CSSE 220 Day 25

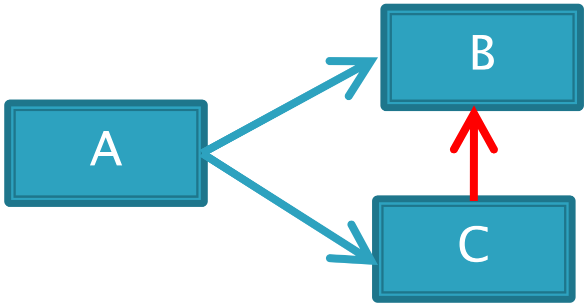
Sorting Algorithms
Algorithm Analysis and Big-O
Function Objects and the Comparator Interface

Checkout *SortingAndSearching* project from SVN

Questions

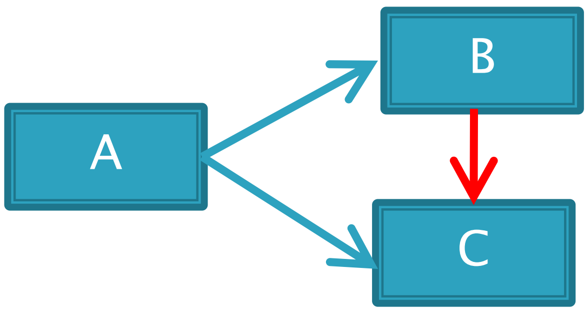
- Exam solutions posted

Tips from Test 2: *implementing has-a*



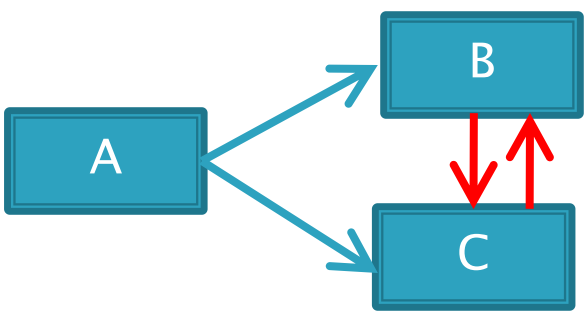
In A:

```
B b = new B(…);
C c = new C(b, …);
```



In A:

```
C c = new C(…);
B b = new B(c, …);
```



In A:

```
B b = new B(…);
C c = new C(…);
b.setC(c);
c.setB(b);
```

In B (and likewise C):

```
public void setC(C c) {
    this.c = c;
}
```

Remember Selection Sort?

- Let’s see…

Why study sorting?

- Remember
  Shlemiel the Painter

Course Goals for Sorting: You should…

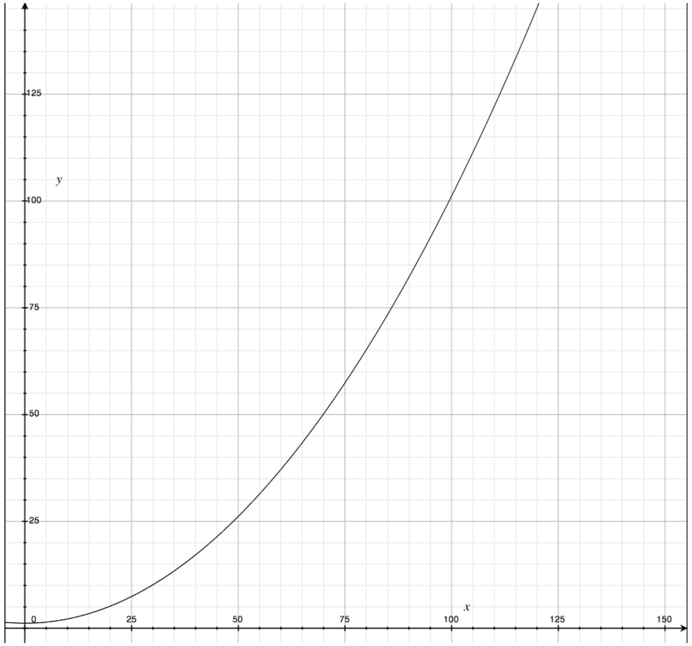
- Be able to describe basic sorting algorithms:
  - Selection sort
  - Insertion sort
  - Merge sort
- Know the run-time efficiency of each
- Know the best and worst case inputs for each

Profiling Selection Sort

- Profiling: collecting data on the run-time behavior of an algorithm

- How long does selection sort take on:
  - 10,000 elements?
  - 20,000 elements?
  - …
  - 80,000 elements?

