CSE 12 – Basic Data Structures and Object-Oriented Design
Lecture 20

Greg Miranda & Paul Cao, Winter 2021

This lecture is being recorded

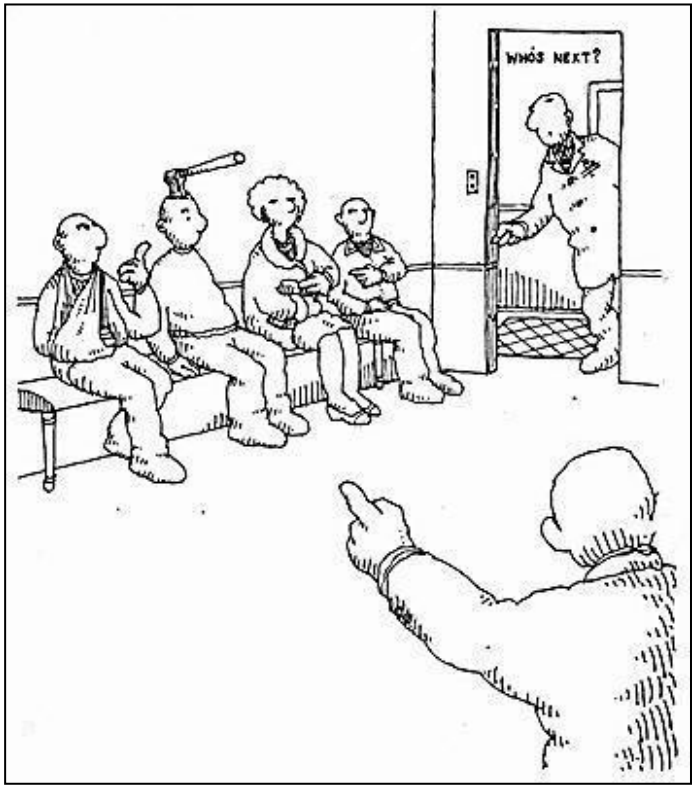
Announcements

- Quiz 20 due Monday @ 8am
  - No class on Friday, only the exam
- Survey 8 due Friday @ 11:59pm
- PA7 due next Tuesday (3/2) @ 11:59pm
- Exam 2 – Released Friday @ 8am, due Saturday @ 10am
  - 90 minutes once you start - see Piazza post for more details

Thursday 5pm – 10 PM
Paul's Zoom Q/A

Priority Queue ADT

- Emergency Department waiting room operates as a priority queue
- Patients sorted according to seriousness, NOT how long they have waited



Implementing a Priority Queue

Which of the following best describes what is true about the implementation of a Priority Queue?

A. There is only one correct way to implement a Priority Queue
B. There are many correct ways to implement a Priority Queue, and they are all equally good (assuming they implement the correct behavior)
C. There are many correct ways to implement a Priority Queue, but they vary in their efficiency (about how long it takes to do basic operations).

Priority queue implementation options

- **Sorted array**
  - Always insert based on the priority sorted order
  - Remove from the front

- **Unsorted linked list**
  - Insert new element in front
  - Remove by searching list for highest-priority item

- **Sorted linked list**
  - Always insert new elements where they go in priority-sorted order
  - Remove from front

Priority queue implementations

Sorted Array

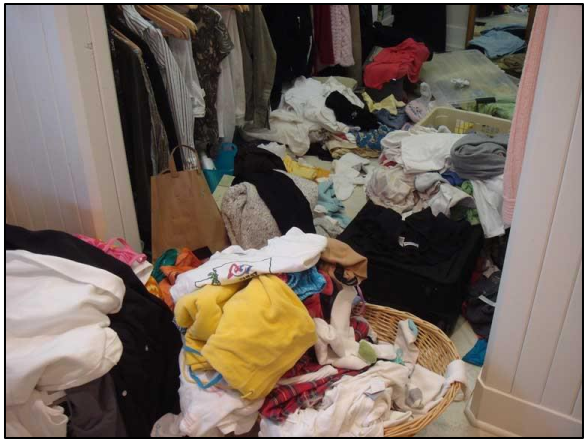
- **Add**
  - Need to step through the array to find where item goes in priority-sorted order. Also need to shift things back O(n)
- **Remove/peek**
  - Easy to find item you are looking for (first in list) O(1)

from towardsdatascience.com

Priority queue implementations

Unsorted linked list

- **Add**
  - Just throw it in the list at the front
- **Remove/peek**
  - Hard to find item the highest priority item—could be anywhere



