HW 7 extended to next week 2x credit
(Lots of details to get right!)
PLEASE look at graded solutions on Gradescope!

Anakin OH: Mon 6-7 next Sat back to normal
Self OH:
next Fri back to normal

Mergeable heaps / PQs
- Insert
- Merge
- Extract Min
- Decrease Key

Leftist heap: $O(\log n)$ worst case
Binomial heap: $O(\log n)$ worst case

At least one of these must take $O(\log n)$ time.

Fibonacci heap
Dec Key $O(1)$ amortized
Insert/Merge $O(1)$
Decrease/Ex Min: $O(\log n)$

Pairing heap
Insert/Merge $O(1)$
Dec Key $O(\log n)$
Ex Min $O(\log n)$

Binomial heap = list of binomial trees
heap-ordered

$B_0 = 0$
$B_n = B_{n-1} + B_{n-1}$

Insert = increment $O(\log n)$ time
Merge = add
LAZY Insert + Merge: $O(1)$ worst case amortized

$\rightarrow$ add Bo $\rightarrow$ concatenate lists

Extract Min:
- delete + remember min - pr node
- repeatedly merge same size trees $\leftarrow O(\#\text{roots})$ time
- find new min $\rightarrow O(\log n)$

$O(\log n)$ amortized

Decrease Key:

Bubble or shatter $\Rightarrow O(\log n)$ time

Promote ($v$):
- move $v$ to main list
- if parent ($v$) is marked
  - unmark $P$
- promote $P$
- else
  - mark $P$

$O(\log n)$ worst case

$O(1)$ amortized time

Key: $F_k \leq \#\text{nodes in tree with rank } \leq 2^k$

Pairing heap:
- Single heap-ordered tree.
- Merge = link $O(1)$
- Decrease key
Extract Min  \( \Theta(n) \) worst case

Pairing – pairs

Cleanup – link last two

\[ \Delta \]

\[ \text{link} \]

\[ \text{rotation} \]