Linked List:

1. Singly-linked list: each element contains the data for the element and a pointer to the next element

2. doubly-linked list: each element contains the data for the element, a pointer to the next element, and a pointer to the previous element

Example Uses: mailing lists, cooking recipes (ingredients list), file systems, in other data structures/algorithms

↳ What if we wanted to report all the eyes on a go board, not just the number?

Why use lists instead of arrays?:

1. Efficiency: many operations can be more efficiently implemented using lists
2. Abstraction: Interface provided by a list often more closely follows the intended operation.

Common List Operations:

Initialization: Initialize data structure for list to an empty list

→ list_init()

Destruction: Destroy linked list and free any memory used

→ list_destroy()

Insertion: Insert a new item into the list, often a relative insertion given an existing element

→ list_ins_next()

Removal / Deletion: Remove an item from the list, often a relative removal

→ list_rem_next()

Size: Determine size of list
→ list_size()

Head/Tail: Determine the element at the start (head) or end (tail) of list
→ list_head()
→ list_tail()

Movement: Function to move to next (or prev) list element
→ list_next()

Example (List of strings):

+ Each list element must contain a char * (for string) and a pointer to the next list element.

+ Define a structure using struct declaration to group these items into a single type

```
struct ListElmt {
    char *str;                  // List element data
    struct ListElmt *next;      // Pointer to next list element
};
```

⇓

Defines new type "struct ListElmt". Not always convenient to use "struct ListElmt", so it is often combined with a type declaration

```
typedef struct ListElmt_ {
    char *str;
    struct ListElmt_ *next;
} ListElmt;
```

≡ (equivalent to)

```
struct ListElmt_ {
    char *str;
    struct ListElmt_ *next;
};
typedef struct ListElmt_ ListElmt;
```

⇓

Defines a new type "struct ListElmt_" and "ListElmt" that are equivalent.

Example (List of strings) (continued):

+ Need to define a structure for the list itself:

```
typedef struct List_ {
    int      size;          // keeps track of number of elements
    ListElmt  *head;        // pointer to first element
    ListElmt  *tail;        // pointer to last element
} List;
```

+ Initialization:

```
void list_init (List *list) {
    list->size = 0;
    list->head = NULL;
    list->tail = NULL;
}
```

"->" operator can be used to access the elements inside a structure from a pointer to that structure.

list->size = 0; ≡ (*list).size = 0;

+ Insertion:

```
int list_ins_next(List *list, ListElmt *element, char *str) {
    ListElmt *new_element;

    if( (new_element = (ListElmt *)malloc(sizeof(ListElmt))) == NULL) return -1;

    new_element->str = str;

    if (element == NULL) {
        if ( list->size == 0) {
            list->tail = new_element;
        }
        new_element->next = list->head;
        list->head = new_element;
    }
    else {
        if (element->next == NULL) {
            list->tail = new_element;
        }
        new_element->next = element->next;
        element->next = new_element;
    }
    list->size ++;
    return 0;
}
```

creates and inits the new element

insert at head of list

insert somewhere else

Example (List of strings) (continued):

+ Removal: int list_rem_next(List * list, ListElmt * element) {

```
    ListElmt  * old_element;

    if (list -> size == 0) return -1;

    if (element == NULL) {
        old_element = list -> head;
        list -> head = list -> head -> next;

        if (list -> size == 1) list -> tail = NULL;

    }
    else {
        if (element -> next == NULL) return -1;
        old_element = element -> next;
        element -> next = element -> next -> next;
        if (element -> next == NULL) list -> tail = element;

    }
    free (old_element -> str);
    free (old_element);

    list -> size --;
    return 0;
}
```

remove head of list

Example (List of strings) (continued):

+Head / Tail:

```
ListElmt * list_head (List * list) {
    return list->head;
}

ListElmt * list_tail (List * list) {
    return list->tail;
}
```

+Movement:

```
ListElmt * list_next (ListElmt * element) {
    if (element == NULL) return NULL;
    return element->next;
}
```

+Destruction:

```
void list_destroy (List * list) {

    while (list->size > 0) {
        list_rem_next (list, NULL);
    }
}
```

+Size:

```
int list_size (List * list) {
    return list->size;
}
```

* How do we define and use the list?