Priority queue implementations

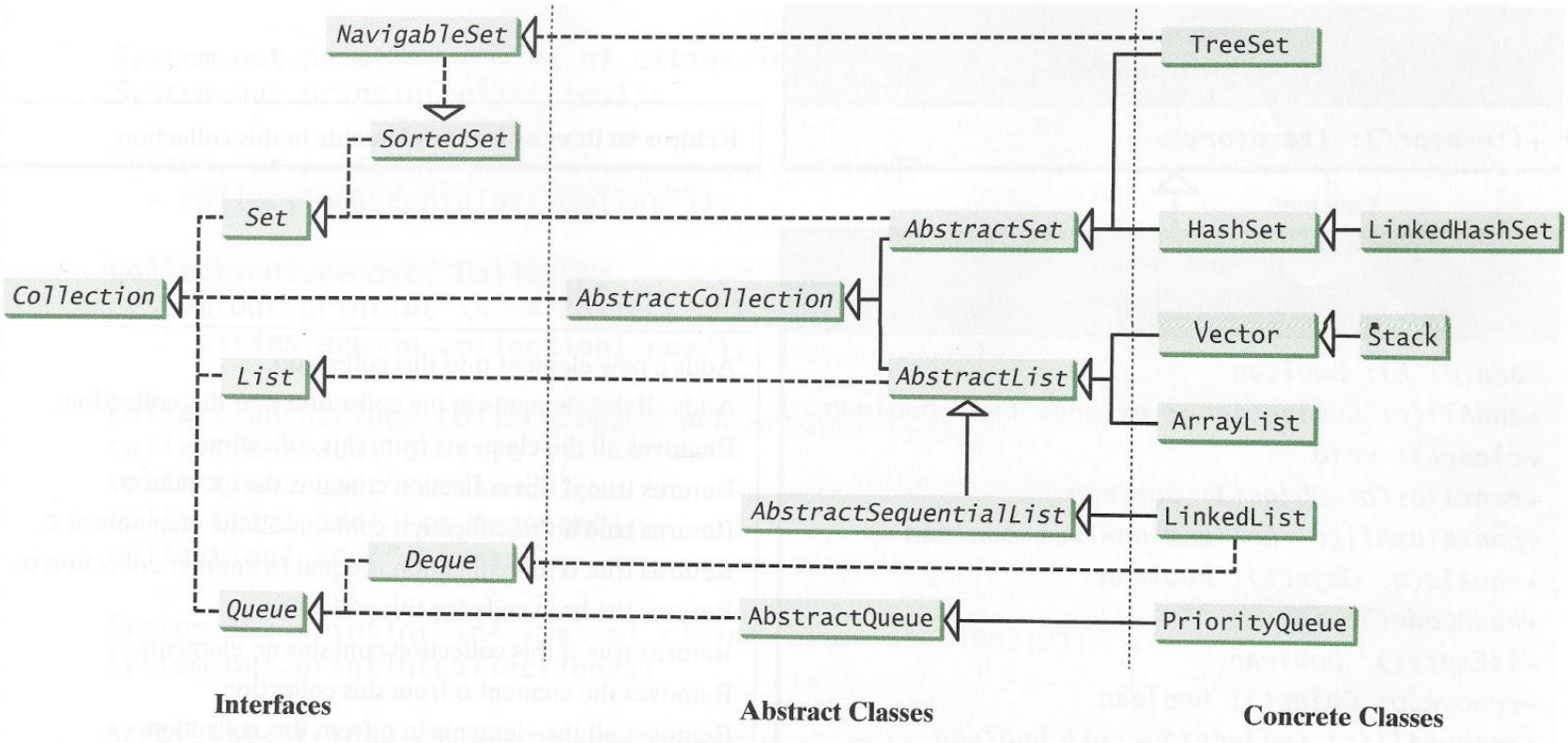
Sorted linked list

- **Add**
  - Need to step through the list to find where item goes in priority-sorted order

