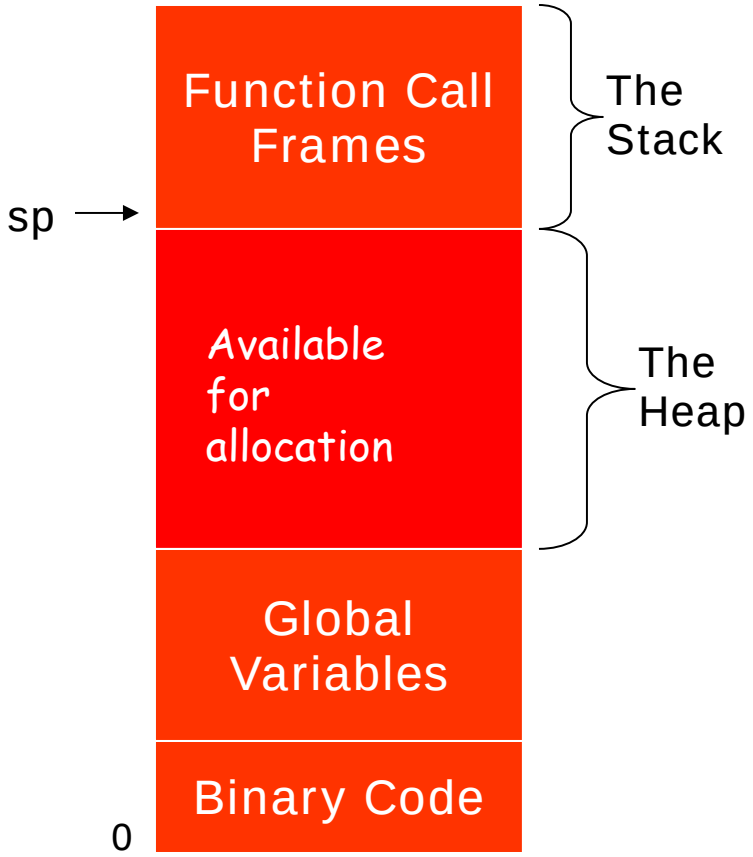
Memory Management in C (Dynamic Strings)

Personal Software Engineering

Memory Organization



- The call stack grows from the top of memory down.
- Code is at the bottom of memory.
- Global data follows the code.
- What's left – the "heap" - is available for allocation.

Allocating Memory From The Heap

`void *malloc( unsigned nbytes )`

- Allocates 'nbytes' of memory in the heap.
- Guaranteed not to overlap other allocated memory.
- Returns pointer to the first byte (or **NULL** if the heap is full).
- Similar to constructor in Java – allocates space.
- Allocated space is uninitialized (random garbage).

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`void free( void *ptr )`

- Frees the memory assigned to ptr.
- The space *must* have been allocated by malloc.
- ***No garbage collection in C (or C++).***
- Can slowly consume memory if not careful.

Examples: Make a Copy of a String

```
#include <stdlib.h>
#include <string.h>

/*
 * Return a copy of an existing NUL-terminated string.
 */
char *make_copy(char *orig) {
    char *copy ;

    copy = malloc(strlen(orig) + 1) ;

    strcpy(copy, orig) ;
    return copy ;
}
```

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Uninitialized pointer - until we assign something to it we have **NO** idea where it points.

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```

Allocate space and assign address of first byte to pointer <copy>

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    char *copy ;

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    return copy ;
}
```

Enough space to hold the characters in <orig> plus the terminating **NUL**

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    return copy ;
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```

Once <copy> points to some space we can copy <orig> to that space.

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    strcpy(copy, orig) ;
    return copy ;
}
```

Return the pointer to the allocated space with the desired string copy.

The caller now "owns" this space.

