Announcements/Follow-ups

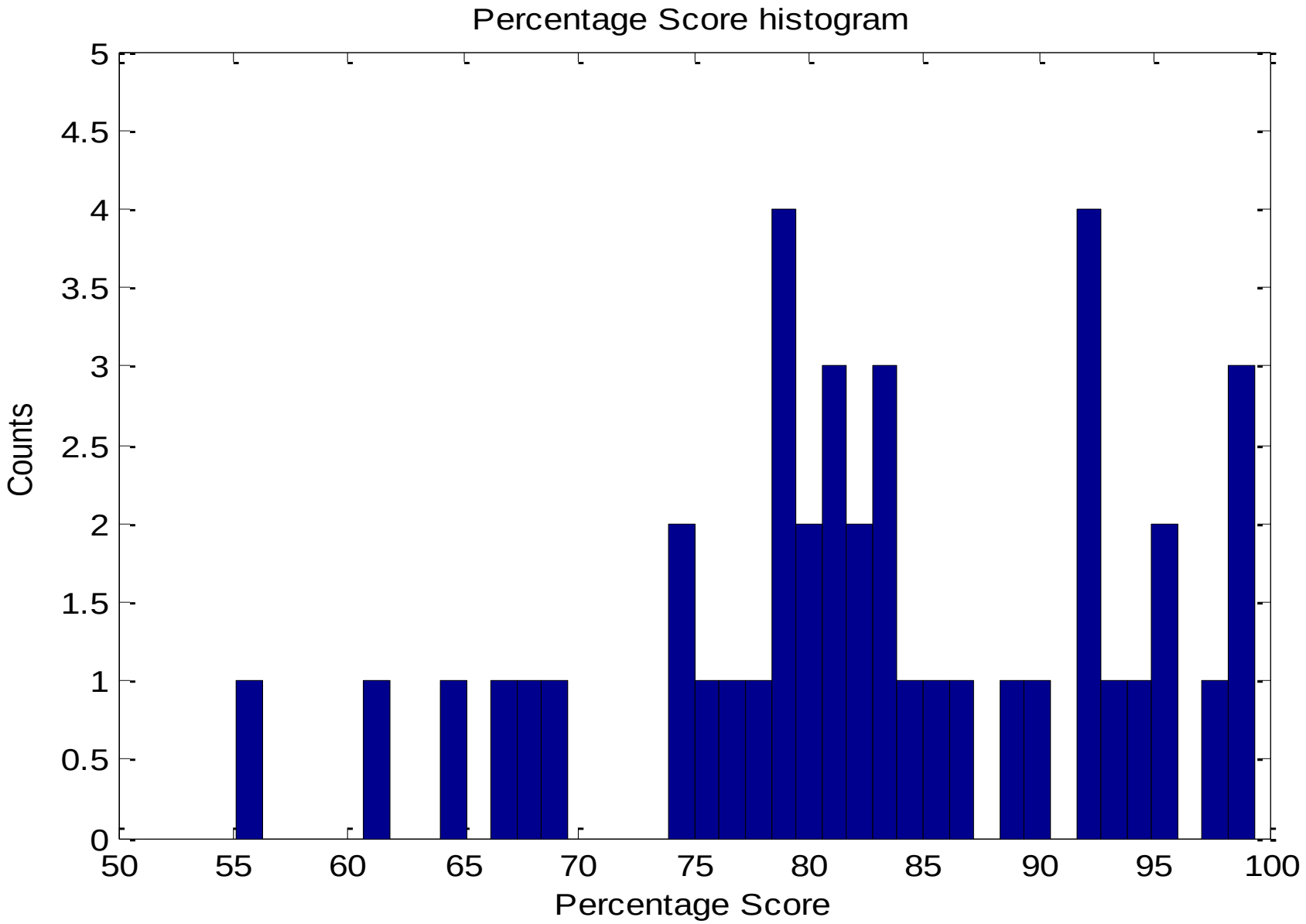
- Final exam
  - This Friday August 2
  - Normal class period – 80 minutes
- P7(‘s) due Friday 11pm
  - Corrections: subMatrix, matrix mult.
  - Equals method and Round-off error
  - ArrayList copy constructor
- Wednesday’s topics
- Grades
- Reflectance

Wednesday's Topics

- Graphical User Interface programming in Java and multi-threading
- Regular expressions and Finite automata
- Other programming languages (C, matlab, ruby, Ocaml)
- Combinatorics and probability
- Neural modeling

Grades

- Midterm 2 has been curved on grades server
- Overall percentage grades so far:
  - Average 81%
  - Standard deviation: 16%
- Remaining grades:
  - P6 style, P7 (5.5 %)
  - Quiz 5, Lab 10 (1.2%)
  - Final exam (24%)
  - Participation (5%)