O(n)

- **Remove/peek**
  - Easy to find item you are looking for (first in list)

O(1)

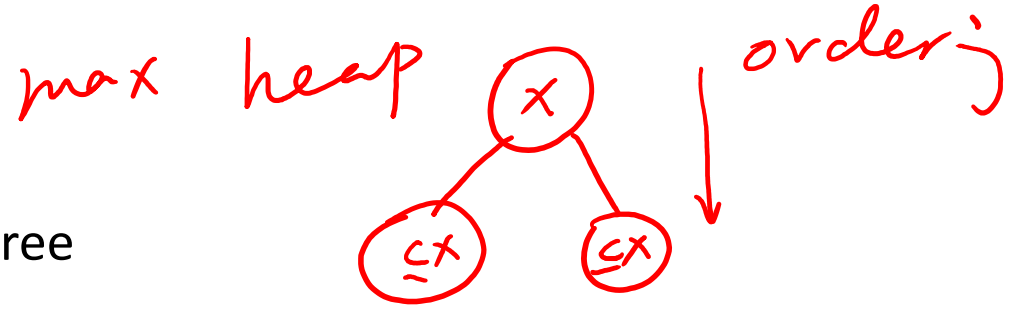

NavigableSet
TreeSet
SortedSet
Set
AbstractSet
HashSet
LinkedHashSet
Collection
AbstractCollection
Vector
Stack
List
AbstractList
ArrayList
AbstractSequentialList
LinkedList
Deque
Queue
AbstractQueue
PriorityQueue
Interfaces
Abstract Classes
Concrete Classes

Priority queue implementations

We want the best of all

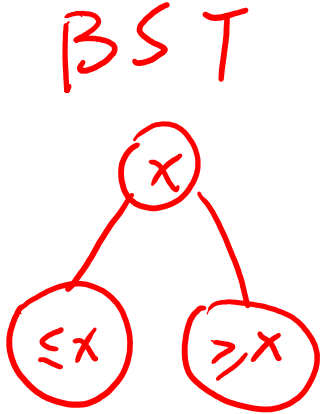
- Fast add AND fast remove/peek
- We will investigate a new data structure called a "heap" as a way to do this

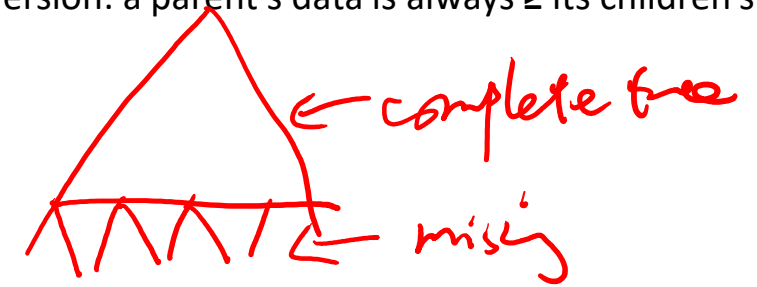
Heaps



- Heaps are **one kind** of binary tree
- They have a few special restrictions, in addition to the usual binary tree requirements:
  - Must be **complete**
  - Ordering of data must obey **heap property**
    - Min-heap version: a parent's data is always **≤** its children's data
    - Max-heap version: a parent's data is always **≥** its children's data

