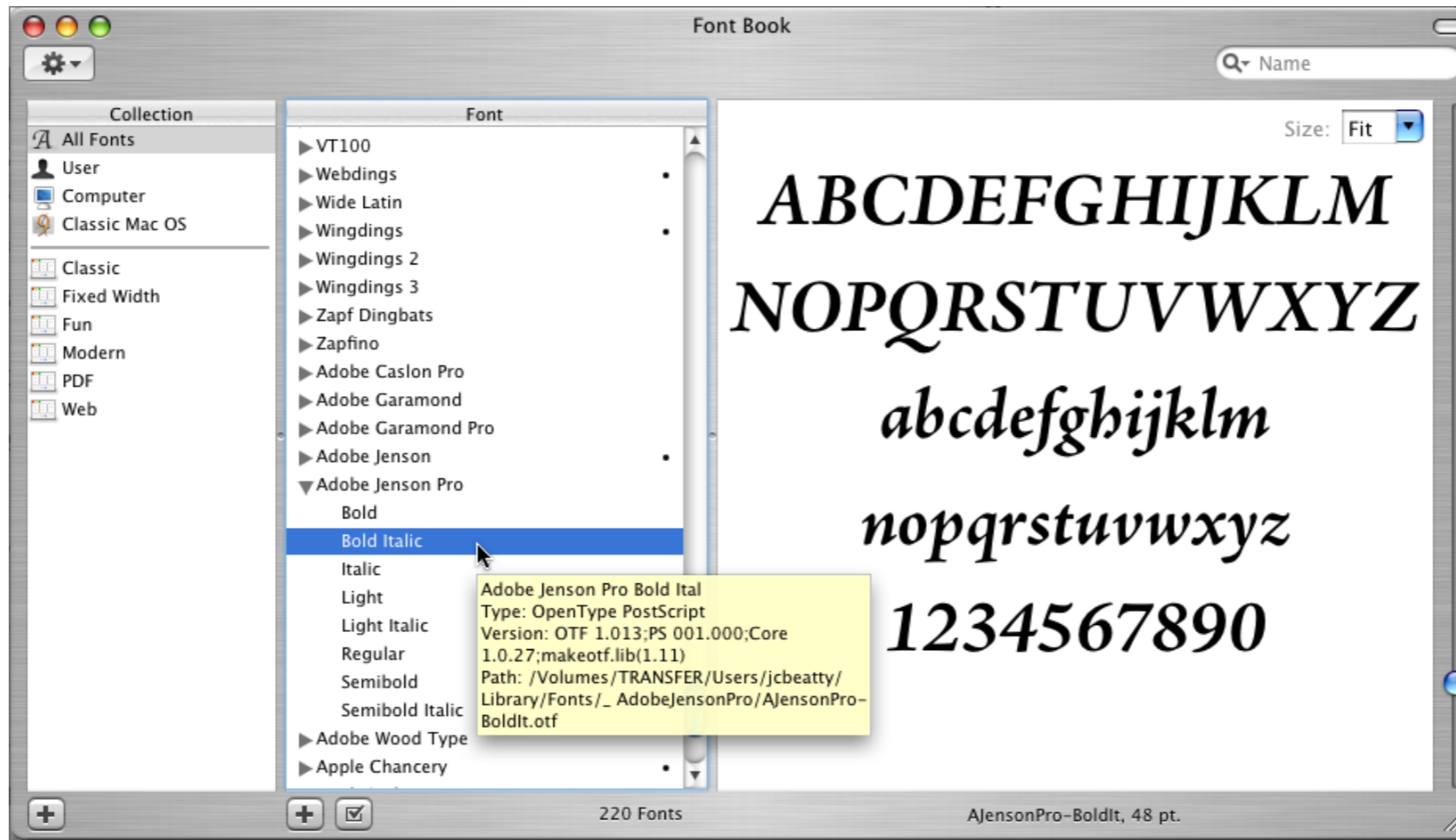
# Converting text to Bézier shapes

Select text, then go to **Path > Object to Path**

