RECITATION8
<table>
<thead>
<tr>
<th>Mon</th>
<th>Tues</th>
<th>Wed</th>
<th>Thurs</th>
<th>Fri</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Today!</strong></td>
<td></td>
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<td>malloc checkpoint</td>
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<td>Exam2</td>
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<td>malloc final</td>
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Today
malloc lab
virtual memory
malloc lab
Architecture

Program

malloc

Heap
Initial empty heap

Heap
a = malloc(2);
a = malloc(2);
b = malloc(3);

Return this address
c = malloc(5);
free(b);

Free this
How do we keep track of blocks?
Proposal: use a data structure

Data structure

Problems?
Implicit list

Problems?
Explicit List

Size: 2
Free

Size: 3

Size: 2
Free
Segregated List
Choosing a block

First fit
Choosing a block

First fit

Next fit
Choosing a block

First fit

Next fit

Best fit
When to coalesce?

After freeing a block
When no sized block exists
When searching the list
What are the best options?

Implicit/Explicit/Segregated

First Fit/Next Fit/Best Fit

Coalescing
C Hints/Tricks

Using structs rather than macros gives one much more flexibility

struct __attribute__((__packed__)) {
  // bit-fields
}
But keep in mind...

“Premature Optimization is the root of all evil”

-Donald Knuth
Virtual Memory
Memory

Process

Memory
Secondary Storage
Multiple Processes

Process

Process

Process

Memory

Storage
How do we deal with all this?
“All problems in computer science can be solved by another level of indirection”

-David Wheeler
WTF is level of indirection?!?!
Abstraction...
Virtualization...
Interfaces...
Layering...
Remember this?

Program

malloc

Heap
Remember this?

- Process
  - #1
  - #0

- Kernel
  - STDOUT
  - STDIN

- Terminal
  - outfile
  - infile
Remember this?
How do we deal with all this?
Virtual Memory

- Process
- Process
- Process

VM

Memory

Storage
Physical Memory for now

- Process
- Process
- Process

VM

Memory
VA -> PA
Process sees entire VM space
How do we map VA->PA?
Keep an Address Map Table

Process

VM

Memory

Problems?
Keep a Page Map Table

Process

VM

Memory
2-level page tables
Common Interview Question

What is Virtual Memory?
Extremely useful level of indirection

- Protect processes from each other
- Seamlessly use secondary storage when physical memory runs out
- Allows processes to use 32/64 bit address space no matter how much physical memory there actually is
- Cool use for memory saving optimizations: COW, zeroed page
START STUDYING!