① Statically allocated List

```c
#define BUFSIZE 1000
int main() {
    char userInput[BUFSIZE];
    char *newStr;

    List word_list;

    // Initialize list
    list_init(&word_list);

    printf("Enter new string (or \"Done\" when finished): ");
    fgets(userInput, BUFSIZE, stdin);

    while(strcmp(userInput, "Done") != 0) {
        // 1. Allocate space for new data in ListElmt
        newStr = (char *)malloc(strlen(userInput)+1);
        if(newStr == NULL) break;

        // 2. Initialize new data
        strcpy(newStr, userInput);

        // 3. Insert at end of list
        list_ins_next(&word_list, word_list.tail, newStr);

        printf("Enter new string (or \"Done\" when finished): ");
        fgets(userInput, BUFSIZE, stdin);
    }

    // Destroy list
    list_destroy(&word_list);

    return 0;
}
```

② Dynamically allocated List

```c
List *word_list;

// Allocate and initialize list
word_list = (List*)malloc(sizeof(List));
if(word_list == NULL) return -1;
list_init(word_list);

list_ins_next(word_list,
              word_list->tail,
              newStr);

// Destroy and free list
list_destroy(word_list);
free(word_list);
word_list = NULL;
```

*Statically Allocated List Example

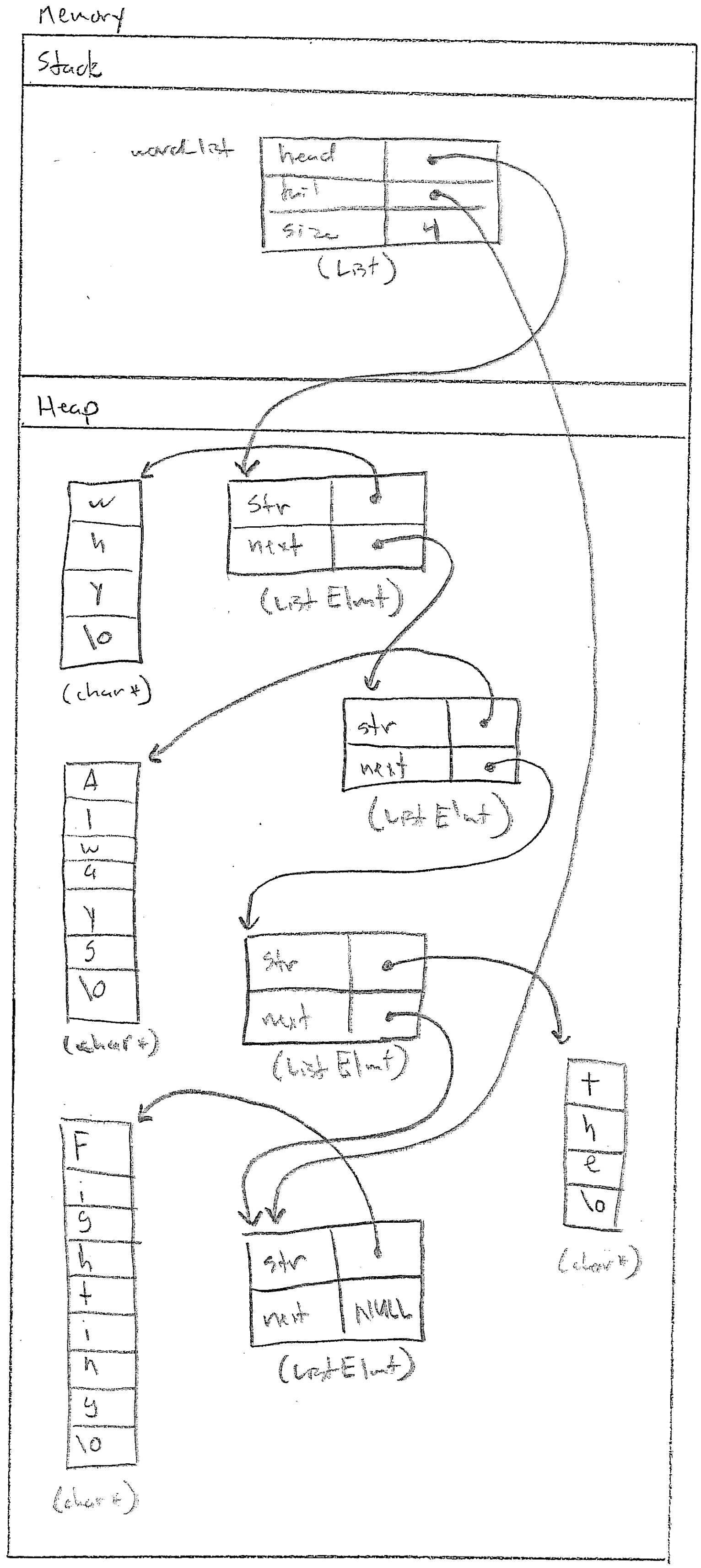
The following words are added:

"why"

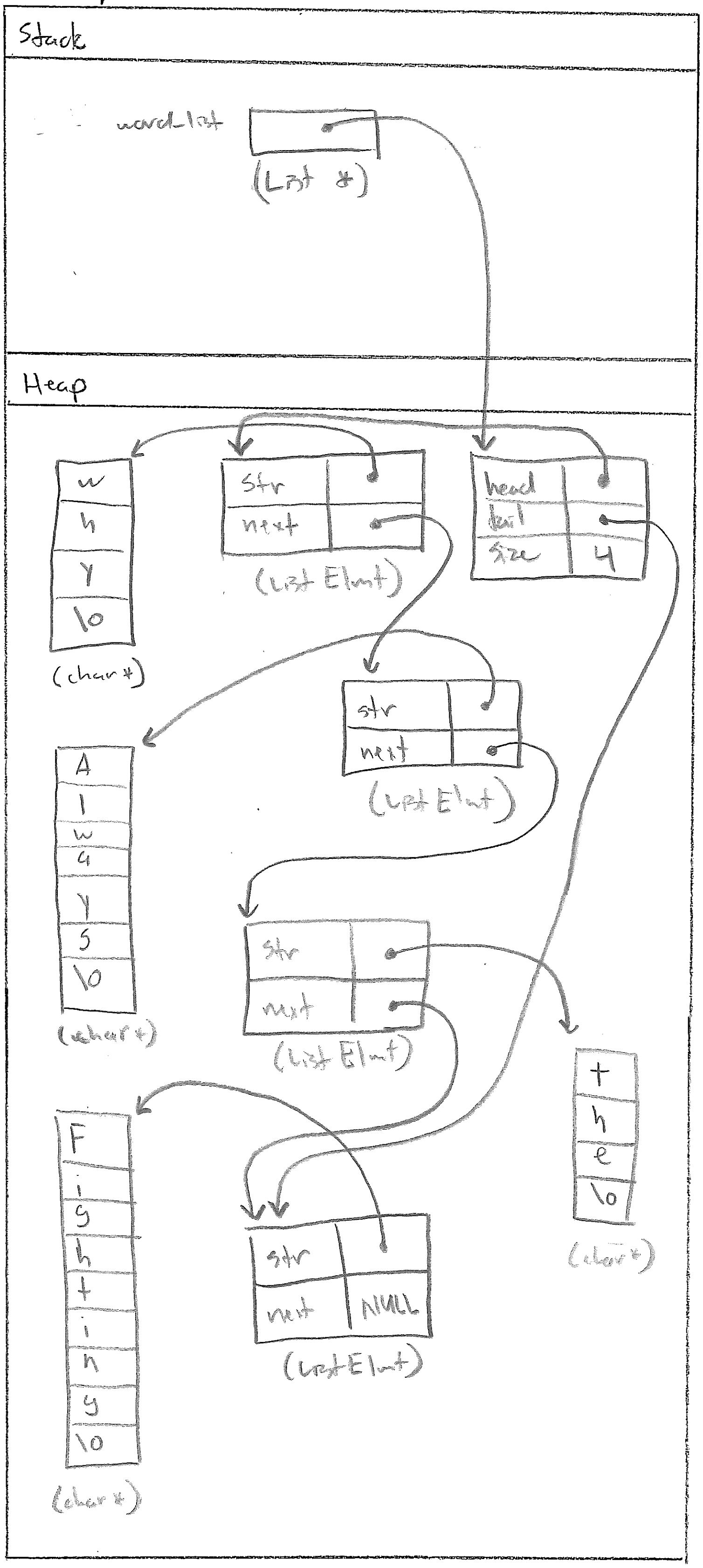
"Always"

"the"

"Fighting"



Memory



* Dynamically Allocated List Example

The following words are added:

"why"

"Always"

"the"

"Fighting"