CS61C – Machine Structures

Lecture 5 – C Structs & Memory Mangement

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C String Standard Functions

```
int strlen(char *string);
```

- compute the length of `string`

```
int strcmp(char *str1, char *str2);
```

- return 0 if `str1` and `str2` are identical (how is this different from `str1 == str2`?)

```
char *strcpy(char *dst, char *src);
```

- copy the contents of string `src` to the memory at `dst`. The caller must ensure that `dst` has enough memory to hold the data to be copied.

Pointers (1/4) …review…

- Sometimes you want to have a procedure increment a variable?
- What gets printed?

```
void AddOne(int  x)
{     x =  x + 1;   }

int y = 5;
AddOne( y);
printf("y = %d\n", y);
```

y = 5

Pointers (2/4) …review…

- Solved by passing in a pointer to our subroutine.
- Now what gets printed?

```
void AddOne(int *p)
{    *p = *p + 1;   }

int y = 5;
AddOne(&y);
printf("y = %d\n", y);
```

y = 6

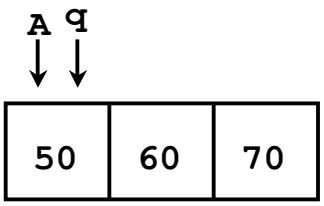
Pointers (3/4)

- But what if what you want changed is a pointer?
- What gets printed?

```
void IncrementPtr(int  *p)
{    p =  p + 1;   }

int A[3] = {50, 60, 70};
int *q = A;
IncrementPtr( q);
printf("*q = %d\n", *q);
```

*q = 50



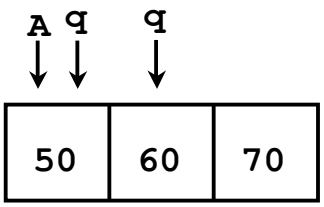
Pointers (4/4)

- Solution! Pass a pointer to a pointer, declared as `**h`
- Now what gets printed?

```
void IncrementPtr(int **h)
{   *h = *h + 1;   }

int A[3] = {50, 60, 70};
int *q = A;
IncrementPtr(&q);
printf("*q = %d\n", *q);
```

*q = 60



Dynamic Memory Allocation (1/4)

- C has operator `sizeof()` which gives size in bytes (of type or variable)
- Assume size of objects can be misleading and is bad style, so use `sizeof(type)`

  (Many years ago an `int` was 16 bits, and programs were written with this assumption. What is the size of integers now?)
- "sizeof" is not a real function - it does its work at compile time. So:

  `char foo[3*sizeof(int)] is valid,`

  - But neither of these is valid in C:

  `char foo[3*myfunction(int)]`

  `char foo[3*myfunction(7)]`

Dynamic Memory Allocation (2/4)

- To allocate room for something new to point to, use `malloc()` (with the help of a typecast and `sizeof`):

```
ptr = (int *) malloc (sizeof(int));
```

  - Now, `ptr` points to a space somewhere in memory of size `(sizeof(int))` in bytes.
  - `(int *)` simply tells the compiler what will go into that space (called a typecast).
- `malloc` is almost never used for 1 var

```
ptr = (int *) malloc (n*sizeof(int));
```

  - This allocates an array of `n` integers.

Dynamic Memory Allocation (3/4)

- Once `malloc()` is called, the memory location contains garbage, so don't use it until you've set its value.
- After dynamically allocating space, we must dynamically free it:

```
free(ptr);
```

- Use this command to clean up.

Dynamic Memory Allocation (4/4)

- The following two things will cause your program to crash or behave strangely later on, and cause VERY VERY hard to figure out bugs:

free()ing the same piece of memory twice

calling free() on something you didn't get back from malloc()

  - The runtime does *not* check for these mistakes (memory allocation is so performance-critical that there just isn't time to do this), and the usual result is that you corrupt the memory allocator's internal structures -- but you won't find out until much later on, in some totally unrelated part of your code.

C structures : Overview

- A `struct` is a data structure composed from simpler data types.
  - Like a class in Java/C++ but without methods or inheritance.

```
struct point {  /* type definition */
    int x;
    int y;
};

void PrintPoint(point p)
{
    printf("(%d,%d)", p.x, p.y);
}

struct point p1 = {0,10};

PrintPoint(p1);
```

As always in C, the argument is passed by "value" - a copy is made.

C structures: Pointers to them

- Usually, more efficient to pass a pointer to the struct.
- The C arrow operator (`->`) dereferences and extracts a structure field with a single operator.
- The following are equivalent:

```
struct point *p;
 code to assign to pointer
printf("x is %d\n", (*p).x);
printf("x is %d\n", p->x);
```

How big are structs?

- Recall C operator `sizeof()` which gives size in bytes (of type or variable)
- How big is `sizeof(p)`?

```
struct p {
   char x;
   int y;
};
```

  - 5 bytes? 8 bytes?
  - Compiler may word align integer y

Linked List Example

- Let's look at an example of using structures, pointers, `malloc()`, and `free()` to implement a linked list of strings.

```
/* node structure for linked list */
struct Node {
    char *value;
    struct Node *next;
};
```

