CS 241: Systems Programming
Lecture 19. Linked Lists

Fall 2019

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Announcements

Project proposal due tonight

Homework 3 due tonight

Aside: returning multiple values

In Python, functions can return multiple values (it returns a tuple)

```
def example():
    return "example", 5
```

In C, functions cannot; instead

- Return a struct

```
struct ret_val { char const *s; int i; };
  struct ret_val example1(void) {
  struct ret_val r = { .s = "example", .i = 5 };
  return r;
}
```

Returning multiple values (cont)

- Add pointer parameters

```
char const *example2(int *out) {
  *out = 5;
  return "example";
}
```

- Use global variables

```
int example_ret;
char const *example3(void) {
  example_ret = 5;
  return "example";
}
```

Aside 2: Avoid globals

Avoid global variables whenever possible

Globals

- make your code difficult to reason about
- make writing correct multi-threaded code extremely difficult
- make testing individual functions difficult
- pollute the namespace because they are available everywhere
- can cause implicit coupling between separate functions

Sometimes globals are fine…but they're usually not what you want

How should a function return multiple values (in most cases)

A. Return a struct

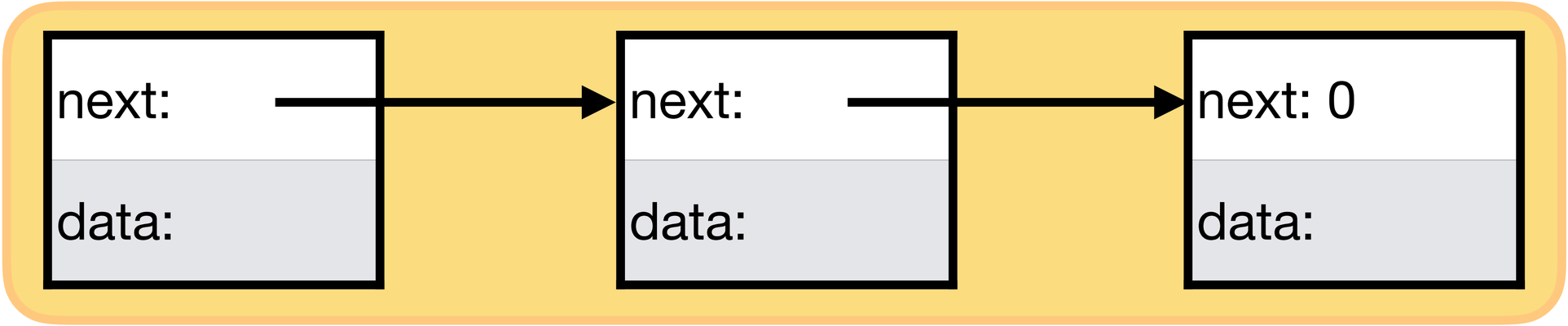
B. Using pointer parameters

C. Using global variables

D. A or B

E. A, B, or C

Review from Data Structures



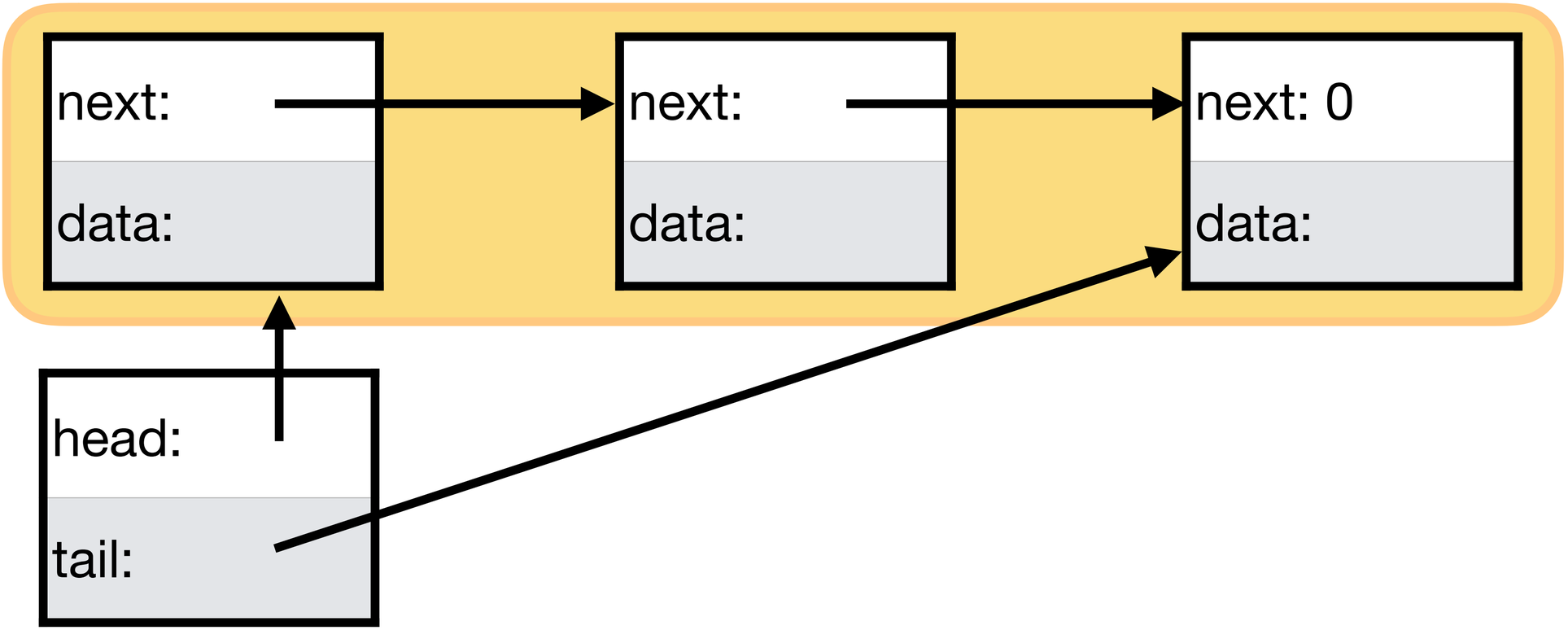
A (singly) linked list is a data structure that implements the List ADT

- Add, insert, remove elements
- Ordered by position in the list

Each node contains

- An element of the list
- A pointer to the next element in the list or 0 (`NULL`) for the last node