Percentage Score histogram
Counts
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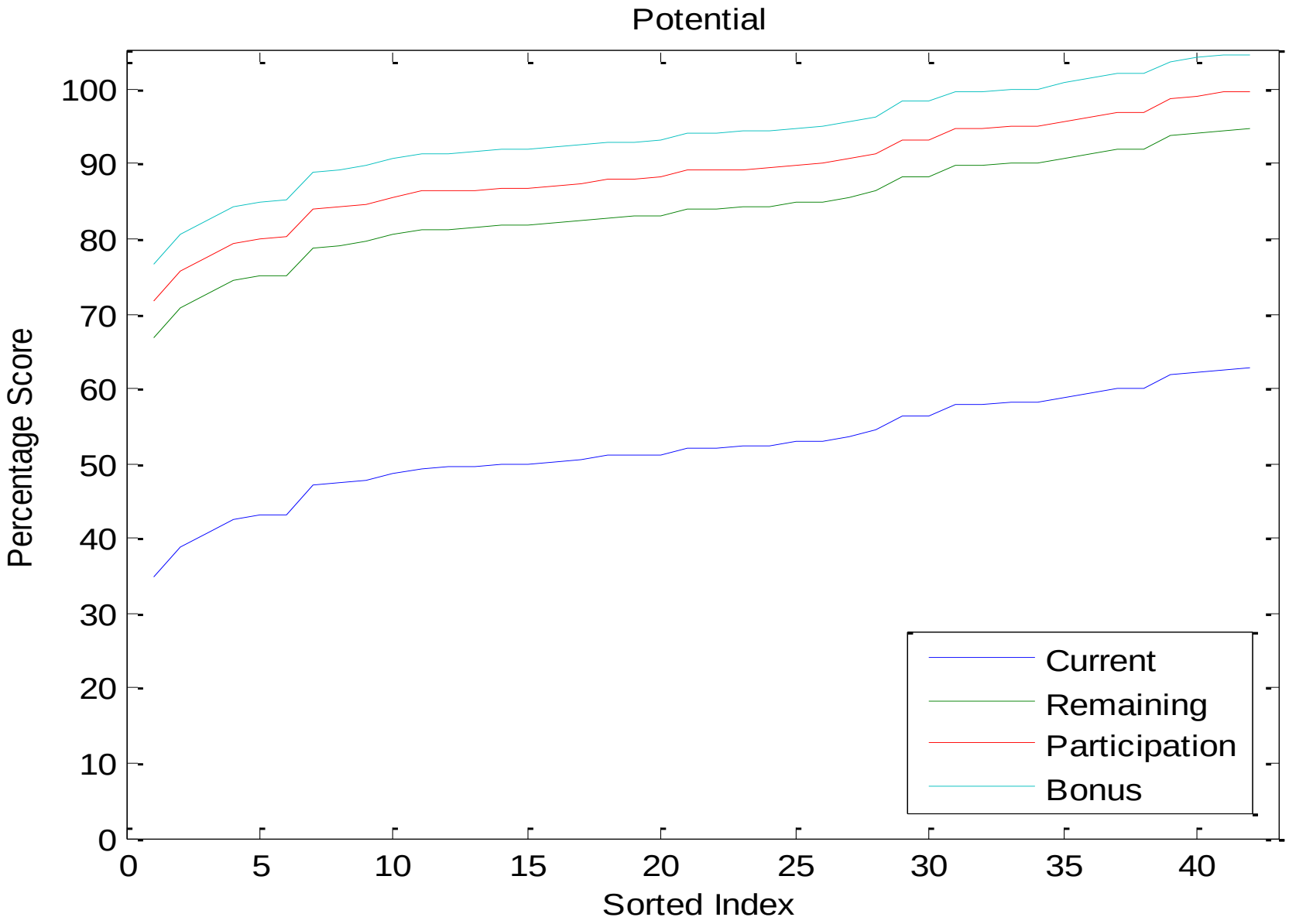
Potential
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Current
Remaining
Participation
Bonus

Reflectance

- The ability of your source code to “hold up a mirror” and inspect itself.
- Allows things like:
  - Manipulating fields (including private ones)
  - Converting between source code and Strings
    - “BasicSoldier”
    - “ShinyCoin”
- Requires certain execution environments
  - Not available in Applets (used on the internet)

The `Class` class

- Represents a data-type
  - Reference types: objects, enums
  - Primitive types
- Is generic!
- All constructors are *private.* Methods are used for acquiring a Class object:
  - myObj.getClass();
  - myPrimitive.class;
  - Class.forName("…");
  - And more: Reflectance example

The Reflection API

- Acquiring Class objects is just the tip of the ice-berg of a large API:
  - myClass.newInstance(); //instantiates the class
  - myClass.getMethods(); //enumerates the methods
  - There is a Method class
    - myMethod.invoke(…);
  - There is a Type class for generic type parameters
  - There is an Annotation class
    - @Override
    - @Test

More on Garbage collection

- Eligibility for garbage collection:
  - Objects are *eligible* for collection once no more reference variables contain their address
  - Circular references are also eligible if they are unreachable from external code
  - GarbageCollection example
- It may be a long time before an eligible object is actually collected
  - You can suggest a round of collection with `System.gc()`, but this does not guarantee that collection actually occurs

More on Garbage collection

- Whenever the collector frees an object, its `finalize()` method is called (inherited from Object)
  - used to make sure resources (e.g. file streams) get released
- The foregoing is true for most JVM implementations
  - Assume for the exam
  - The official JVM spec does not actually specify the underlying garbage collection algorithm!

Command line Java

- Your source-code `filename.java` can be written in any text editor
- Compiling source-code to byte-code on the command line:
  - Stand-alone source:
    ```
    javac filename.java
    ```
  - With libraries:
    ```
    javac –cp path1\lib1.jar;path2\lib2.jar filename.java
    ```
    - "cp" stands for "classpath": directory paths where Java searches for files
- Running byte-code in the JVM:
  - Stand-alone:
    ```
    java filename
    ```
    - No extension
  - With libraries:
    ```
    java –cp .;path1\lib1.jar;path2\lib2.jar filename
    ```
    - '.;' in front
- Mac: ':' instead of ';' to separate paths

Command line Java

- Packaging your library into a JavaARchive:
  - `jar cf output.jar inputdirectory`
  - ‘`cf`’ for create file
  - http://docs.oracle.com/javase/tutorial/deployment/jar/
  - A JAR is essentially a zip archive
- Extracting files from an existing JAR:
  - `jar xf libary.jar`

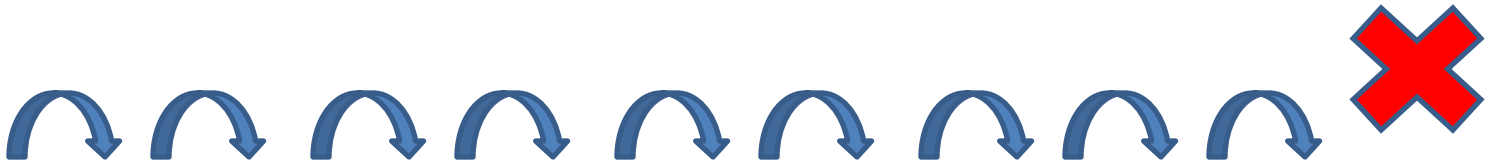
Algorithmic Complexity

- The “complexity” of an algorithm refers to the time and space required
- Complexity is typically a function of the input size.
- Given a list of size n:
  - how many steps are required by linear search, in terms of n?
  - How many steps are required by binary search, in terms of n?

Complexity of Linear search

```
int n = array.length;
for(int i = 0; i < n; i++) {
      if(array[i] == query) return i;
}
return -1;
```

20?