Linked List Example

```
/* add a string to an existing list */
Node * list_add(Node *list, char *string)
{
  struct Node *node =
    (struct Node *) malloc(sizeof(struct Node));

  node->value =
    (char *) malloc(strlen(string) + 1);
  strcpy(node->value, string);
  node->next = list;
  return node;
}

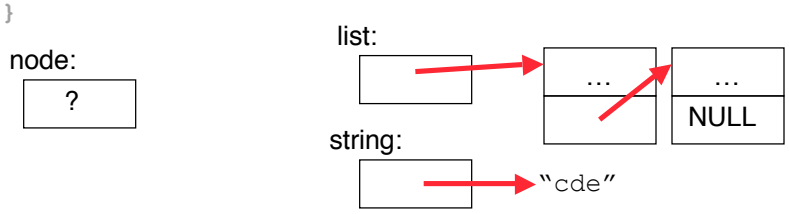
{
   char *s1 = "abc", *s2 = "cde";
   Node *theList = NULL;

   theList = list_add(theList, s1);
   theList = list_add(theList, s2);
```


Linked List Example

```
/* add a string to an existing list, 2nd call */
Node * list_add(Node *list, char *string)
{
  struct Node *node =
    (struct Node *) malloc(sizeof(struct Node));

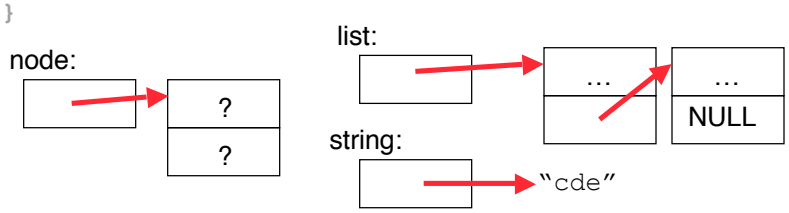
  node->value =
    (char *) malloc(strlen(string) + 1);
  strcpy(node->value, string);
  node->next = list;
  return node;
}
```



Linked List Example

```
/* add a string to an existing list */
Node * list_add(Node *list, char *string)
{
  struct Node *node =
    (struct Node *) malloc(sizeof(struct Node));

  node->value =
    (char *) malloc(strlen(string) + 1);
  strcpy(node->value, string);
  node->next = list;
  return node;
}
```



Linked List Example

```
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Node * list_add(Node *list, char *string)
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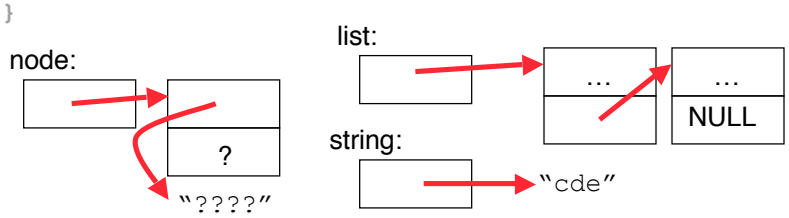
  struct Node *node =
    (struct Node *) malloc(sizeof(struct Node));

  node->value =
    (char *) malloc(strlen(string) + 1);
  strcpy(node->value, string);
  node->next = list;
  return node;
}
```



Linked List Example

```
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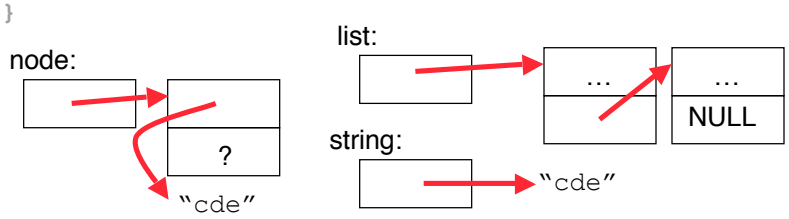
    (char *) malloc(strlen(string) + 1);
  strcpy(node->value, string);
  node->next = list;
  return node;
}
```



Linked List Example

```
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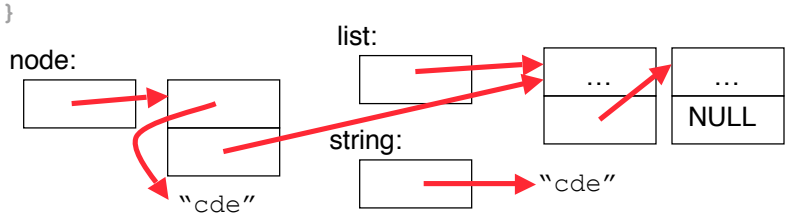
Node * list_add(Node *list, char *string)
{
  struct Node *node =
    (struct Node *) malloc(sizeof(struct Node));

  node->value =
    (char *) malloc(strlen(string) + 1);
  strcpy(node->value, string);
  node->next = list;
  return node;
}
```



Linked List Example

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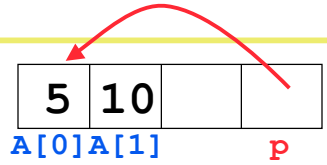
  node->value =
    (char *) malloc(strlen(string) + 1);
  strcpy(node->value, string);
  node->next = list;
  return node;
}
```

"And in Conclusion…"

- Can use pointers to change pointers
- Create abstractions with structures
- Dynamically allocated heap memory must be manually deallocated in C.
  - Use `malloc()` and `free()` to allocate and deallocate memory from heap.

Question




```
int main(void){
 int A[] = {5,10};
 int *p = A;

 printf("%u %d %d %d\n",p,*p,A[0],A[1]);
  p =  p + 1;
 printf("%u %d %d %d\n",p,*p,A[0],A[1]);
 *p = *p + 1;
 printf("%u %d %d %d\n",p,*p,A[0],A[1]);
 }
```

If the first `printf` outputs `100 5 5 10`, what will the other two `printf` output?

```
1: 101 10 5 10       then 101 11 5 11
2: 104 10 5 10       then 104 11 5 11
3: 101 <other> 5 10  then 101 <3-others>
4: 104 <other> 5 10  then 104 <3-others>
5: One of the two printfs causes an ERROR
6: I surrender!
```