Review from Data Structures



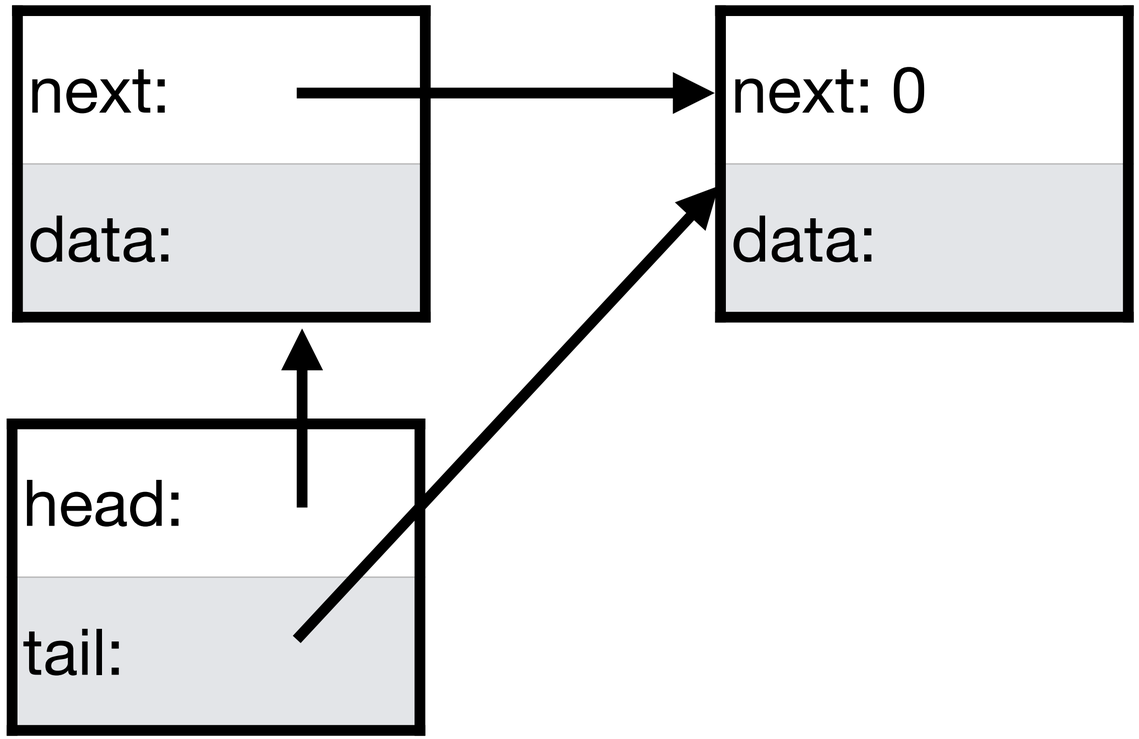
The list itself usually contains a pointer to the head of the list (first node) and the tail of the list (last node)

Data types for a list of ints

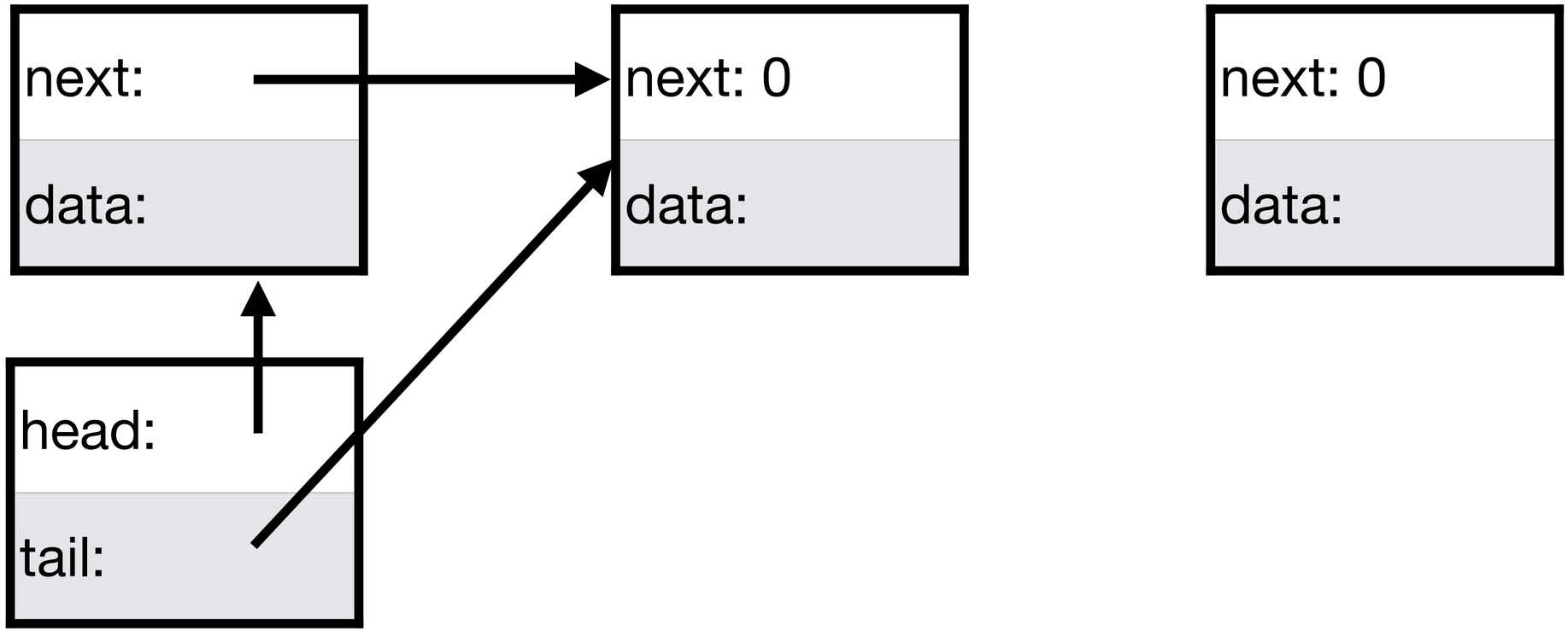
```
typedef struct Node {
  struct Node *next;
  int data;
} Node;

typedef struct List {
  Node *head;
  Node *tail;
} List;
```

