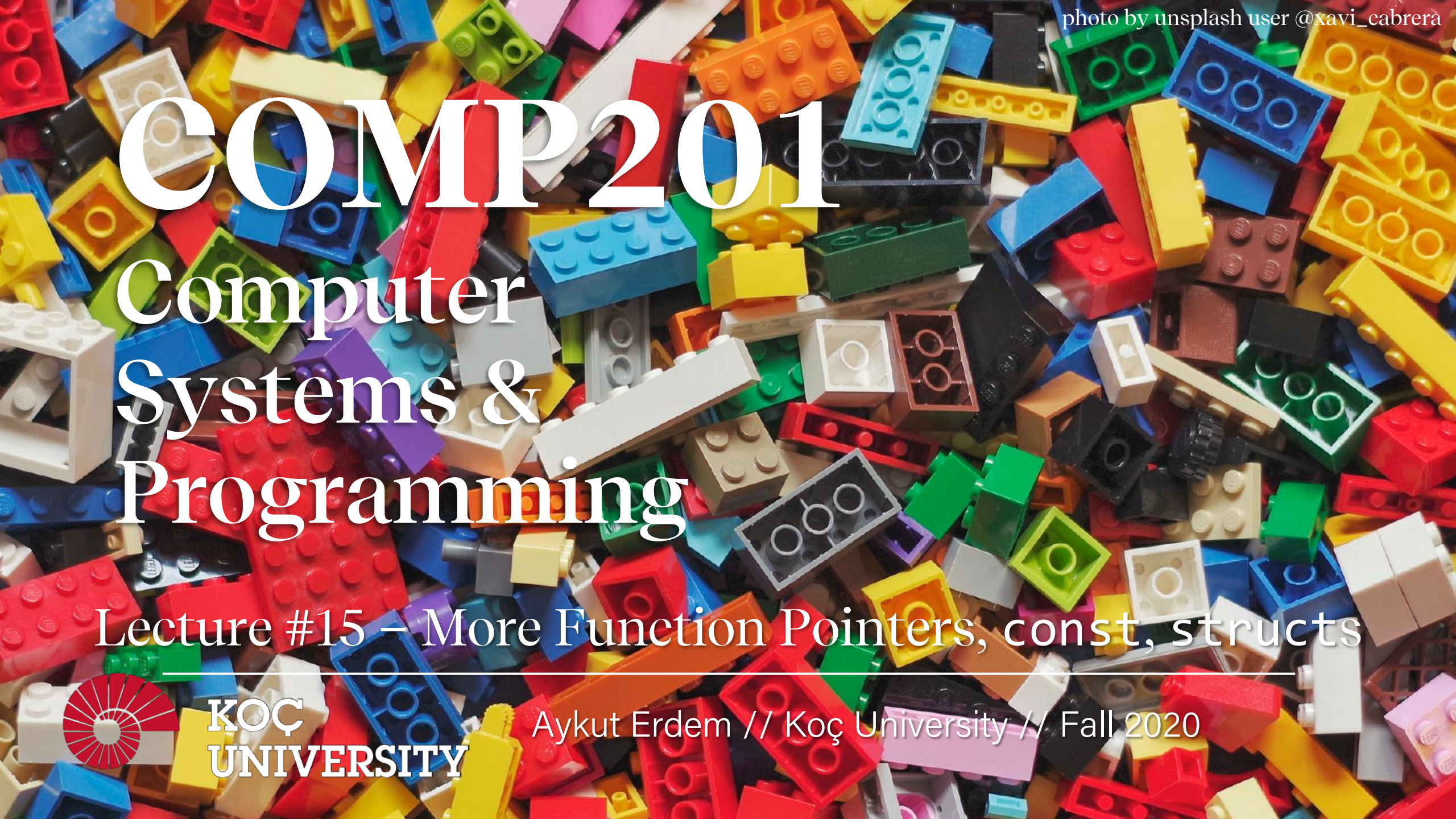


photo by unsplash user @xavi_cabrera

COMP201

Computer Systems & Programming

Lecture #15 – More Function Pointers, `const`, `structs`

KOÇ UNIVERSITY

Aykut Erdem // Koç University // Fall 2020

Recap

- Generics So Far
- Motivating Example: Bubble Sort
- Function Pointers

Recap: Generics Overview

- We use **`void *`** pointers and memory operations like **`memcpy`** and **`memmove`** to make data operations generic.
- We use **function pointers** to make logic/functionality operations generic.