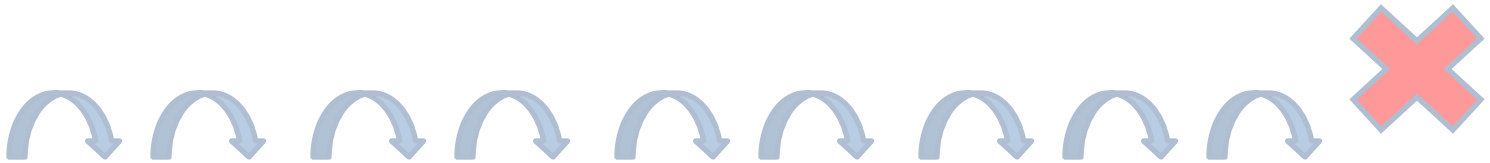
0	1	2	3	4	5	6	7	8	9
16	3	22	7	9	8	11	1	18	4

Complexity of Linear search

```
int n = array.length;
for(int i = 0; i < n; i++) {
      if(array[i] == query) return i;
}
return -1;
```

< n steps?

20?



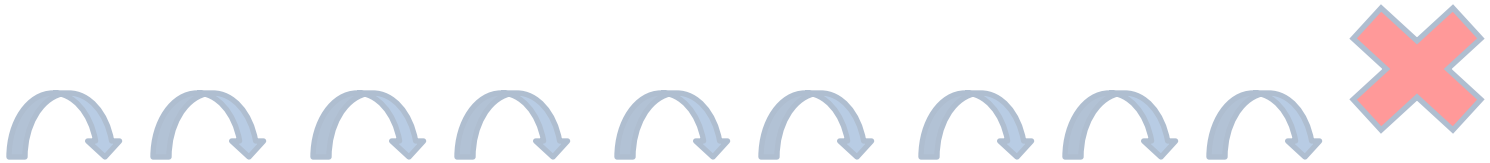
0	1	2	3	4	5	6	7	8	9
16	3	22	7	9	8	11	1	18	4

Complexity of Linear search

```
int n = array.length;
for(int i = 0; i < n; i++) {
      if(array[i] == query) return i;
}
return -1;
```

< 4n steps?

20?



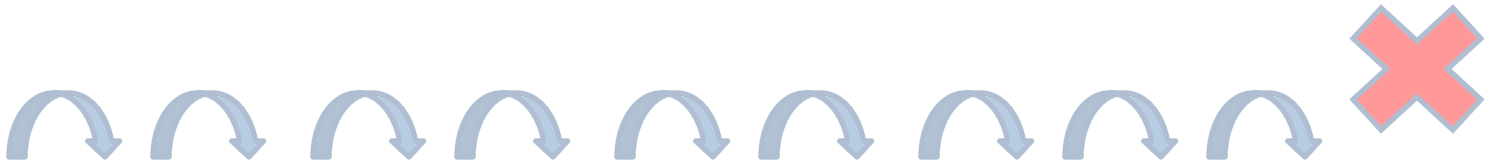
0	1	2	3	4	5	6	7	8	9
16	3	22	7	9	8	11	1	18	4

Complexity of Linear search

```
int n = array.length;
for(int i = 0; i < n; i++) {
      if(array[i] == query) return i;
}
return -1;
```

< 4n+2 steps?

20?



0	1	2	3	4	5	6	7	8	9
16	3	22	7	9	8	11	1	18	4

Complexity of Linear search

```
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for(int i = 0; i < n; i++) {
      if(array[i] == query) return i;
}
return -1;
```
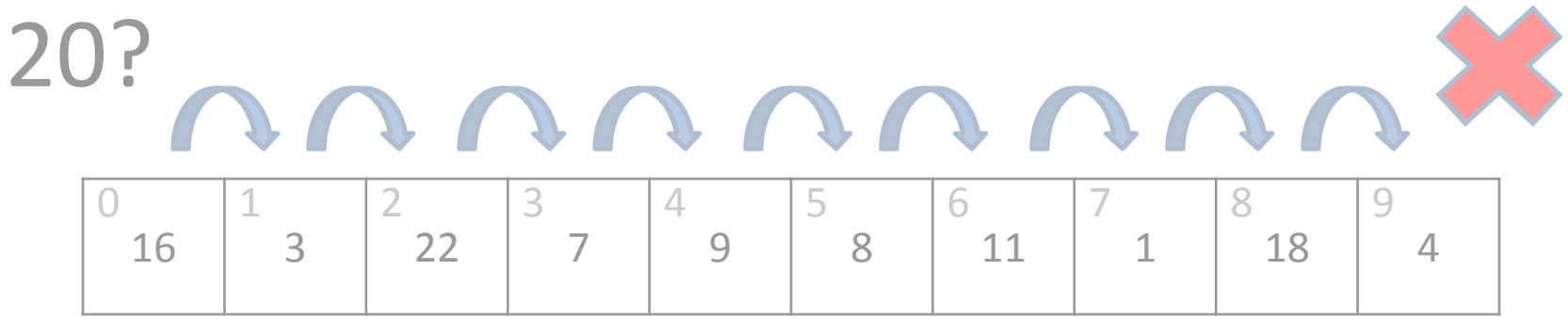
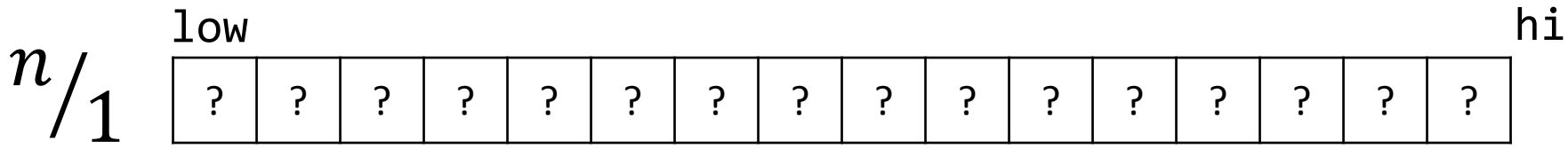
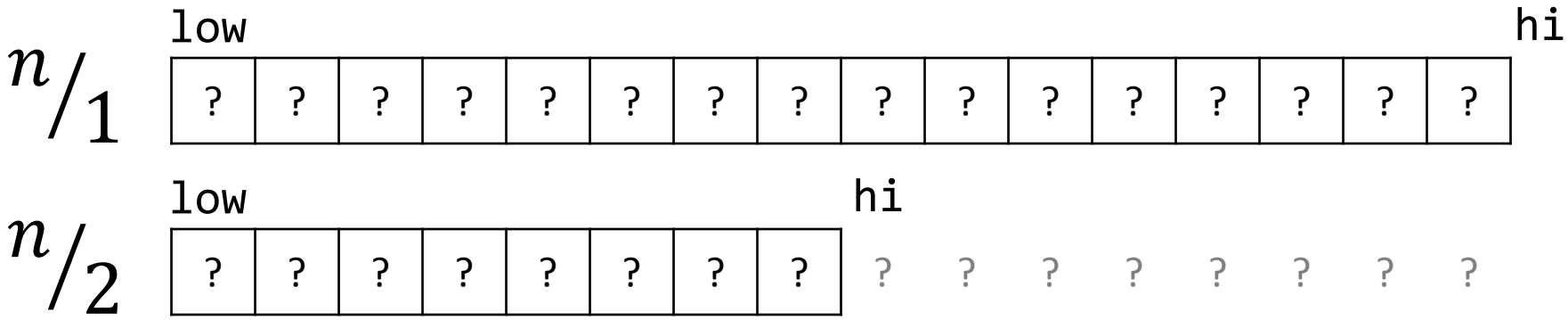