- $O(n^2)$



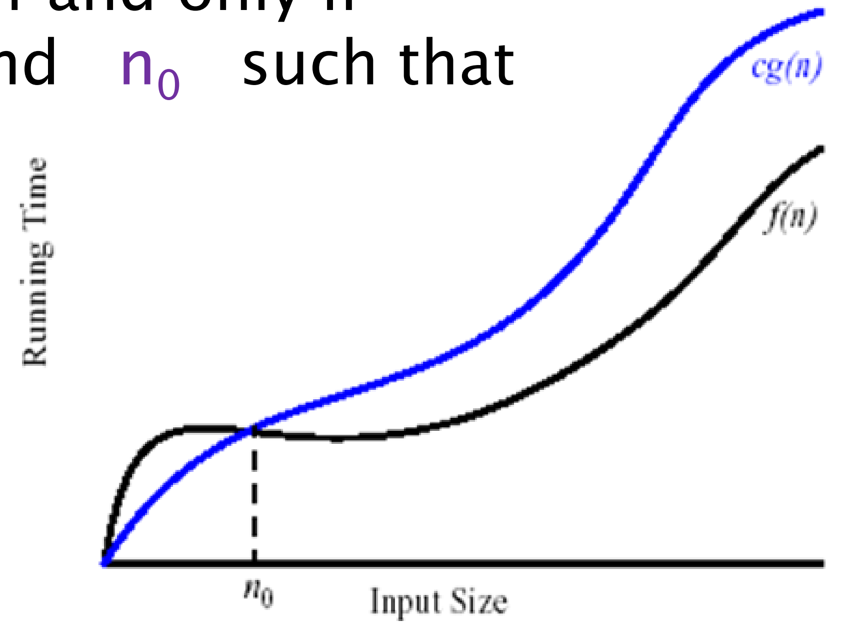
Q1–3

Big-Oh Notation

- In analysis of algorithms we care about differences between algorithms on very large inputs
- We say, “selection sort takes on the order of n^2 steps”
- Big-Oh gives a formal definition for “on the order of”

Definition of big-Oh

- Formal:
  - We say that $f(n)$ is $O(g(n))$ if and only if
  - there exist constants c and n_0 such that
  - for every $n \geq n_0$ we have
  - $f(n) \leq c \times g(n)$



- Informal:
  - $f(n)$ is *roughly proportional* to $g(n)$, for large n

- Example: $7n^3 + 24n^2 + 3000n + 45$ is $O(n^3)$
  - Because it is $\leq 3{,}077 \times n^3$ for all $n \geq 1$

Big-Oh rules

- Formal:
  - We say that f(n) is O(g(n)) if and only if
  - there exist constants c and n_0 such that
  - for every $n \geq n_0$ we have
  - $f(n) \leq c \times g(n)$

- Polynomials: keep the highest power, discard its coefficient
  - $34n^5 + 20n^2 + 10000$ is $O(n^5)$
- More generally:
  1. Discard all multiplicative constants
  2. Pick the "dominating" additive expression per chart to the right, discard other additive terms

$$30n^2 + 4n^3 \log n + 45n + 70n^3 + 85 \text{ is } O(n^3 \log n)$$

Function	Name
c	Constant
$\log N$	Logarithmic
$\log^2 N$	Log-squared
N	Linear
$N \log N$	$N \log N$ ←
N^2	Quadratic
N^3	Cubic
2^N	Exponential

Q4-5

Insertion Sort

- Basic idea:
  - Think of the list as having a sorted part (at the beginning) and an unsorted part (the rest)
  - Get the first number in the unsorted part
  - Insert it into the correct location in the sorted part, moving larger values up to make room

Repeat until unsorted part is empty

Insertion Sort Exercise

- Profile insertion sort
- Analyze the *worst case*
  - Assume that the inner loop runs as *many* times as it can
  - Count the number of times compareTo is executed
  - What input causes this worst-case behavior
- Analyze the *best case*
  - Assume that the inner loop runs as *few* times as it can
  - Count the number of times compareTo is executed
  - What input causes this best-case behavior
- Does the input affect insertion sort?