Appending to the list

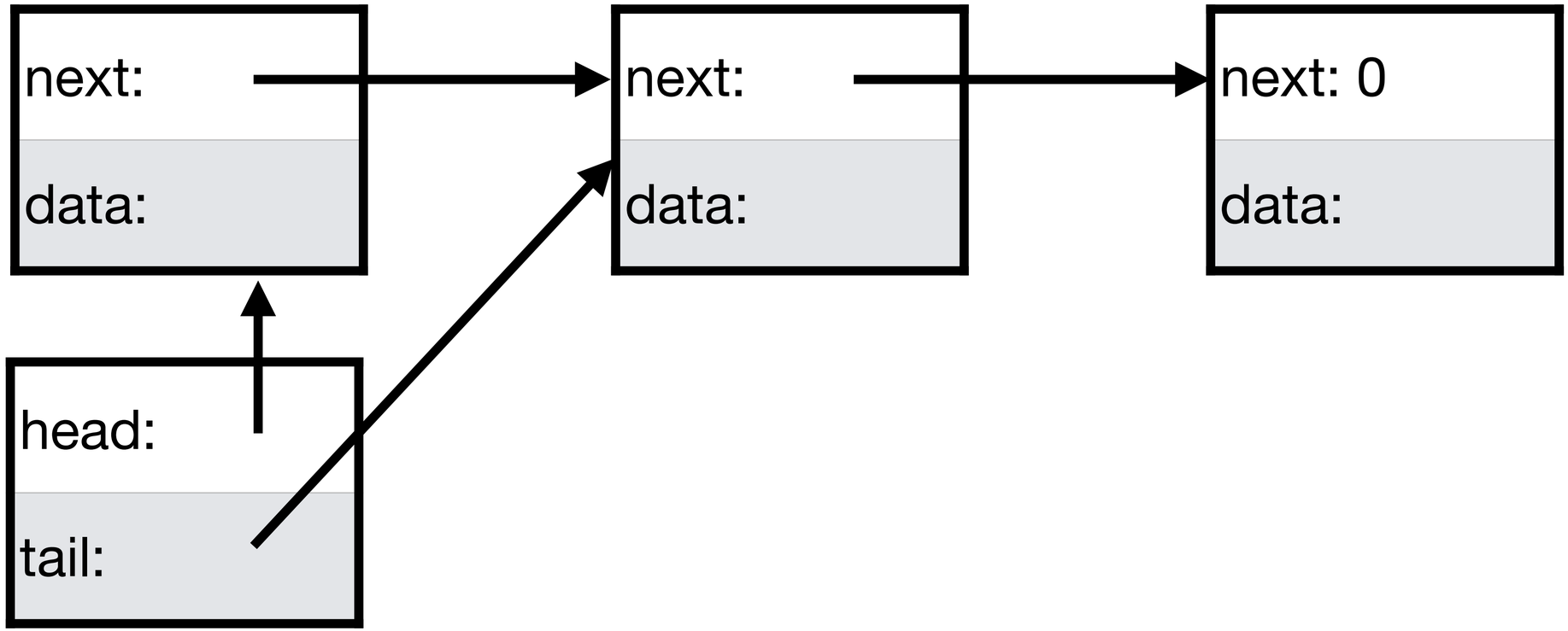


Appending to the list



