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601.220 Intermediate Programming

Summer 2022, Meeting 9 (June 27th)

Today's agenda

- Exercise 15 review
- ~~Midterm project overview~~
- "Day 17" material
  - Linked lists
  - Exercise 17
- "Day 18" material
  - More linked lists
  - Exercise 18

Reminders/Announcements

- Midterm project: due Friday, July 1st
- Midterm exam: in class on Wednesday, July 6th

review materials posted

Exercise 15 review

983
100s 10s 1s

hexadecimal
0 - 9
A - F
10 15

```
(gdb) break endian.c:21
Breakpoint 1 at 0x1243: file endian.c, line 21.
(gdb) run
[...output omitted...]
Breakpoint 1, main () at endian.c:21
21    printf("%u\n", *p);
(gdb) print/x ((unsigned char *)p)[0]
$1 = 0x83
(gdb) print/x ((unsigned char *)p)[1]
$2 = 0x7e
(gdb) print/x ((unsigned char *)p)[2]
$3 = 0xa3
(gdb) print/x ((unsigned char *)p)[3]
$4 = 0x38
```

In base-16, 950238851 is 38A37E83. Since we're seeing the bytes in order from least to most significant, the ugrad machines are *little endian*.

Exercise 15 review

To negate a two's complement value:

- Invert all of the bits (the ~ operator is useful for this)
- Add 1

Exercise 15 review

could also use (1U << 31)

Note that `0x80000000U` is the `unsigned int` value with only the most significant bit set to 1. This is the sign bit, and values with this bit set are negative.

```
unsigned int magnitude(unsigned int value) {
  if ((value & 0x80000000U) == 0U) {
    return value; // value is non-negative
  }

  // value is negative, so invert bits and add 1
  value = ~value;  // invert bits
  value += 1U;     // add 1
  return value;
}
```

Exercise 15 review

Generating a uniformly distributed pseudo-random integer in the range 0 (inclusive) to `max_num` (exclusive):

```
int gen_uniform(int max_num) {
  return rand() % max_num;
}
```

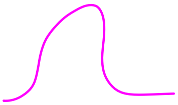
Generating 500 random values in range 0 (inclusive) to `max_range` (exclusive) and tallying them in the `hist` array:

```
for (int i = 0; i < 500; i++) {
  hist[gen_uniform(max_range)]++;
}
```

Exercise 15 review

Generating normally-distributed integer values in the range 0 (inclusive) to `max_range` (exclusive):

```
int normal_rand(int max_num) {
  int result = 0;
  for (int i = 1; i < max_num; i++) {
    if ((rand() & 1) == 1) {
      result++;
    }
  }
  return result;
}
```



This is basically flipping a coin `max_num-1` times and counting how many times it's heads.

Exercise 15 review

Generating 500 normally-distributed values in the range 0 (inclusive) to `max_range` (exclusive) and tallying them in the `hist` array:

```
for (int i = 0; i < 500; i++) {
  hist[normal_rand(max_range)]++;
}
```

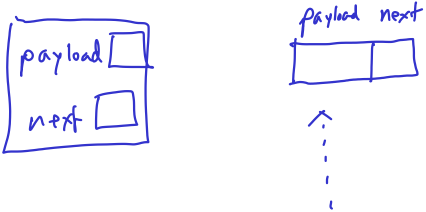
Day 17 recap questions

1. Describe the linked list structure by a diagram.
2. Compare arrays and linked lists. Write down their pros and cons.
3. What is a linked list's head? How is it different from a node? Explain.
4. How do you calculate `length` of a linked list?
5. How do you implement `add_after` on a singly linked list?

1. Describe the linked list structure by a diagram.

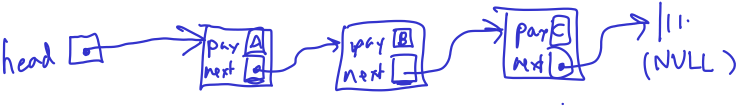
`struct Node` type:

```c
struct Node {
  char payload; // payload could be any data type
  struct Node *next;
};
```

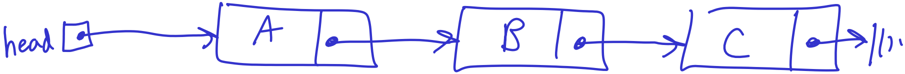


Example linked list

```c
// code creating a linked list
struct Node *head = malloc(sizeof(struct Node));
head->payload = 'A';
head->next = malloc(sizeof(struct Node));
head->next->payload = 'B';
head->next->next = malloc(sizeof(struct Node));
head->next->next->payload = 'C';
head->next->next->next = NULL;
```



A more concise representation



2. Compare arrays and linked lists. Write down their pros and cons.

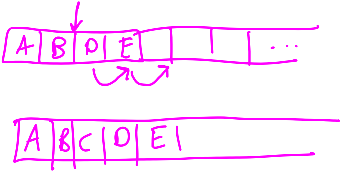
N = # elements

"random access"