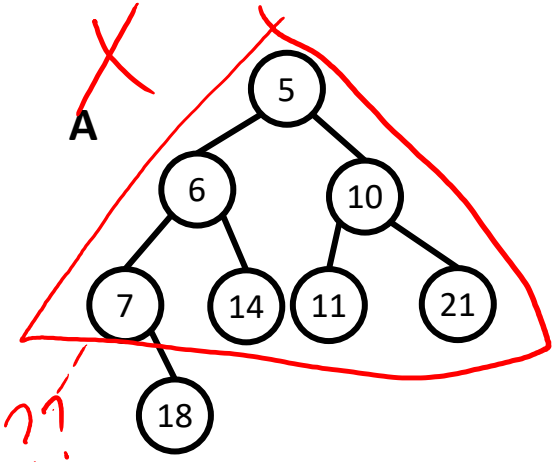
min/max Structure requirement



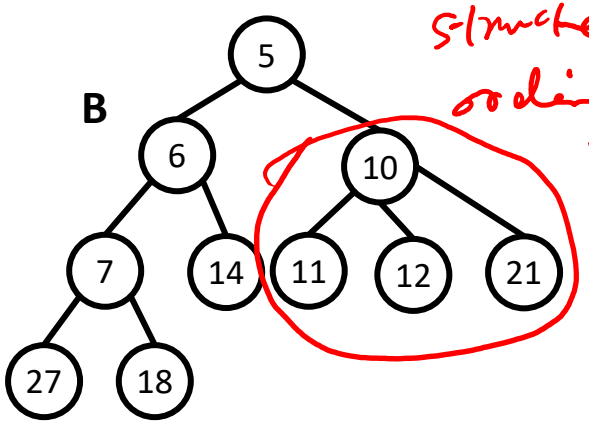


Which of the following are valid heaps?

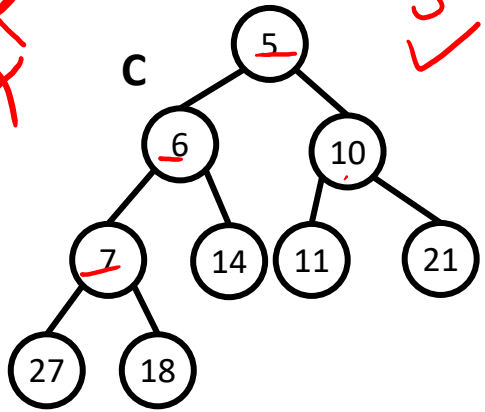
A



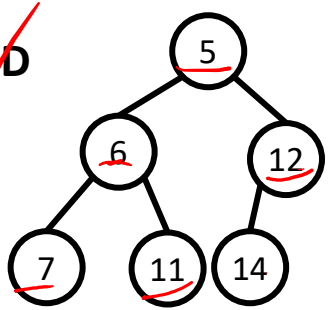
B



C



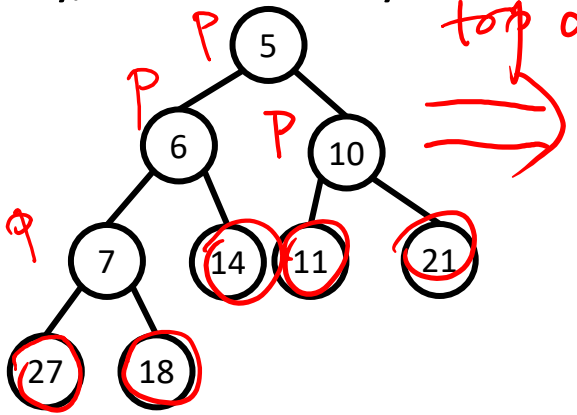
D

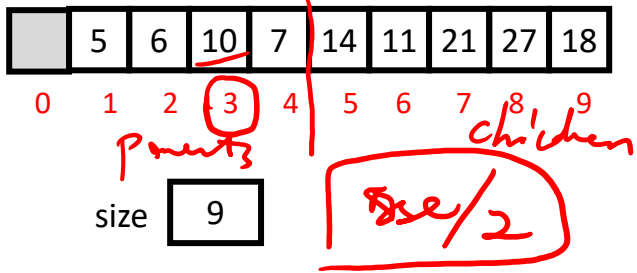


E. More than one is valid

Heap in an array (vs a linked structure)

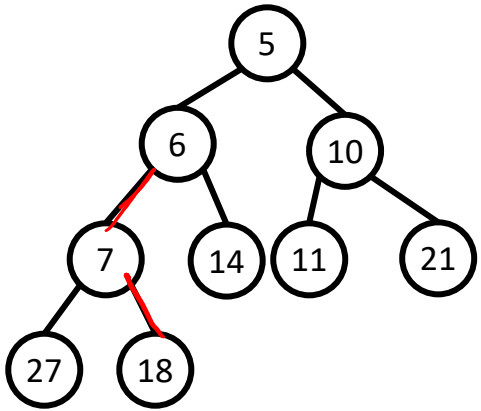
- We actually do NOT typically use a node object to implement heaps
- Because they must be **complete**, they fit nicely into an array, so we usually do that

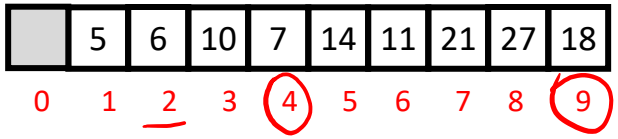




Why are arrays better than linked lists?