$< mn+b$ steps



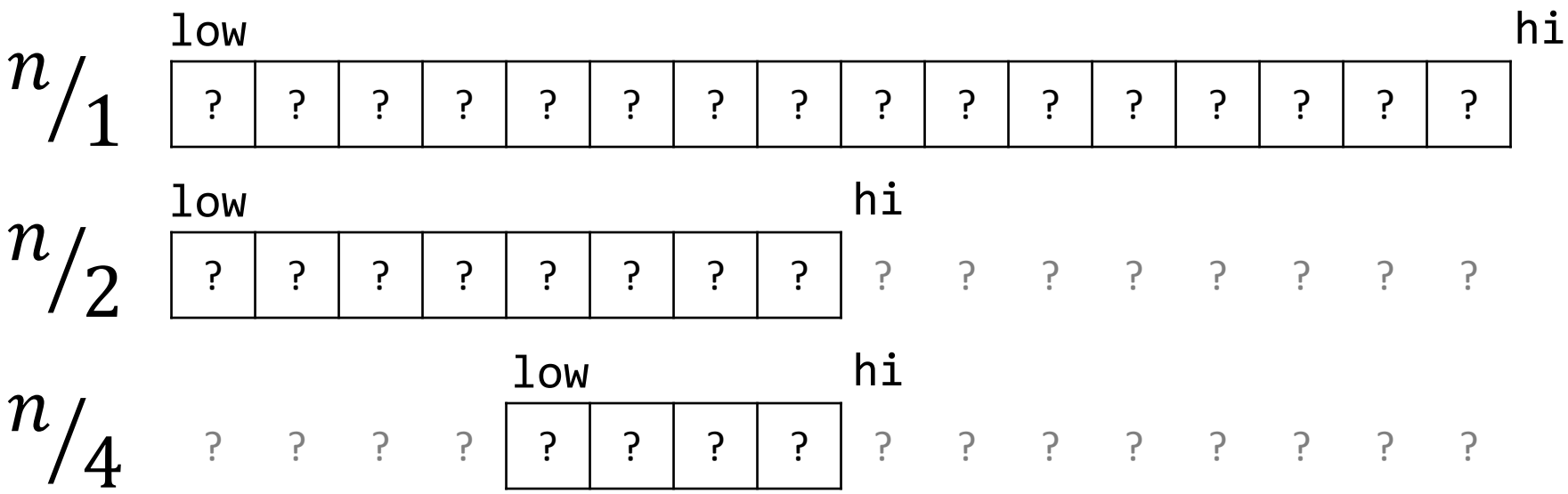
Complexity of Binary search



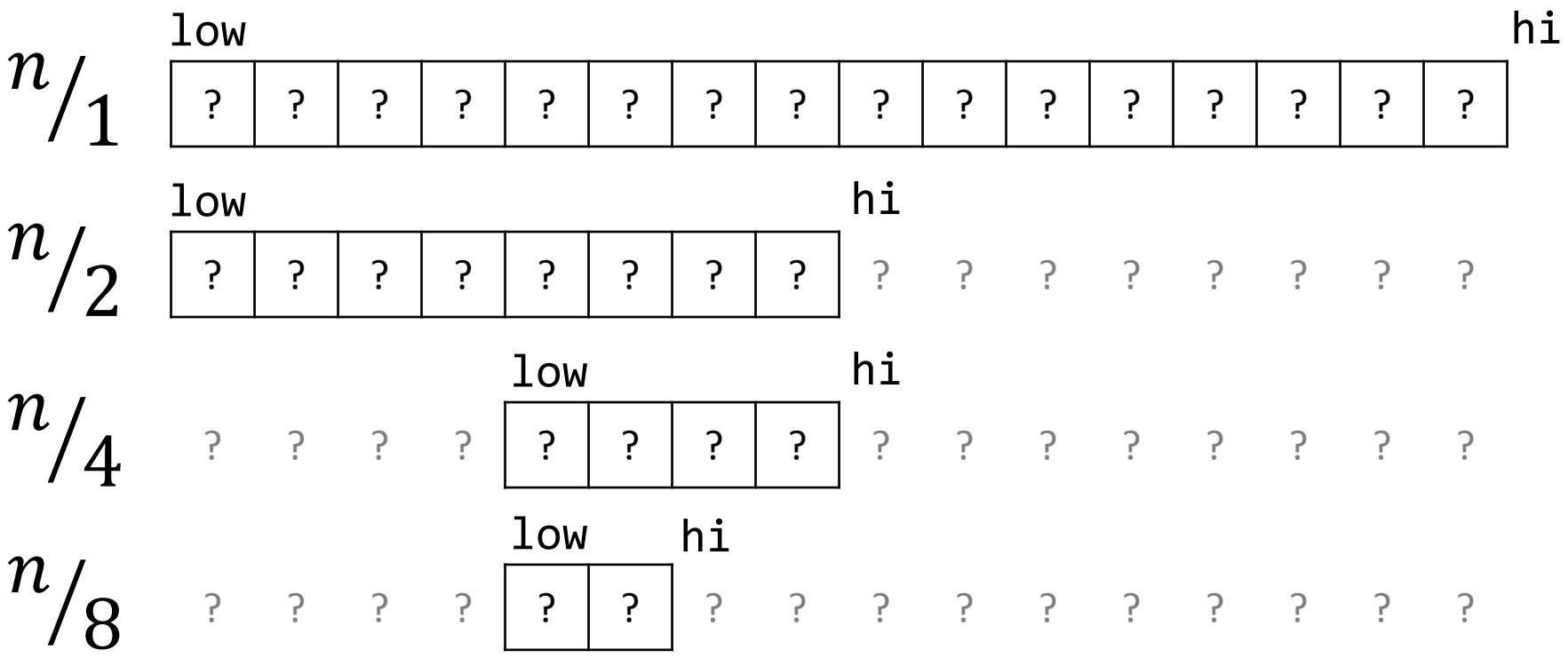
Complexity of Binary search



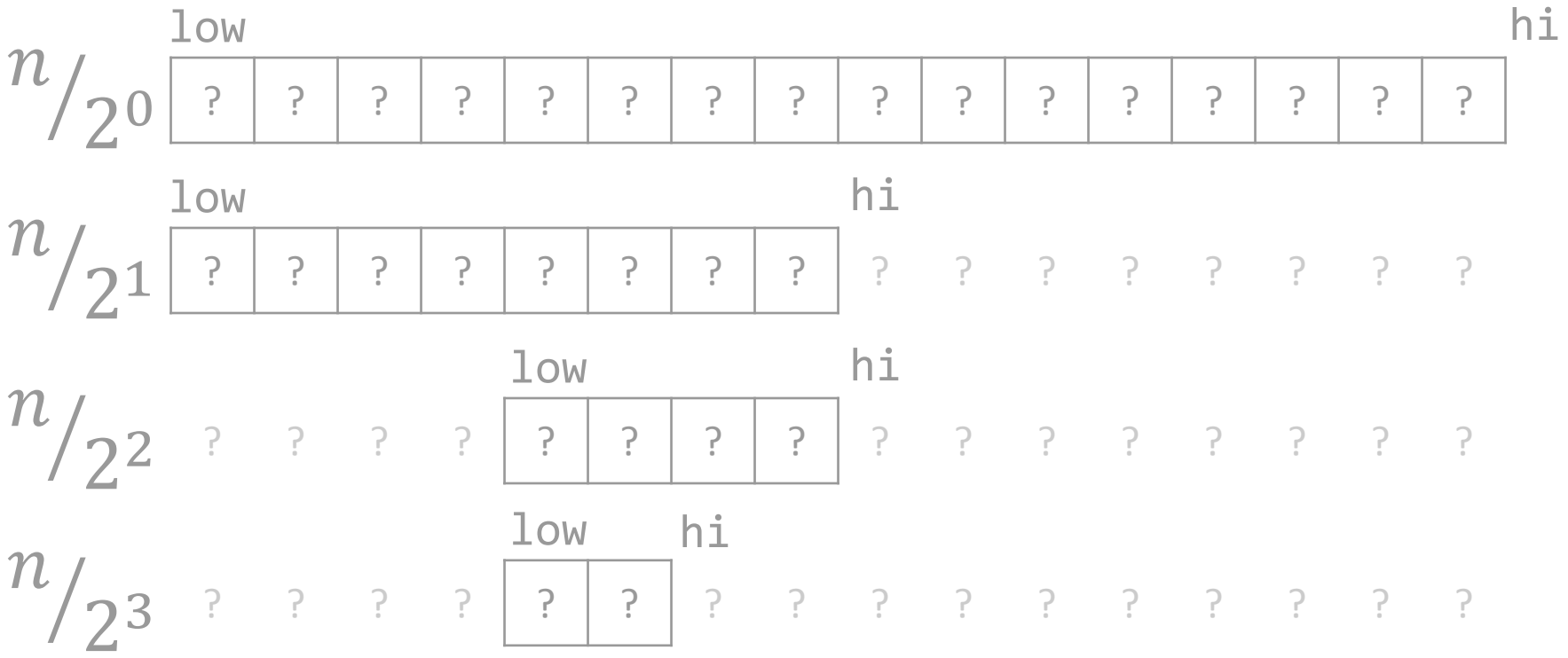
Complexity of Binary search



Complexity of Binary search

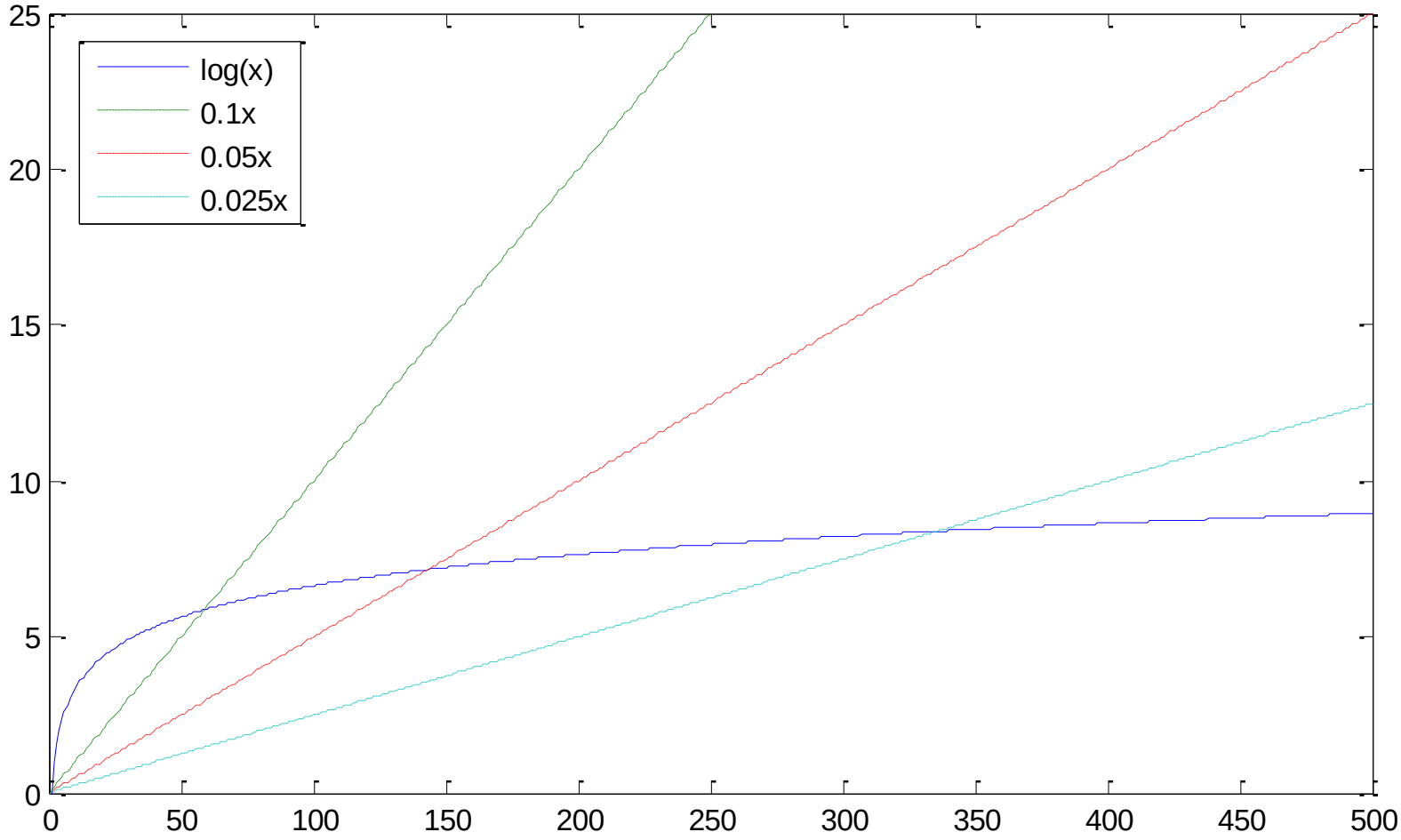


Complexity of Binary search



Steps: $^{n}/_{2^T} = 1 \longrightarrow n = 2^T \longrightarrow \log_2 n = T$

Linear vs Binary



Asymptotic Complexity

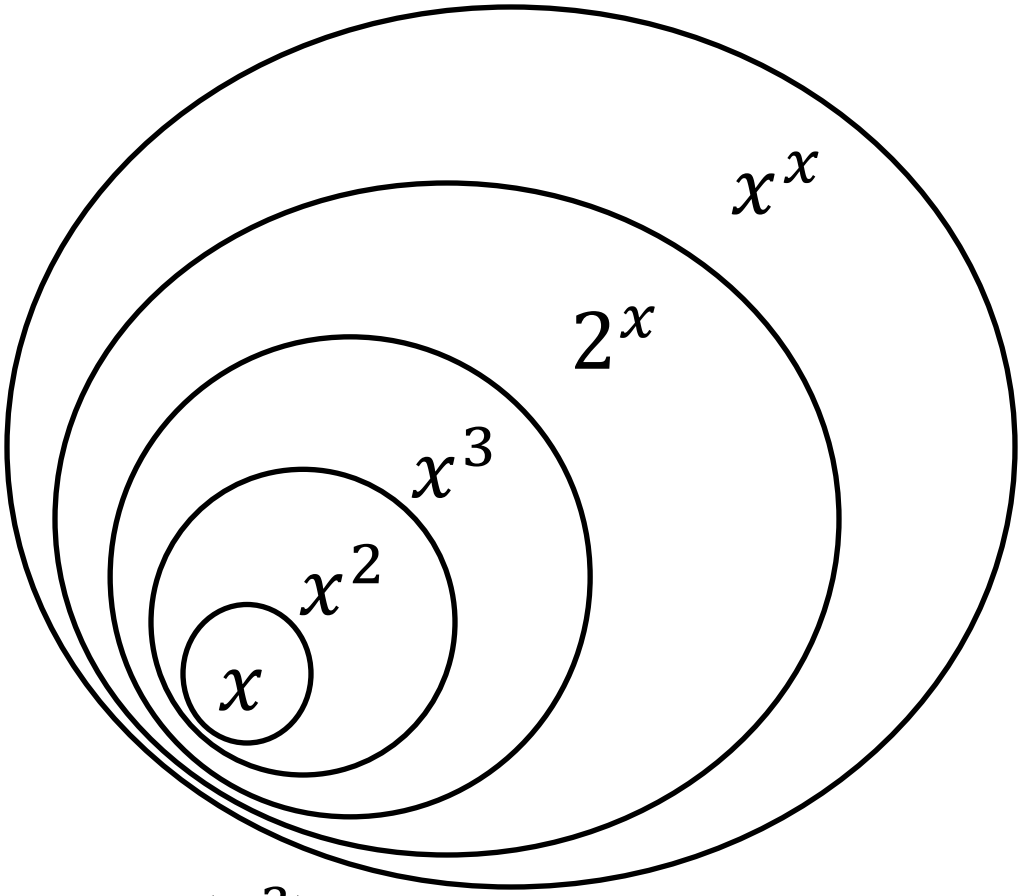
- Solving $\log_2 x < mx + b$ numerically (with a computer)
  - BigO example
- Key ideas of asymptotic notation:
  - Only behavior for large input sizes is significant
    - Small input is processed in milliseconds, with either algorithm
  - Constant factors are not important
    - Small fixed values of $m = 0.1,\ 0.05,\ 0.025$, etc. don't help much when input size is huge
  - Focus is often on the worst-case scenarios
    - When linear search goes to the end of the list
    - When binary search goes to a length 1 sub-list

“Big-O” notation

- Roughly speaking (when x gets big enough):
  - “$\log_2 x < x$”
  - “$1000\mathrm{x} < x^2$”
  - “$x^{1000} < 2^x$”
  - “$1000^x < x^x$”
- Roughly speaking (relative to higher-degree polynomials, exponentials, logarithms, etc.):
  - “$x^3 + 3x^2 + 3x + 1 = x^3$”