"constant time"

Arrays:

- Pro: O(1) access to arbitrary element
- Con: O(N) to insert or remove element at arbitrary position
- Pro: better locality (fewer cache misses when iterating)
- Pro: more compact
- Con: fixed size, to reallocate must allocate new array and copy existing data



"proportional to N"

Linked list pros and cons

"sequential access"

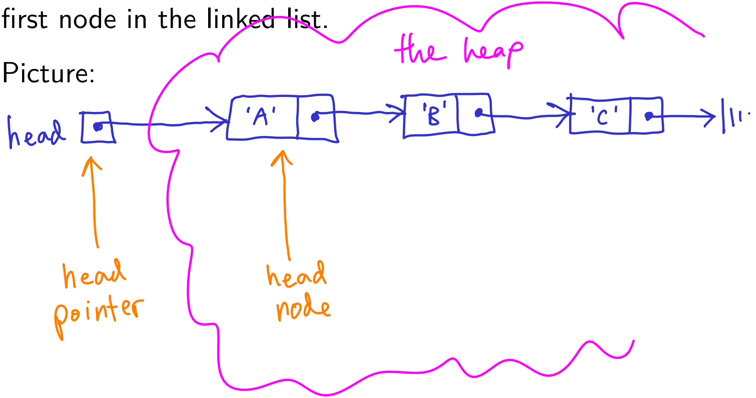
Linked list:

- Con: O(N) access to arbitrary element
- Pro: O(1) to remove element at arbitrary position
- Con: worse locality (more cache misses when iterating)
- Con: less compact (next pointers require space)
- Pro: can grow incrementally, nodes are allocated one at a time

3. What is a linked list's head? How is it different from a node? Explain.

Contrast: *head pointer* vs. *head node*. The head pointer is a pointer variable storing a pointer to the first node. The head node *is* the first node in the linked list.

Picture:



4. How do you calculate `length` of a linked list?

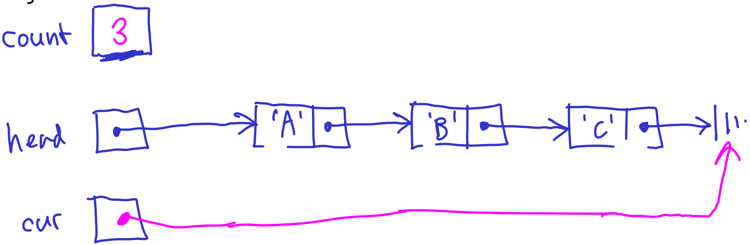
cur = head;

A loop is required:

```
struct Node *head = /* points to first node */;
int count = 0;
```

advance

```
for (struct Node *cur = head; cur != NULL; cur = cur->next) {
  count++;
}
```



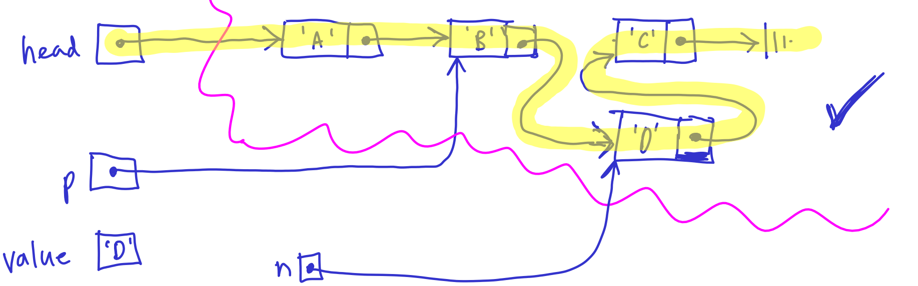
5. How do you implement add_after on a singly linked list?

A B C

A B D C

```
void add_after(struct Node *p, char value) {
  struct Node *n = malloc(sizeof(struct Node));
  n->payload = value;
  n->next = p->next;
  p->next = n;
}
```

heap



Exercise 17

11:30

- Basic linked list functions
- Drawing pictures to reason about how linked lists operations should work is very helpful!
- Note that `reverse_print` is most easily implemented using recursion
- Breakout rooms 1–10 are "social"
- Use Slack to let us know if you have questions

Day 18 recap questions

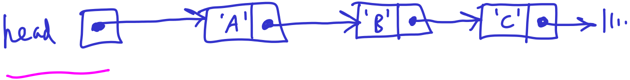
1. How do you implement *add_front* on a linked list?
2. How do you modify a singly linked list to create a doubly linked list?
3. How do you make a copy of a singly linked list?
4. Why does *add_after* takes a `struct Node *` as input, but *add_front* takes `struct Node **`?
5. What cases should be handled when implementing *remove_front*?