Ask for help if you're stuck!

Handy Fact
$1 + 2 + \ldots + (n-1) + n = \frac{n(n+1)}{2}$

Q6–13b

Searching

- For searching *unsorted* data, what’s the worst case number of comparisons we would have to make?

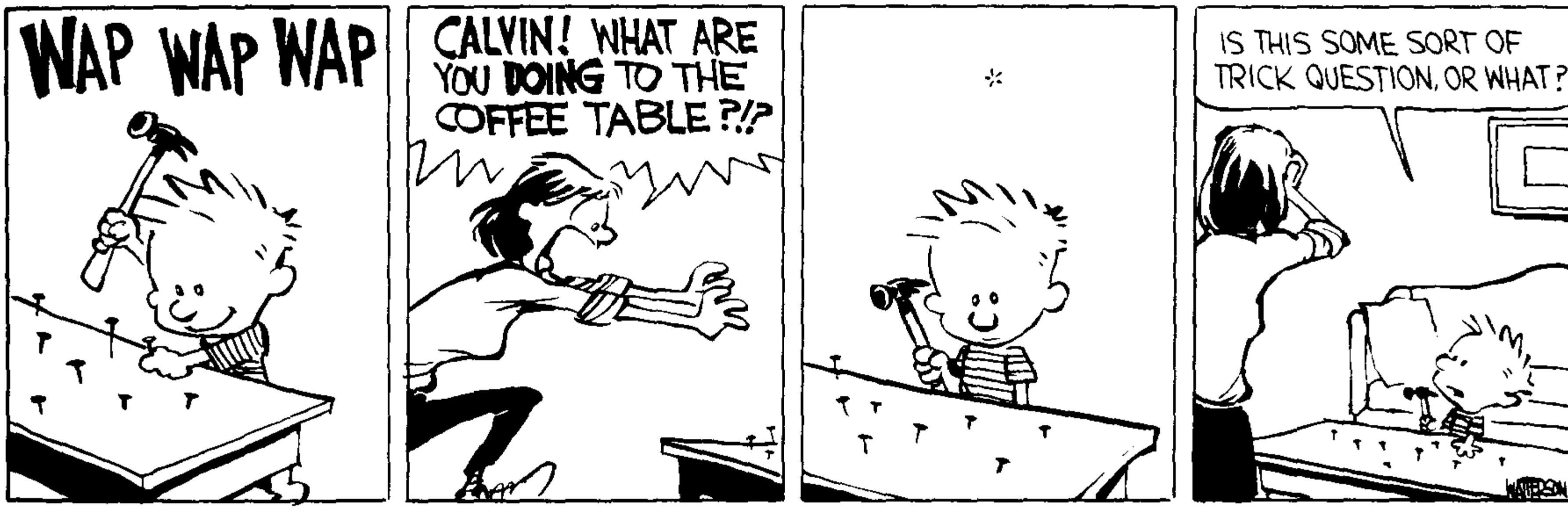
Binary Search of Sorted Data

- A divide and conquer strategy
- Basic idea:
  - Divide the list in half
  - Should result be in first or second half?
  - Recursively search that half

Analyzing Binary Search

- What's the best case?
- What's the worst case?

Q14



Perhaps it's time for a break.