Heap in an array, starting at index 1

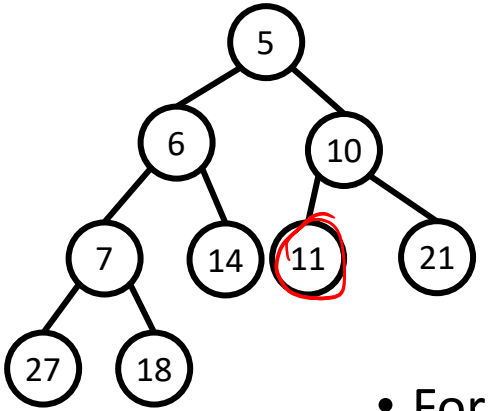


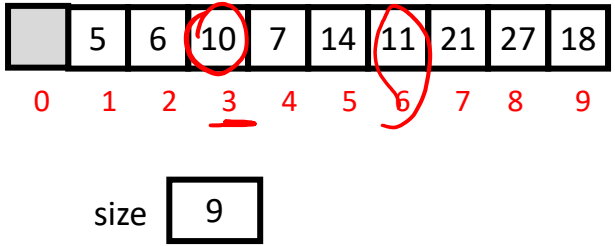


size 9

- For a node in array index i:
  - Parent is at array index:
    A. i – 2
    B. i / 2
    C. (i – 1)/2
    D. 2i

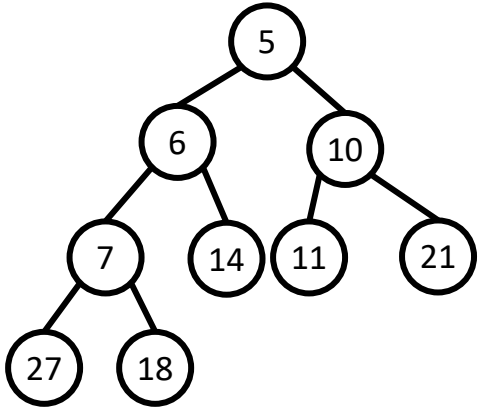
Heap in an array, starting at index 1

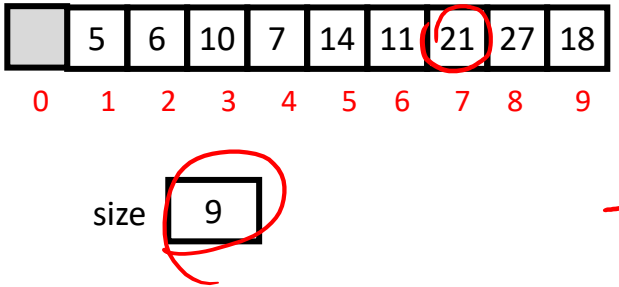




- For a node in array index i:
  - Left child is at array index:
    A. i +1
    B. i + 2
    C. 2i
    D. 2i + 1

Heap in an array, starting at index 1





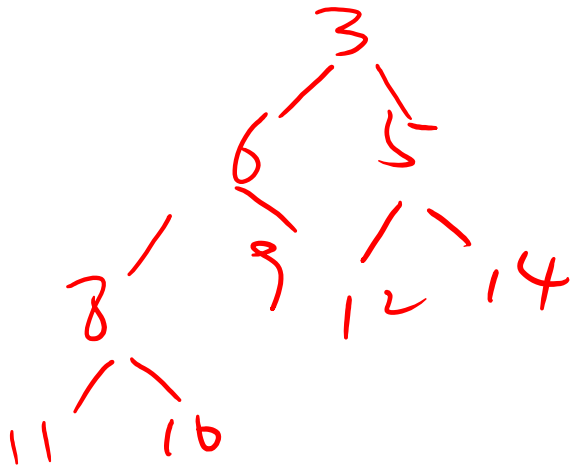
2 * 7 = 14

- For a node in array index i:
  - Parent is at array index: i /2
  - Left child is at array index: 2i
  - Right child is at array index: 2i + 1

