

## 1 Pre-Check

This section is designed as a conceptual check for you to determine if you conceptually understand and have any misconceptions about this topic. Please answer true/false to the following questions, and include an explanation:

- 1.1 True or False: C is a pass-by-value language.
  
- 1.2 What is a pointer? What does it have in common to an array variable?
  
- 1.3 If you try to dereference a variable that is not a pointer, what will happen? What about when you free one?
  
- 1.4 When should you use the heap over the stack? Do they grow?

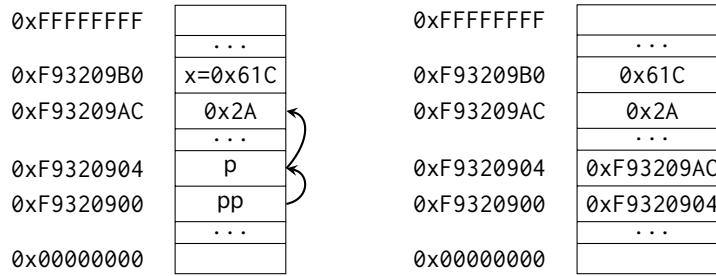
## 2 C

C is syntactically similar to Java, but there are a few key differences:

1. C is function-oriented, not object-oriented; there are no objects.
2. C does not automatically handle memory for you.
  - Stack memory, or *things that are not manually allocated*: data is garbage immediately after the *function in which it was defined* returns.
  - Heap memory, or *things allocated with malloc, calloc, or realloc*: data is freed only when the programmer explicitly frees it!
  - There are two other sections of memory that we learn about in this course, *static* and *code*, but we'll get to those later.
  - In any case, allocated memory always holds garbage until it is initialized!
3. C uses pointers explicitly. If `p` is a pointer, then `*p` tells us to use the value that `p` points to, rather than the value of `p`, and `&x` gives the address of `x` rather than the value of `x`.

On the left is the memory represented as a box-and-pointer diagram.

On the right, we see how the memory is really represented in the computer.



Let's assume that `int* p` is located at `0xF9320904` and `int x` is located at `0xF93209B0`. As we can observe:

- `*p` evaluates to `0x2A` ( $42_{10}$ ).
- `p` evaluates to `0xF93209AC`.
- `x` evaluates to `0x61C`.
- `&x` evaluates to `0xF93209B0`.

Let's say we have an `int **pp` that is located at `0xF9320900`.

2.1 What does `pp` evaluate to? How about `*pp`? What about `**pp`?

2.2 The following functions are syntactically-correct C, but written in an incomprehensible style. Describe the behavior of each function in plain English.

- (a) Recall that the ternary operator evaluates the condition before the `?` and returns the value before the colon (`:`) if true, or the value after it if false.

```

1 int foo(int *arr, size_t n) {
2     return n ? arr[0] + foo(arr + 1, n - 1) : 0;
3 }

```

- (b) Recall that the negation operator, `!`, returns 0 if the value is non-zero, and 1 if the value is 0. The `~` operator performs a *bitwise not* (NOT) operation.

```

1 int bar(int *arr, size_t n) {
2     int sum = 0, i;
3     for (i = n; i > 0; i--)
4         sum += !arr[i - 1];
5     return ~sum + 1;
6 }

```

- (c) Recall that `^` is the *bitwise exclusive-or* (XOR) operator.

```

1 void baz(int x, int y) {
2     x = x ^ y;

```

```

3     y = x ^ y;
4     x = x ^ y;
5 }

```

(d) (Bonus: How do you write the *bitwise exclusive-nor* (XNOR) operator in C?)

### 3 Programming with Pointers

3.1 Implement the following functions so that they work as described.

(a) Swap the value of two **ints**. *Remain swapped after returning from this function.*

```
void swap(
```

(b) Return the number of bytes in a string. *Do not use strlen.*

```
int mystrlen(
```

3.2 The following functions may contain logic or syntax errors. Find and correct them.

(a) Returns the sum of all the elements in **summands**.

```

1  int sum(int* summands) {
2      int sum = 0;
3      for (int i = 0; i < sizeof(summands); i++)
4          sum += *(summands + i);
5      return sum;
6  }

```

(b) Increments all of the letters in the **string** which is stored at the front of an array of arbitrary length,  $n \geq \text{strlen}(\text{string})$ . Does not modify any other parts of the array's memory.

```

1  void increment(char* string, int n) {
2      for (int i = 0; i < n; i++)

```

```

3         *(string + i)++;
4     }

```

(c) Copies the string `src` to `dst`.

```

1     void copy(char* src, char* dst) {
2         while (*dst++ = *src++);
3     }

```

(d) Overwrites an input string `src` with “61C is awesome!” if there’s room. Does nothing if there is not. Assume that `length` correctly represents the length of `src`.

```

1     void cs61c(char* src, size_t length) {
2         char *srcptr, replaceptr;
3         char replacement[16] = "61C is awesome!";
4         srcptr = src;
5         replaceptr = replacement;
6         if (length >= 16) {
7             for (int i = 0; i < 16; i++)
8                 *srcptr++ = *replaceptr++;
9         }
10    }

```

## 4 Memory Management

4.1 For each part, choose one or more of the following memory segments where the data could be located: **code**, **static**, **heap**, **stack**.

- (a) Static variables
- (b) Local variables
- (c) Global variables
- (d) Constants
- (e) Machine Instructions
- (f) Result of `malloc`
- (g) String Literals

- 4.2 Write the code necessary to allocate memory on the heap in the following scenarios
- (a) An array `arr` of  $k$  integers
  - (b) A string `str` containing  $p$  characters
  - (c) An  $n \times m$  matrix `mat` of integers initialized to zero.
- 4.3 What's the main issue with the code snippet seen here? (Hint: `gets()` is a function that reads in user input and stores it in the array given in the argument.)

```

1 char* foo() {
2     char buffer[64];
3     gets(buffer);
4
5     char* important_stuff = (char*) malloc(11 * sizeof(char));
6
7     int i;
8     for (i = 0; i < 10; i++) important_stuff[i] = buffer[i];
9     important_stuff[i] = '\0';
10    return important_stuff;
11 }
```

Suppose we've defined a linked list `struct` as follows. Assume `*lst` points to the first element of the list, or is `NULL` if the list is empty.

```

struct ll_node {
    int first;
    struct ll_node* rest;
}
```

- 4.4 Implement `prepend`, which adds one new value to the front of the linked list. Hint: why use `ll_node **lst` instead of `ll_node*lst`?

```
void prepend(struct ll_node** lst, int value)
```

- 4.5 Implement `free_ll`, which frees all the memory consumed by the linked list.

```
void free_ll(struct ll_node** lst)
```