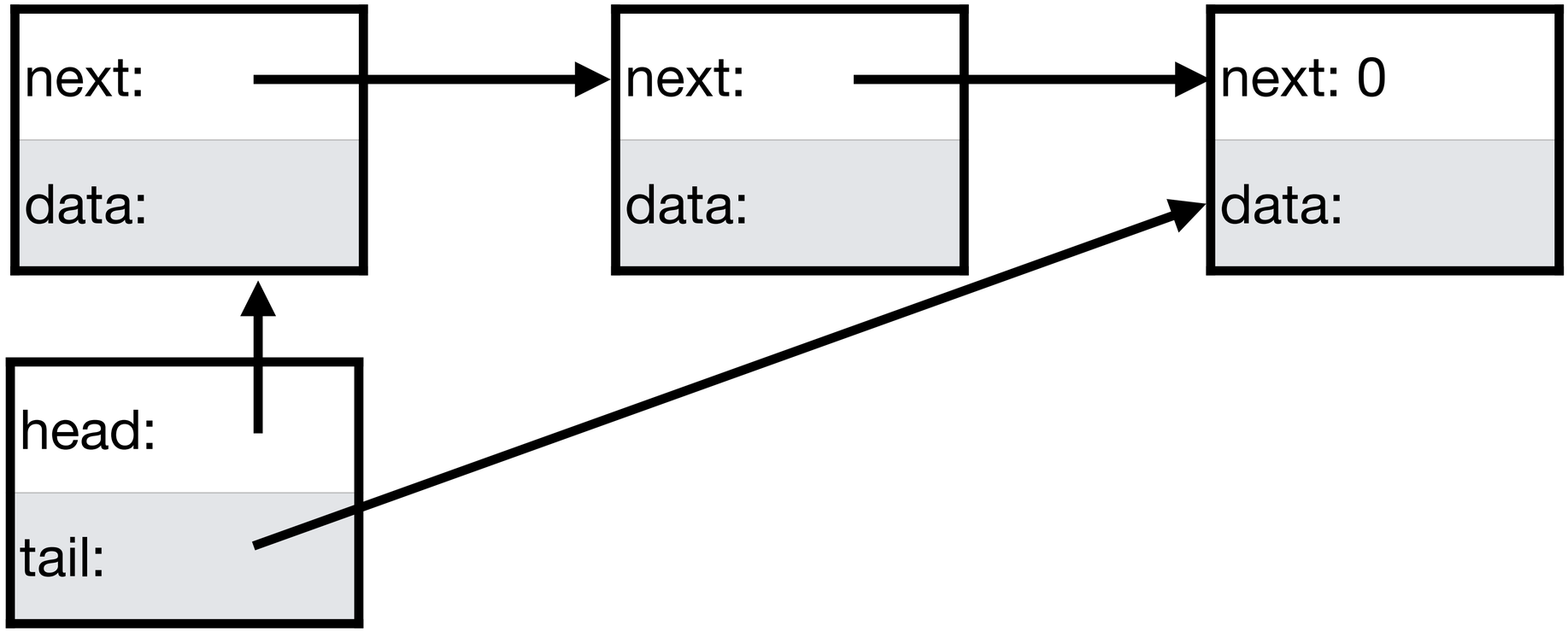
1. Create a new node with next = 0 and data set to the new element