Merge Sort

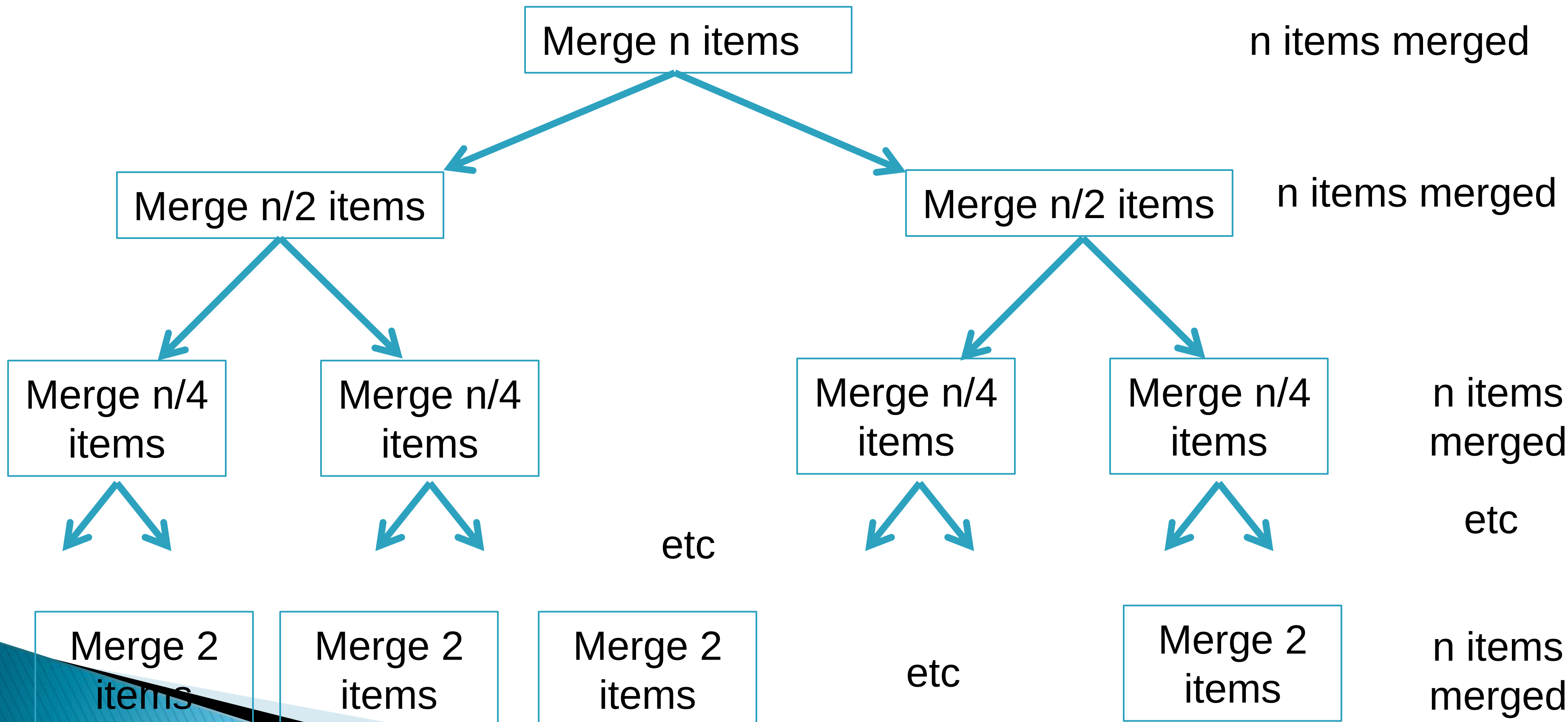
- Basic recursive idea:
  - If list is length 0 or 1, then it's already sorted
  - Otherwise:
    - Divide list into two halves
    - Recursively sort the two halves
    - **Merge** the sorted halves back together

- Let's profile it…

Analyzing Merge Sort

If list is length 0 or 1,
then it's already sorted

- Otherwise:
  - Divide list into two halves
  - Recursively sort the two halves
  - **Merge** the sorted halves back together



Q13c, 15

Function Objects

- Another way of creating reusable code

A Sort of a Different Order

- Java libraries provide efficient sorting algorithms
  - `Arrays.sort(…)` and `Collections.sort(…)`

- But suppose we want to sort by something other than the "natural order" given by `compareTo()`

- Function Objects to the rescue!

Function Objects

- Objects defined to just “wrap up” functions so we can pass them to other (library) code

- We’ve been using these for awhile now
  - Can you think where?