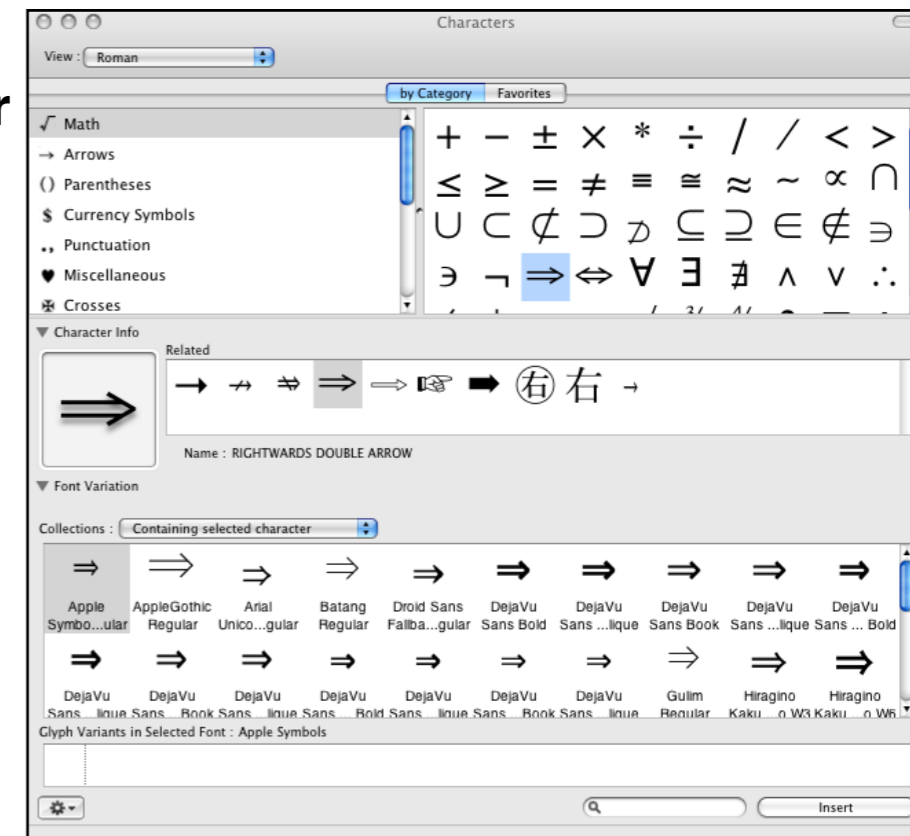
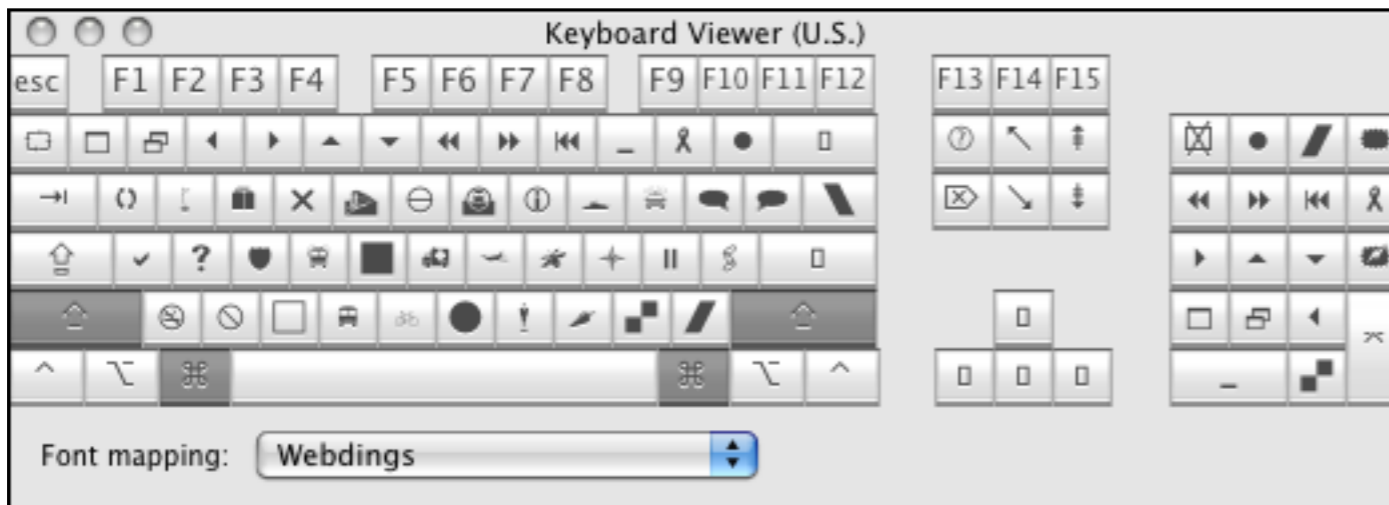
- converts text to graphical objects
- whose outlines are Bézier curves