Appending to the list



1. Create a new node with next = 0 and data set to the new element
2. Update tail->next to point to the new node

Appending to the list



1. Create a new node with next = 0 and data set to the new element
2. Update tail->next to point to the new node
3. Update tail to point to the new node

Appending to the list

```
void list_append(List *list, int data) {
  // Create a new node.
  Node *node = malloc(sizeof *node);
  node->next = 0;
  node->data = data;
  // Update tail->next to point to the new node.
  list->tail->next = node;
  // Update tail to point to the new node.
  list->tail = node;
}
```

What happens if we append to an empty list using this code?

```
void list_append(List *list, int data) {
  // Create a new node.
  Node *node = malloc(sizeof *node);
  node->next = 0;
  node->data = data;
  // Update tail->next to point to the
  // new node.
  list->tail->next = node;
  // Update tail to point to the new node.
  list->tail = node;
}
```

A. head and tail both point to the new node

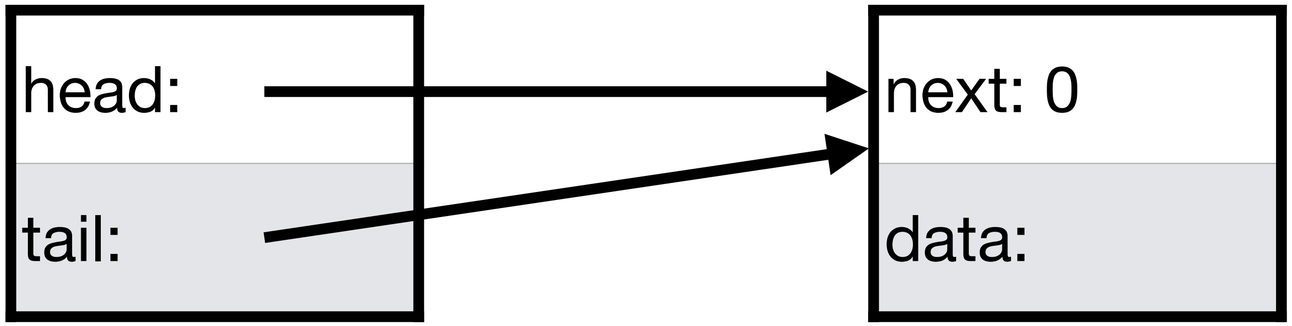
B. head points to the new node and tail is 0

C. tail points to the new node and head is 0

D. head and tail are both 0

E. Undefined behavior

Appending the first element



Set the head and tail pointers to point to the new node

Appending to the list

```
void list_append(List *list, int data) {
  // Create a new node.
  Node *node = malloc(sizeof *node);
  node->next = 0;
  node->data = data;
  if (list_isempty(list)) {
    // Insert the first element in the list.
    list->head = node;
    list->tail = node;
  } else {
    // Update tail->next to point to the new node.
    list->tail->next = node;
    // Update tail to point to the new node.
    list->tail = node;
  }
}
```

isempty and size

```
// Returns true if the list is empty.
bool list_isempty(List const *list) {
  return list->head == 0;
}

// Return the list size.
size_t list_size(List const *list) {
  size_t size = 0;
  for (Node const *node = list->head; node; node = node->next)
    ++size;
  return size;
}
```

What steps should we follow to prepend an element to the beginning of a nonempty linked list

```
void list_prepend(List *list, int data);
```

A. – Create a new node `n` containing the element
   – Set `n->next` to `list->head`
   – Set `list->head` to `n`

B. – Create a new node `n` containing the element
   – Set `list->head` to `n`
   – Set `n->next` to `list->head`

C. – Create a new node n containing the element
   – Set `list->head` to `n`
   – Set `list->tail` to `n`

In-class exercise

https://checkoway.net/teaching/cs241/2019-fall/exercises/Lecture-19.html

Grab a laptop and a partner and try to get as much of that done as you can!