4. Why does *add_after* takes a `struct Node *` as input, but *add_front* takes `struct Node **`?

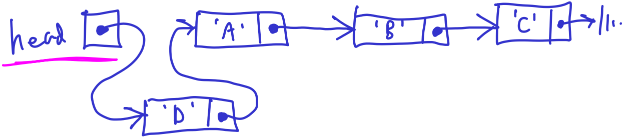
Because `add_after` needs to change which node the head pointer points to. For example:

```
struct Node *head = /* linked list containing 'A', 'B', 'C' */;
// ...
add_front(&head, 'D');
```

Before:



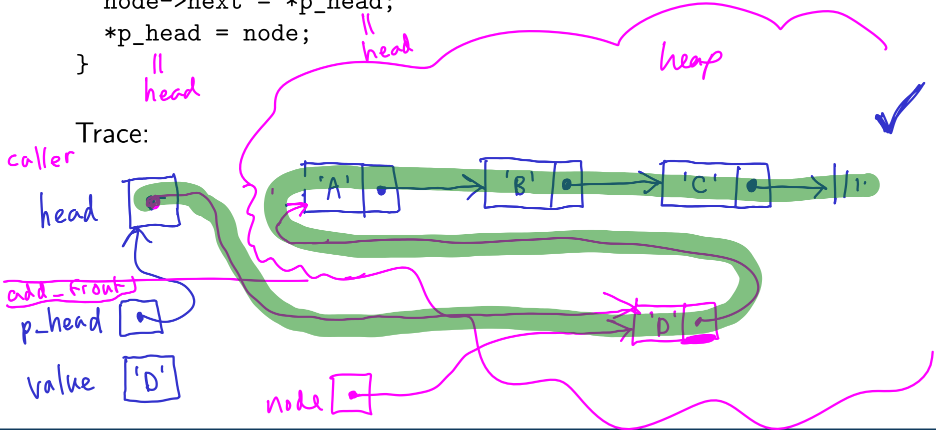
After:



1. How do you implement *add_front* on a linked list?

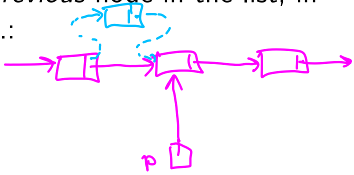
```c
void add_front(struct Node **p_head, char value) {
  struct Node *node = malloc(sizeof(struct Node));
  node->data = value;
  node->next = *p_head;
  *p_head = node;
}
```

Trace:



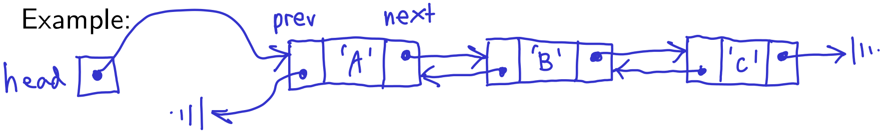
2. How do you modify a singly linked list to create a doubly linked list?

Have each node store a pointer to the *previous* node in the list, in addition to the next node in the list. I.e.:

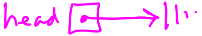



```
struct Node {
  char payload;
  struct Node *prev, *next;
};
```

Example:

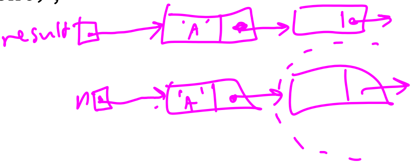


3. How do you make a copy of a singly linked list?



One way is to use recursion:

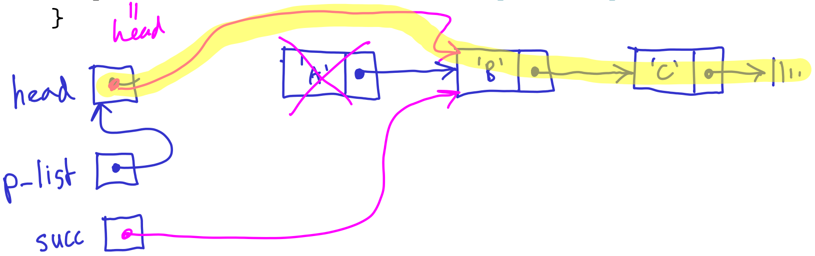
```
struct Node *copy_list(struct Node *n) {
  struct Node *result;
  if (n == NULL) {
    result = NULL;
  } else {
    result = malloc(sizeof(struct Node));
    result->payload = n->payload;
    result->next = copy_list(n->next);
  }
  return result;
}
```



5. What cases should be handled when implementing *remove_front*?

There should not be any special cases.

```
void remove_front(struct Node **p_list) {
  assert(*p_list != NULL);                 head
  struct Node *succ = (*p_list)->next;
              head
  free(*p_list);    // free original head node
  *p_list = succ;   // make head pointer point to second node
}
```



Exercise 18

- More linked list operations (including ones requiring pointer to head pointer)
- Again, drawing diagrams is very helpful for reasoning about linked list operations
- Breakout rooms 1–10 are “social”
- Use Slack to let us know if you have any questions!

Notes

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