# / Applications / Font Book (OS X)



For special characters, look up “Keyboard Viewer” and/or “Character



# Anti-Aliasing

Vary the intensity of pixels to make edges look smoother

## How it's done

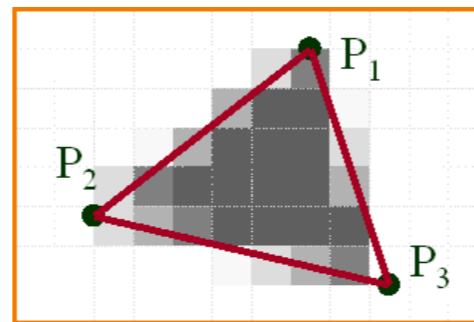
Model a line as a 1-pixel-wide rectangle.

Set the intensity of each pixel to be 255 times the fraction of the pixel that intersects the rectangle.

## Works for ALL kinds of graphics

eg for the edges of regions

eg for text



## In fact, Acrobat Reader anti-aliases text

with variable success

(it depends on how the lookup table is set)

## So do Mac OS X

System Preferences

> Appearance

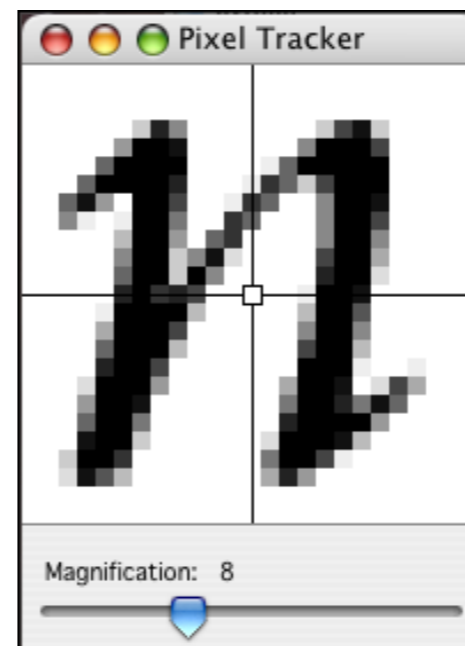
> Use LCD font smoothing when available

## and Windows XP

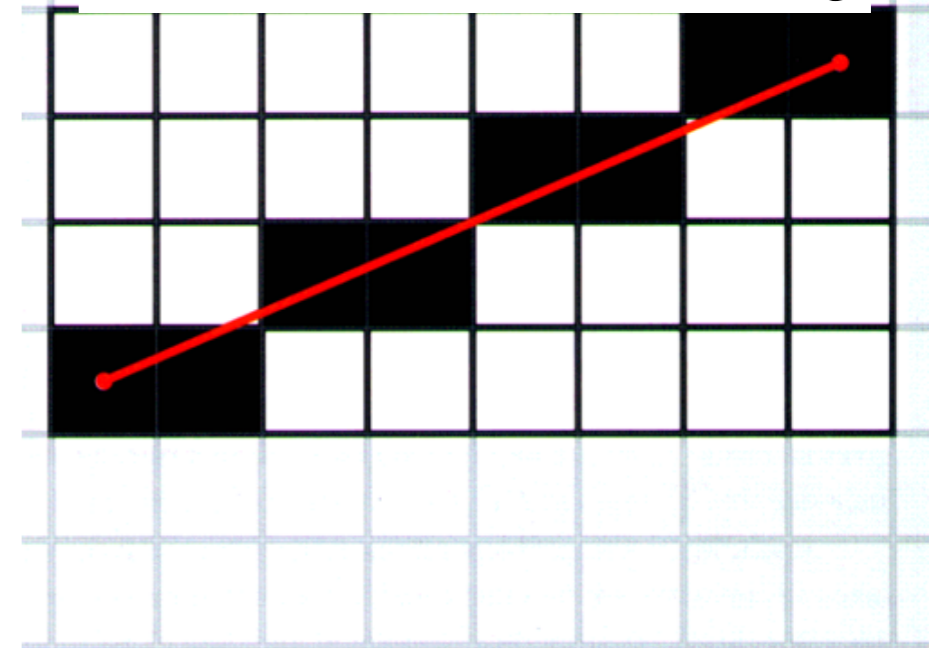
though apparently you

have to turn it on

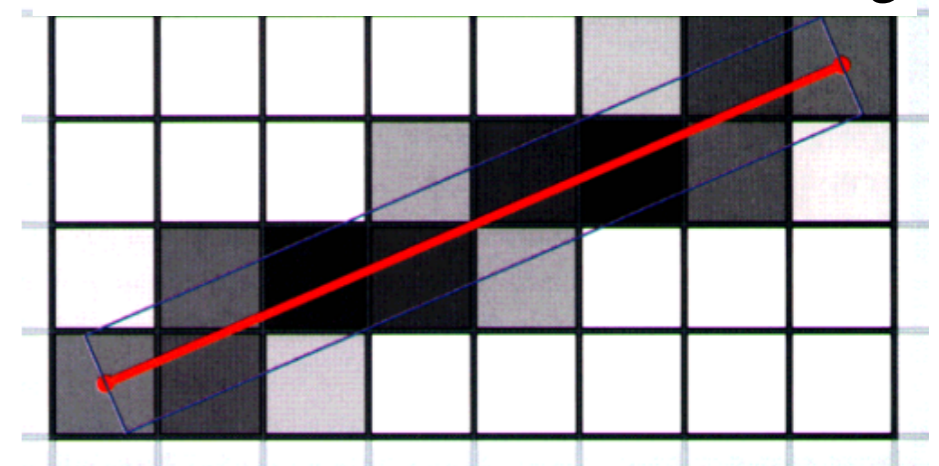
(next slide)