Examples: Catenate 2 Strings

```
/*
 * Return a pointer to concatenated strings.
 */
char *catenate(char *s1, char *s2) {
    char *cat ;
    int space_needed = strlen(s1) + strlen(s2) + 1 ;

    cat = malloc(space_needed) ;

    strcpy(cat, s1) ;
    strcpy(cat + strlen(s1), s2) ;

    return cat ;
}
```

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```

Number of bytes needed for 2 strings + **NUL**

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    return cat ;
}
```

Allocate the space and assign the address to <cat>.

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    return cat ;
}
```

Add string <s2> to the end of the copied <s1>

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}
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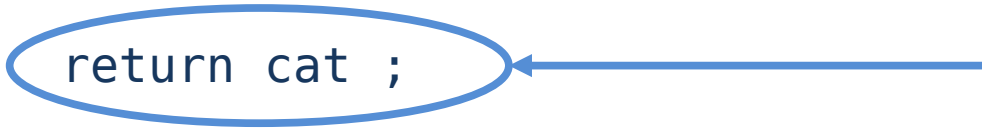

Return the address of the final concatenated strings.

Caller now "owns" this space.

Example: Client Side

```
char *p1 = make_copy("Hello, ") ;
char *p2 = make_copy("world!") ;

char *p3 = catenate(p1, p2) ;

char *p4 = catenate("Hello, ", "world!") ;
```

Example: Client Side

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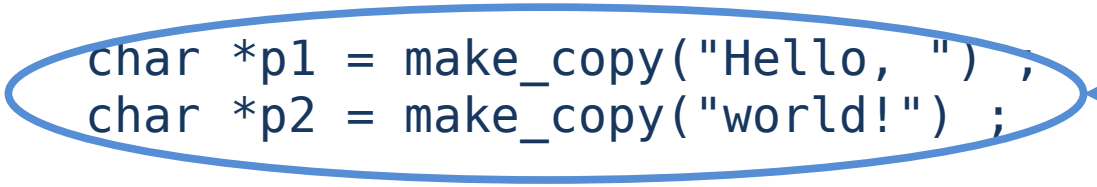

Make copies of two constant strings.

Example: Client Side

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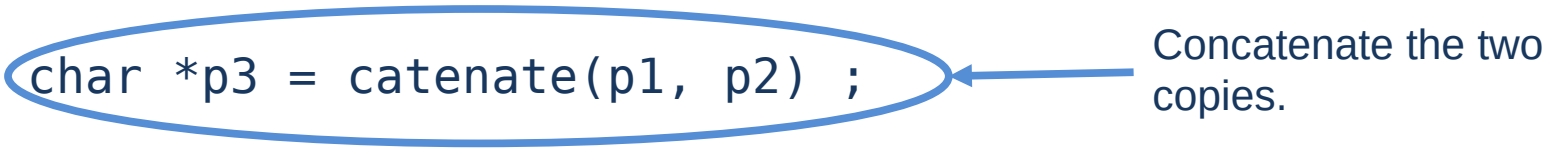

Concatenate the two copies.

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So what is the difference between the 2 calls to **`catenate`**?

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So what is the difference between the 2 calls to **`catenate`**?

- The *constant* strings have *preallocated static storage*.
- The *dynamic* strings (**`p1`** and **`p2`**) are in *dynamically allocated space*.

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Dynamically allocated space must eventually be freed or memory will slowly fill up with unused garbage.

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Example: suppose we only want the concatenated result in **`p3`**. Then:

```
free(p1) ;
free(p2) ;
```