“Big-O” notation

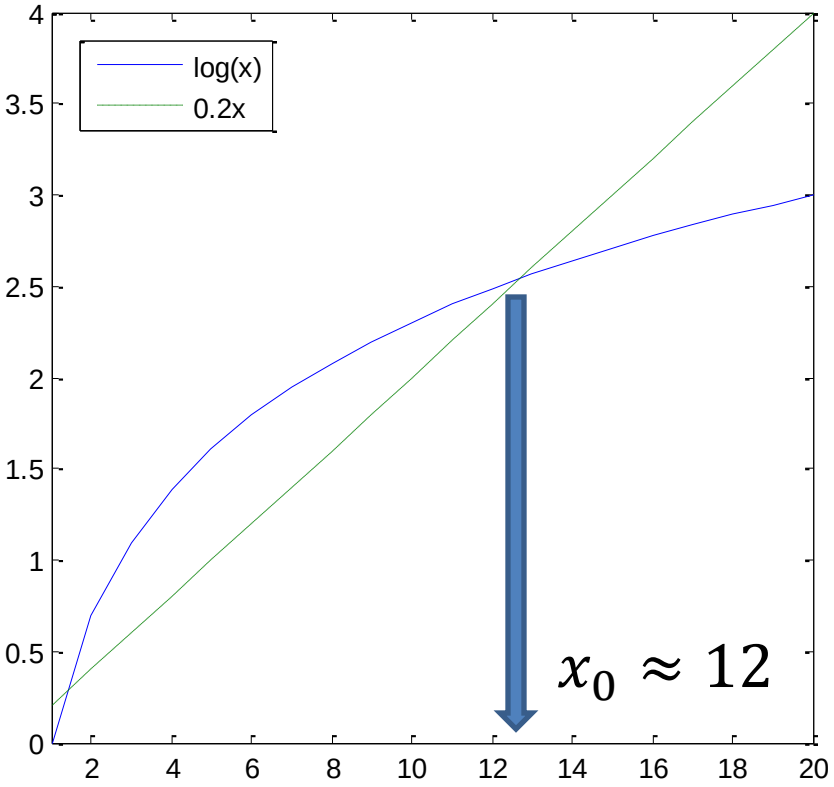
- Formal notation:
  - $\log_2 x = O(x)$
  - $1000\mathrm{x} = O(x^2)$
  - $x^{1000} = O(2^x)$
  - $1000^x = O(x^x)$
- Formal notation:

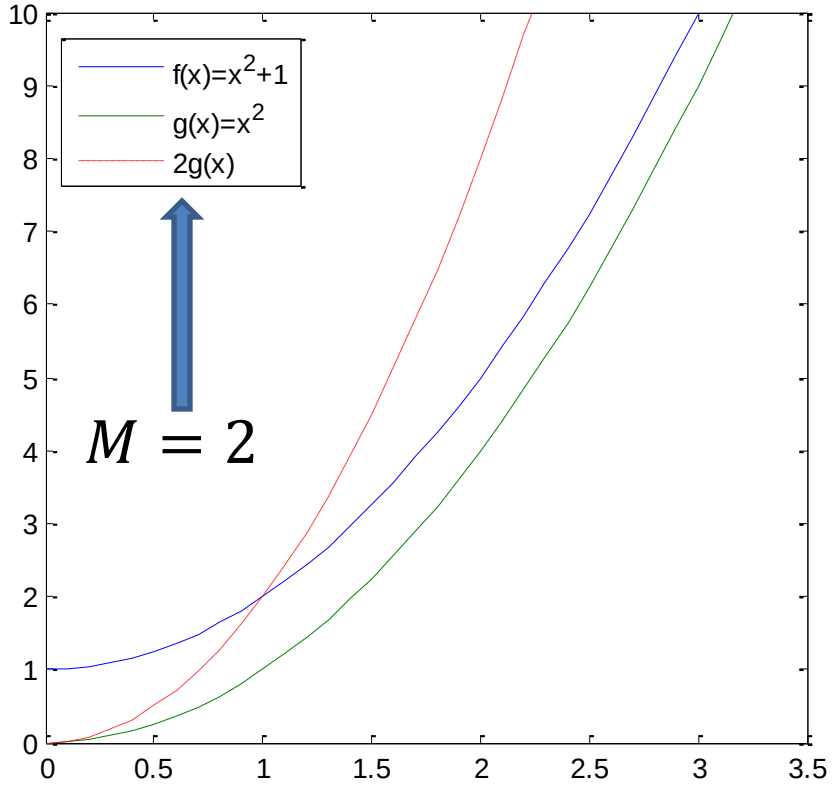


  - $x^3 + 3x^2 + 3x + 1 = O(x^3)$

$f(x) = O(g(x))$

Definition: $\exists M, x_0 : x > x_o \Rightarrow |f(x)| \leq M|g(x)|$

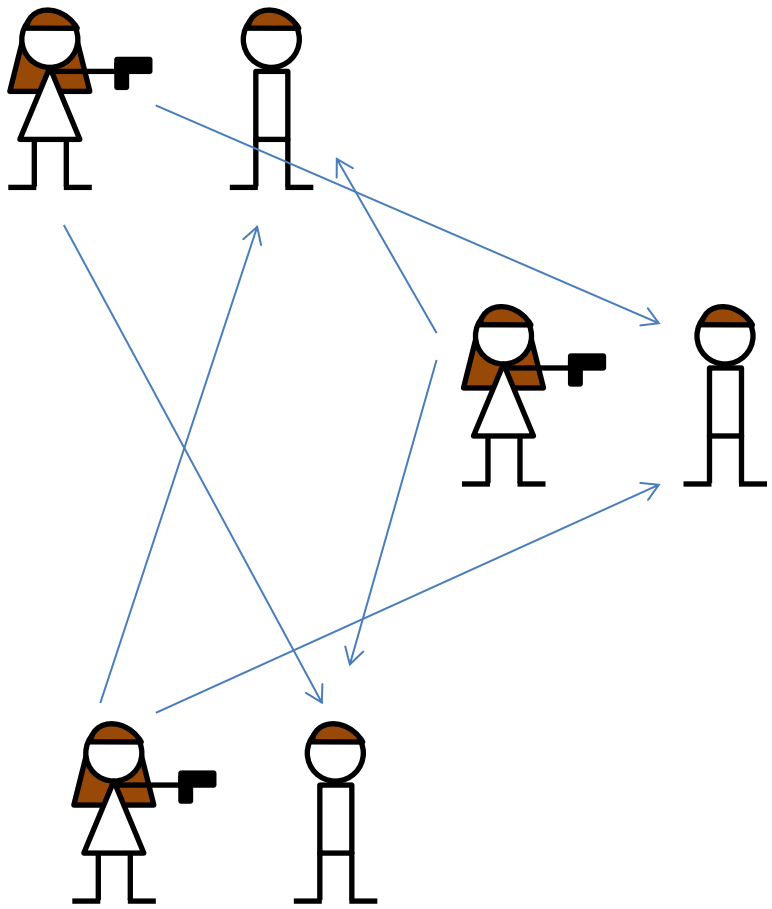




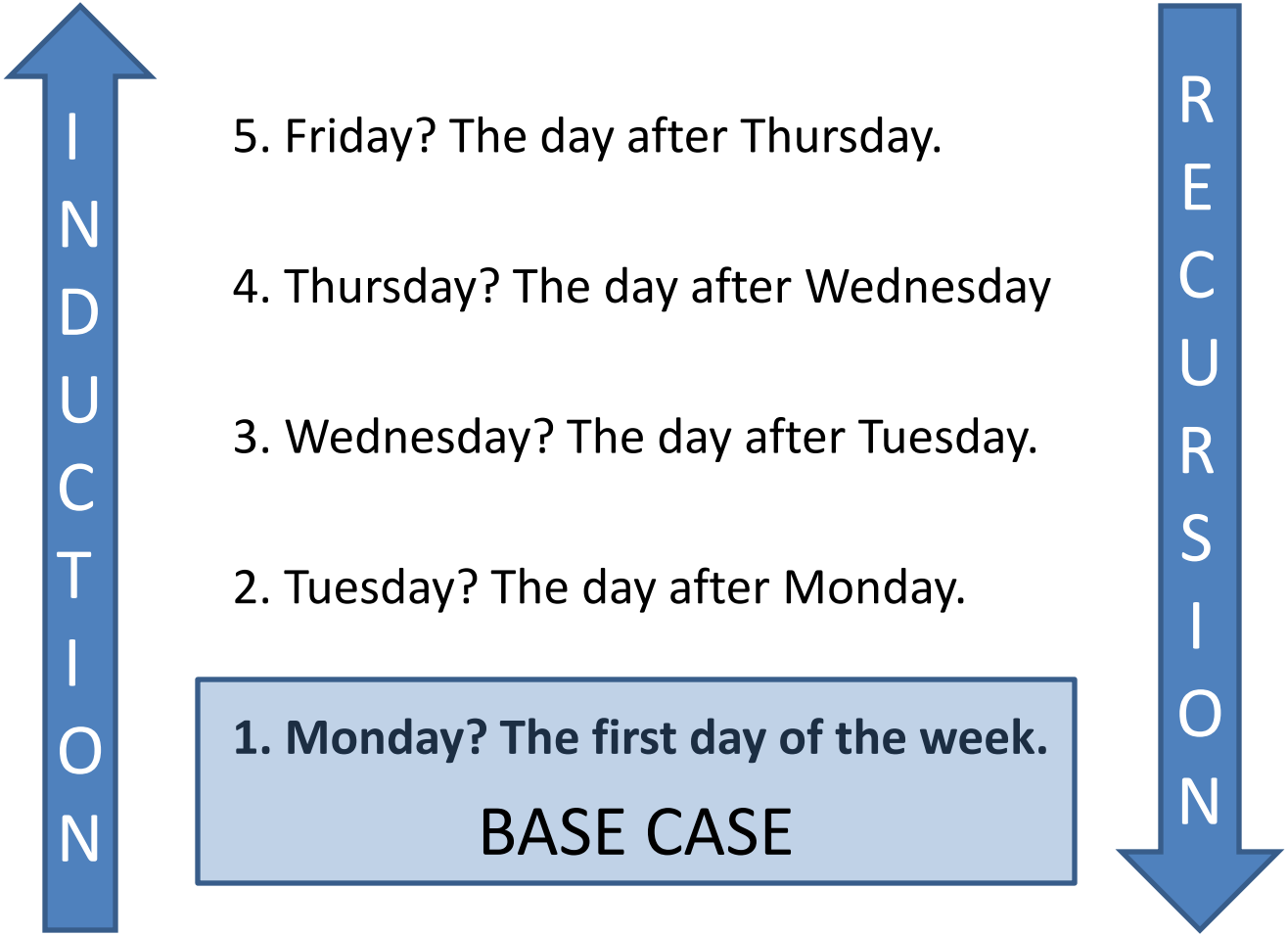
Induction and Recursion: Josephine's Problem

- Queen Josephine rules a land of female logicians and their husbands
- At least one husband is unfaithful
- Wives know all husbands' fidelities but their own
- Gunshots can be heard by all
- As soon as a woman deduces her own husbands fidelity, she must shoot him at midnight the same day
- After several nights, all women make the correct deductions. How?

LAS VEGAS



Induction and Recursion



Induction

Sums of odds:

- 1 = 1
- 1 + 3 = 4
- 1 + 3 + 5 = 9
- 1 + 3 + 5 + 7 = 16
- 1 + 3 + 5 + 7 + 9 = 25
- $\sum_{i=1}^{n} 2n - 1 = n^2$???

Induction

Fermat Numbers: $2^{2^n} + 1$