*A line with no anti-aliasing*

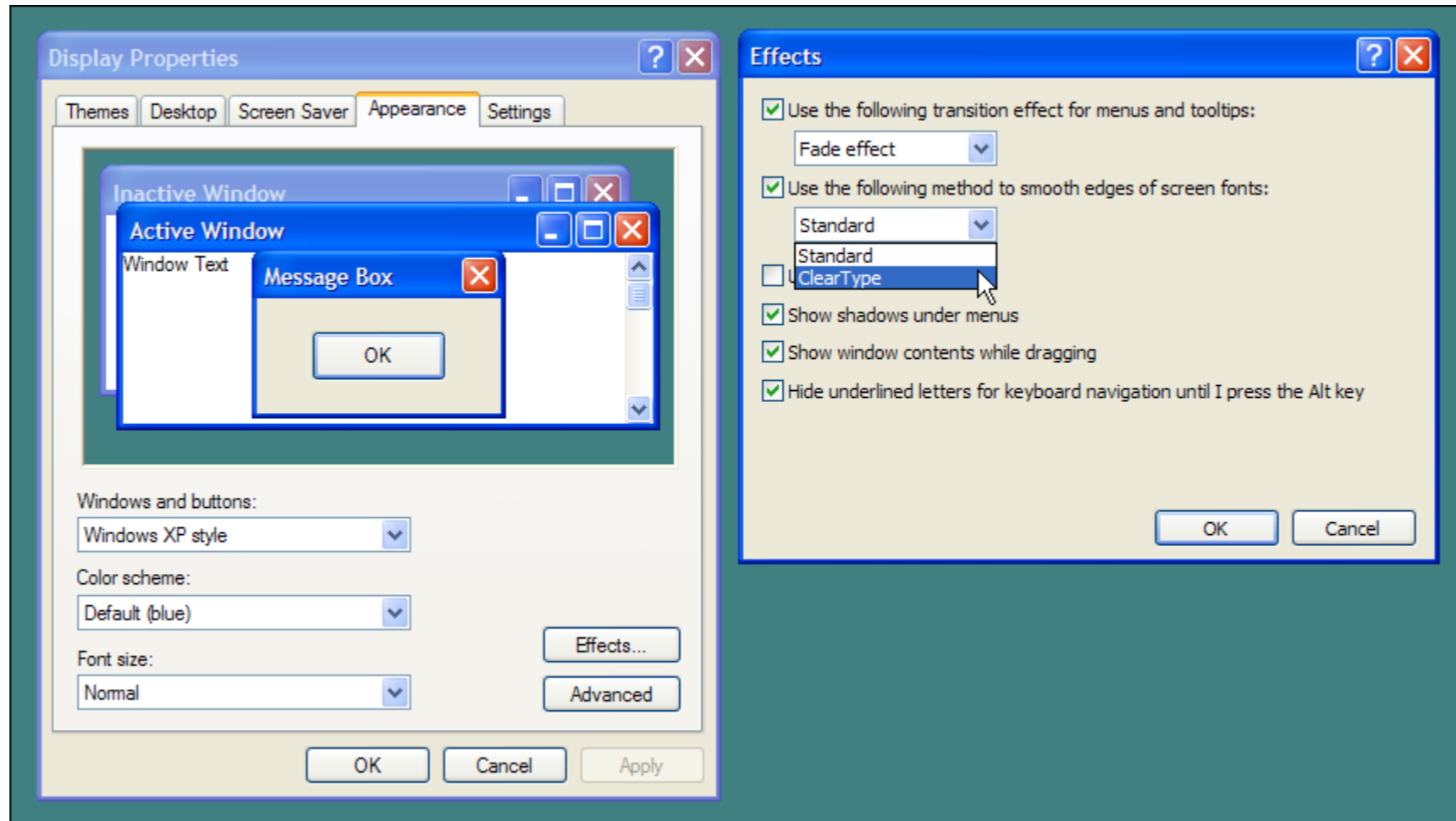


*The same line w/anti-aliasing*



from HCGW, p 70

# Anti-Aliasing in Windows XP

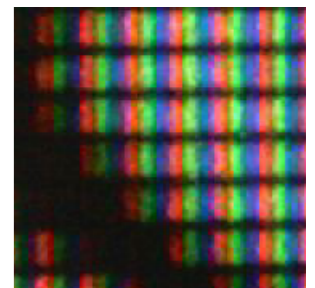
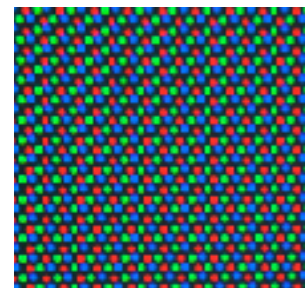


*The popularity of laptops shows that people are eager to use mobile technology. Windows XP Professional is designed to make mobile computing easier. New features for mobile computing will help you accomplish as much on the road or at home as you do in the office, so you can be productive no matter where you are.*

Black and White

*The popularity of laptops shows that people are eager to use mobile technology. Windows XP Professional is designed to make mobile computing easier. New features for mobile computing will help you accomplish as much on the road or at home as you do in the office, so you can be productive no matter where you are.*

ClearType




Example from

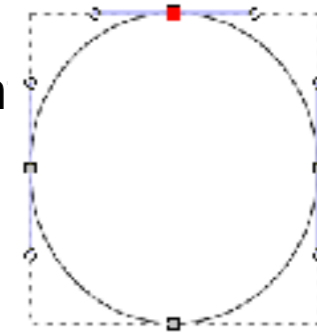
<http://www.microsoft.com/typography/cleartype/tuner/>

Use "Standard" for CRTs;  
Use "ClearType" for LCDs.

# Other Important Concepts

## Everything is a Bézier curve

- select an object with the Edit Paths by Node tool  to see the anchor point
- click on an anchor point to see its direction vectors
- zooming helps when working with closely-packed anchor points or short direction vectors
- for a default object like a circle, square, or text, first select the object, then select Path > Object to Path. You can then edit it as above.