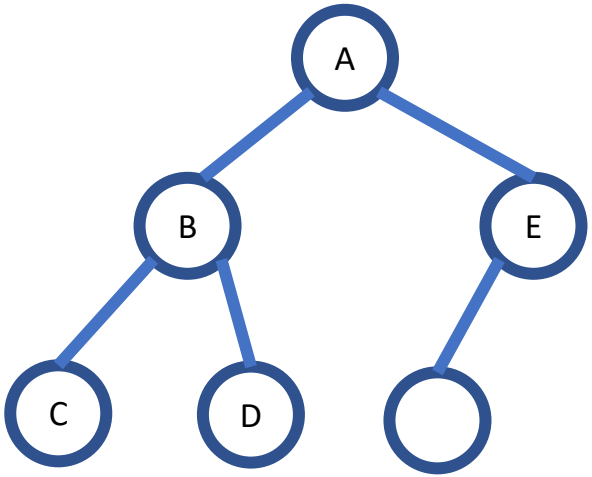
Heap

Can you draw the heap structure based on the following array representation?

0	1	2	3	4	5	6	7	8	9
	3	6	5	8	9	12	14	11	10



Given the heap structure, which node corresponds to the red location in the array?



0	1	2	3	4	5	6
	A	B	E	C	D	

Who is the direct parent of the red cell?

0	1	2	3	4	5	6	7	8	9	10
			C	A	B	D		E		

Who are the children of the red cell?

0	1	2	3	4	5	6	7	8	9	10

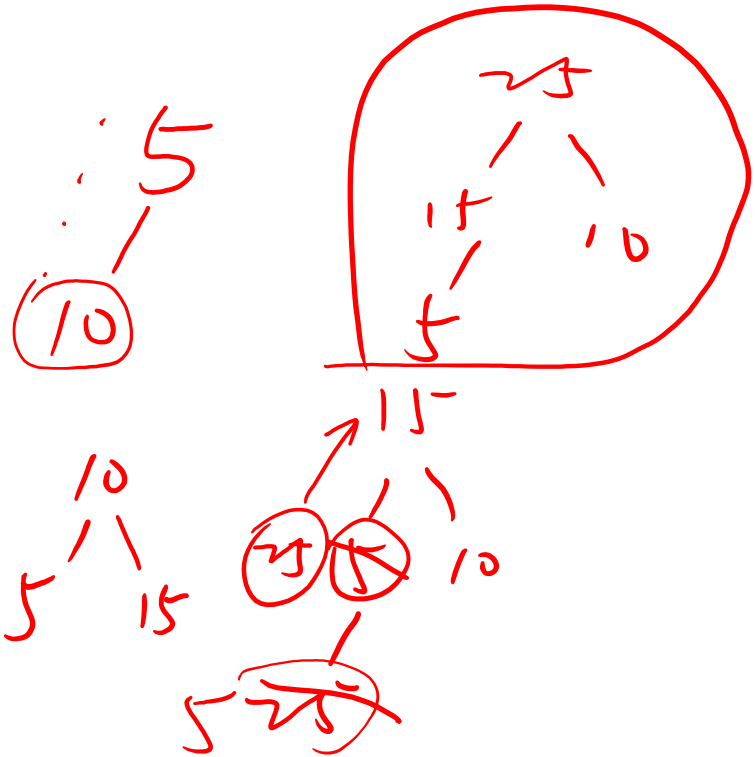
2*5

2*5 +1

A. cell 9 and 10
B. cell 10 only
C. cell 6 and 7
D. cell 8 and 9
E. none of the above

Max Heap (draw the picture and array)

- Assume the key and value are identical for this example
- Draw the picture and the array for the following:
  - Add the following elements to the max heap (in this order):
    - 5, 10, 15, 25, 30, 35, 40
  - Call poll() twice
    - What elements were returned?



Questions on Lecture 20?