- For sorting we can create a function object that implements `Comparator`

Data Structures

- Understanding the engineering trade-offs when storing data

Data Structures

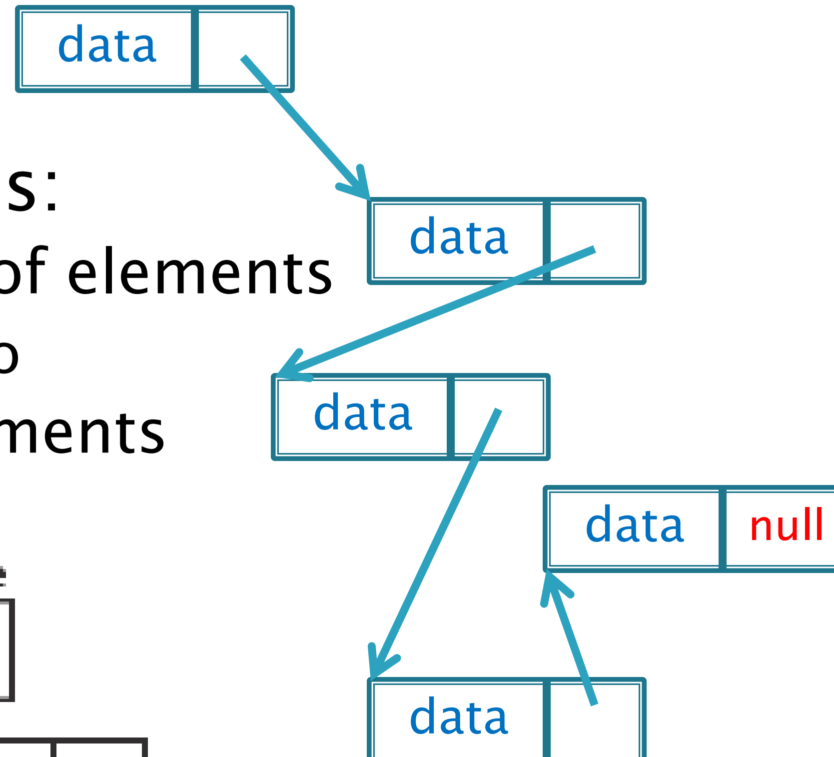
- Efficient ways to store data based on how we'll use it

- So far we've seen `ArrayLists`
  - Fast addition **to end of list**
  - Fast access to any existing position
  - Slow inserts to and deletes from middle of list

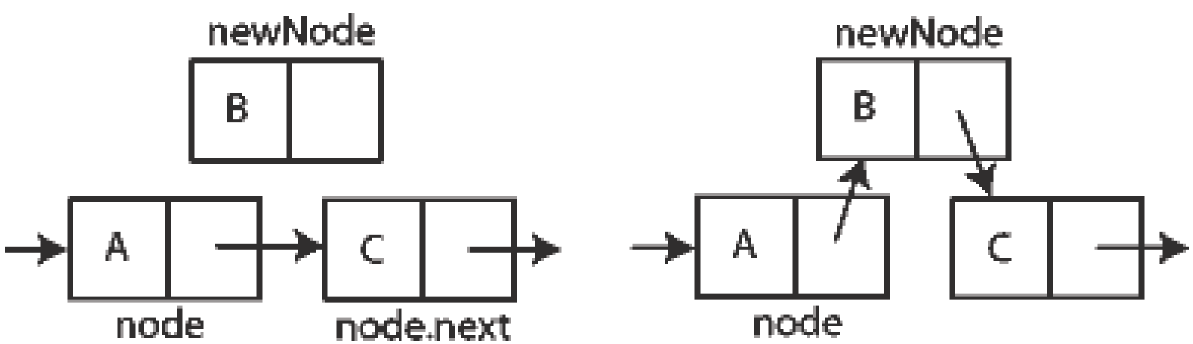
Q16

Another List Data Structure

- What if we have to add/remove data from a list frequently?



- `LinkedList`s support this:
  - Fast insertion and removal of elements
    - Once we know where they go
  - Slow access to arbitrary elements



Insertion, per Wikipedia

Q17,18

Next Time

- Implementing `ArrayList` and `LinkedList`
- A tour of some data structures
- Some VectorGraphics work time