## Object > Group

- select / move / scale several objects as if they were one

## Layer > Lock/Unlock Current Layer

- turn off select / edit capability

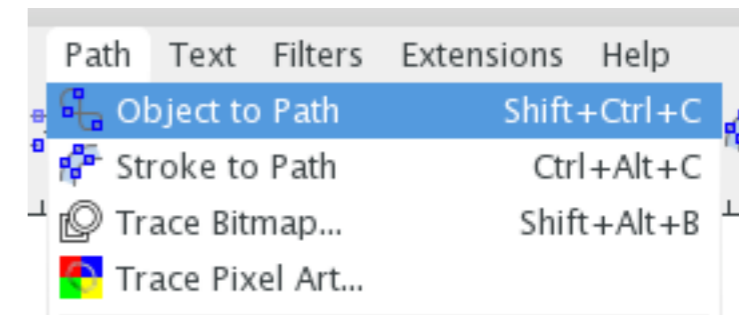
## View > Page Grid

## File > Document Properties > Snap > Always Snap

- make objects snap to grid

## View > Guides

## Poke and/or read online help for details as necessary



# Learning to Drive Inkscape

**Inkscape's interface is a little different than other applications we have looked at**

- it doesn't use Apple's toolbar, but has a toolbar within the window like Windows programs.
- It also uses ctrl instead of cmd like Windows programs, even when running on a Mac.

**Right-click for contextual menus**

**To find out what a button does**

- Try it (the Poke pearl)
- Hover over the button to see a "tool tip"
- Look it up in online help
  - ex. by searching for the name shown in the tool tip)

# Aside – Text in Photoshop – Lest you be confused...

**Text in Photoshop is placed in a “type layer”**

where it is treated as a geometric object

**It can be edited, provided it's kept in that type layer;  
if you merge it with another layer, it's converted to pixels (“rasterized, rendered”),  
and can no longer be edited,  
though you can then apply standard image transformations/manipulations.**

**So ... text in Photoshop is really**

a geometric component

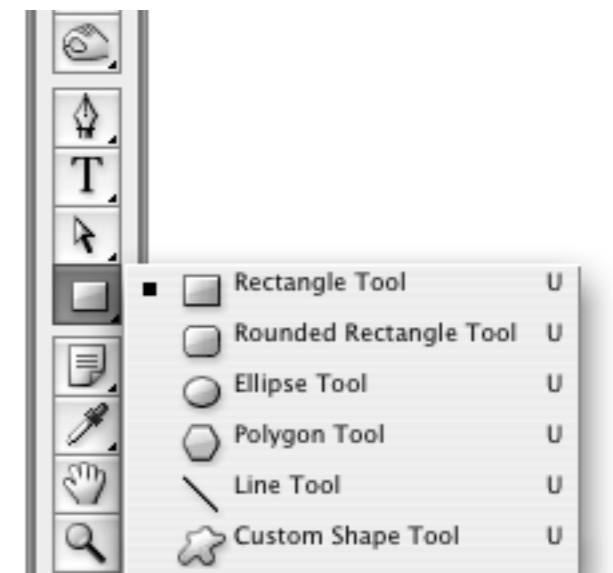
in an otherwise pixel graphics application

**Well, actually...Photoshop also has “paths,” “shapes,” and “vector masks”**

these are also geometric objects (that you can stroke or fill, or use as masks)

they can be manipulated with Photoshop-like geometric tools

but unfortunately we don't have time to explore them — see online help (or 3rd party books) if you're curious





# Final Comments

**Hmm.**

Characters and paragraphs have properties ...

Often it's convenient to name collections of these ...

Does it make sense to have named graphical styles, too?

Would that be useful?

**Be sure you understand the difference between**

- what's in a Inkscape/geometric layer
- Don't let these confuse you about the difference between pixel & geometric graphics

# Study Questions

## Selection

you can click on an object in the canvas to select it

would it be helpful to also be able to click on an object through the layers palette?

## Stacking order

you can change the stacking order of objects within a layer

you can change the stacking order of layers

— why have both capabilities?