Problems: Orphan Storage

```
char *p1 ;
p1 = catenate("Merchant ", "of ") ;
p1 = catenate(p1, "Venice") ;
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Result of first call on catenate:

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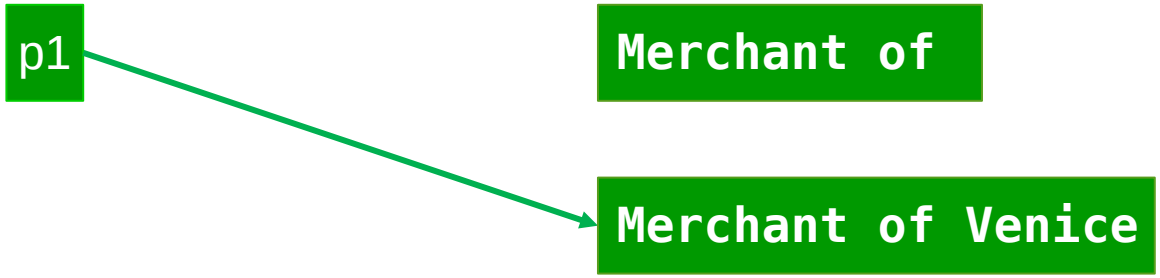
Result of first call on catenate:

Result of second call on catenate:



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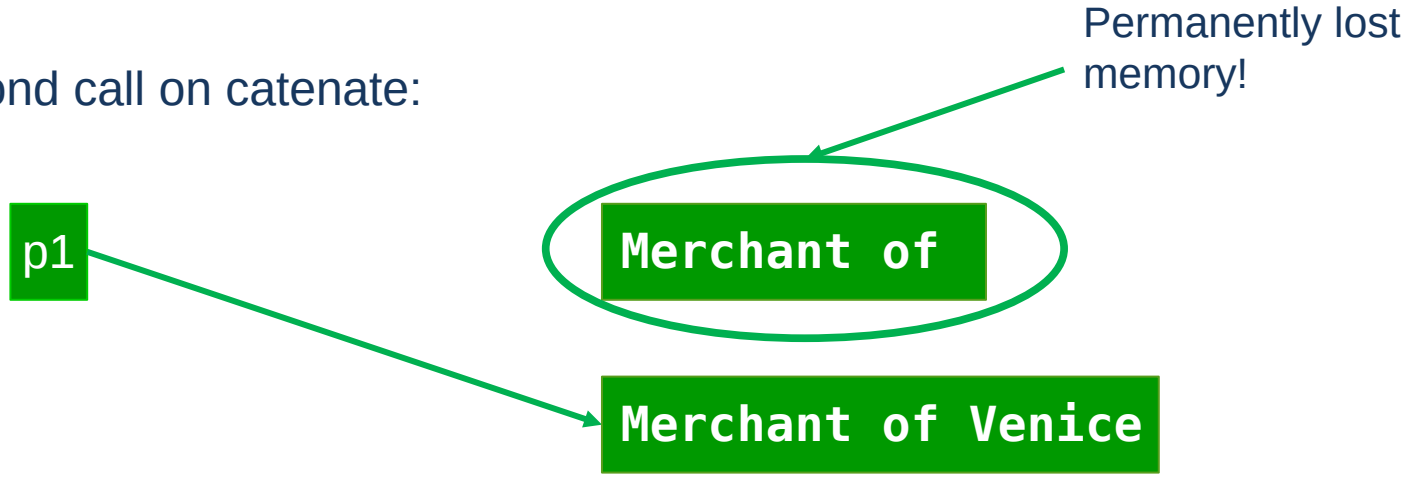

Problems: Dangling Reference

```
char *p1 ;
char *p2 ;
p1 = catenate("Merchant ", "of ") ;

    . . .

free(p1) ;

    . . . p1 not changed . . .

p2 = make_copy(p1) ;
```

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← Allocate space assigned to **p1**

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Free up space assigned to **p1**

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```

Reference to deallocated space!

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- If you are confused, lost, or bewildered: ask for help - ***all*** professionals need help at times.

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- Are you interested in the ***pointer*** or in what it ***points to***?
- Random hacking won't work! You'll just tie yourself into knots.
- MJL: After 45+ years in the field, I ***still*** have to reason carefully when using pointers - and I ***still*** make mistakes!
- If you are confused, lost, or bewildered: ask for help - ***all*** professionals need help at times.
- ***BUT:*** Be ready to explain ***why*** you did what you did.