- $2^{2^1} + 1 = 5$ is prime.
- $2^{2^2} + 1 = 17$ is prime.
- $2^{2^3} + 1 = 257$ is prime.
- $2^{2^4} + 1 = 65537$ is prime.
- $2^{2^5} + 1 = 4294967297$ is not prime! (Euler)

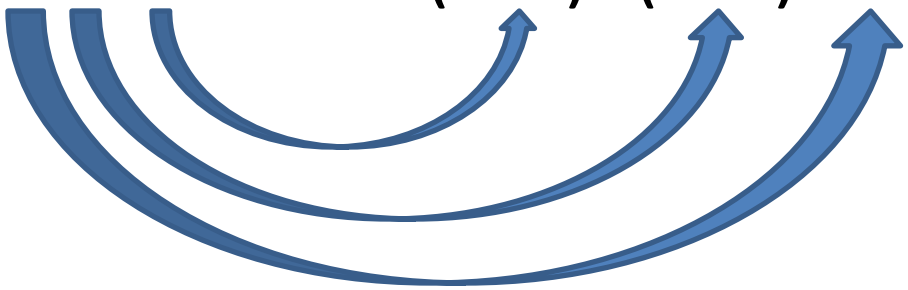
Induction

Sums of odds:

- $1 = 1 = 1^2$. (Base Case)
- Suppose $\sum_{i=1}^{n} 2n - 1 = n^2$ … (Inductive Hypothesis)
- Does $\sum_{i=1}^{n+1} 2n - 1 = (n+1)^2$??? (Inductive proof)

Sum of Naturals:

$1+2+3+4+\ldots+(n-2)+(n-1)+n = \frac{n(n+1)}{2}$???



Recursion: Induction in reverse

$n! = n \times (n-1)!$ Friday

$(n-1)! = (n-1) \times (n-2)!$ Thursday

$(n-2)! = (n-2) \times (n-3)!$ Wednesday

…

$1! = 1$ Monday (Base Case)

Writing recursive methods:

1. Handle the base case!!!
2. Assume the method already works at every sub-step, and call it.
3. Combine the result of the recursive call with the current step.

Recursion Examples