Plan for Today

- Function Pointers (cont'd.)
- `const`

Disclaimer: Slides for this lecture were borrowed from
—Nick Troccoli's Stanford CS107 class

Lecture Plan

- Function Pointers (cont'd.)
- `const`

Function Pointers

- Function pointers can be used in a variety of ways. For instance, you could have:
  - A function to compare two elements of a given type
  - A function to print out an element of a given type
  - A function to free memory associated with a given type
  - And more…

Function Pointers

- Function pointers can be used in a variety of ways. For instance, you could have:
  - A function to compare two elements of a given type
  - A function to print out an element of a given type
  - A function to free memory associated with a given type
  - And more…

Demo: Generic Printing

`print_array.c`

Common Utility Callback Functions

- Comparison function – compares two elements of a given type.

```
int (*cmp_fn)(void *addr1, void *addr2)
```

- Printing function – prints out an element of a given type

```
void (*print_fn)(void *addr)
```

- There are many more! You can specify any functions you would like passed in when writing your own generic functions.

Demo: Count Matches

`count_matches.c`

Count Matches

- Let's write a generic function `count_matches` that can count the number of a certain type of element in a generic array.
- It should take in as parameters information about the generic array, and a function parameter that can take in a pointer to a single array element and tell us if it's a match.

```
int count_matches(void *base, int nelems,
                  int elem_size_bytes, bool (*match_fn)(void *));
```

Count Matches

```
int count_matches(void *base, int nelems, int elem_size_bytes,
                  bool (*match_fn)(void *)) {

    int match_count = 0;

    for (int i = 0; i < nelems; i++) {
        void *curr_p = (char *)base + i * elem_size_bytes;
        if (match_fn(curr_p)) {
            match_count++;
        }
    }

    return match_count;
}
```

Function Pointers As Variables

In addition to parameters, you can make normal variables that are functions.

```
int do_something(char *str) {
    …
}

int main(int argc, char *argv[]) {
    …
    int (*func_var)(char *) = do_something;
    …
    func_var("testing");
    return 0;
}
```

Generic C Standard Library Functions

- **`qsort`** – I can sort an array of any type! To do that, I need you to provide me a function that can compare two elements of the kind you are asking me to sort.
- **`bsearch`** – I can use binary search to search for a key in an array of any type! To do that, I need you to provide me a function that can compare two elements of the kind you are asking me to search.
- **`lfind`** – I can use linear search to search for a key in an array of any type! To do that, I need you to provide me a function that can compare two elements of the kind you are asking me to search.
- **`lsearch`** - I can use linear search to search for a key in an array of any type! I will also add the key for you if I can't find it. In order to do that, I need you to provide me a function that can compare two elements of the kind you are asking me to search.

Generic C Standard Library Functions

- **`scandir`** – I can create a directory listing with any order and contents! To do that, I need you to provide me a function that tells me whether you want me to include a given directory entry in the listing. I also need you to provide me a function that tells me the correct ordering of two given directory entries.

Summary: Function Pointers

- We can pass functions as parameters to pass logic around in our programs.
- Comparison functions are one common class of functions passed as parameters to generically compare the elements at two addresses.
- Functions handling generic data must use *pointers to the data they care about*, since any parameters must have *one type* and *one size*.

Lecture Plan

- Function Pointers (cont'd.)
- `const`

const

- Use **`const`** to declare global constants in your program. This indicates the variable cannot change after being created.

```
const double PI = 3.1415;
const int DAYS_IN_WEEK = 7;

int main(int argc, char *argv[]) {
     …
     if (x == DAYS_IN_WEEK) {
          …
     }
     …
}
```

const

- Use **const** with pointers to indicate that the data that is pointed to cannot change.

```
char str[6];
strcpy(str, "Hello");
const char *s = str;

// Cannot use s to change characters it points to
s[0] = 'h';
```

const

Sometimes we use **const** with pointer parameters to indicate that the function will not / should not change what it points to. The actual pointer can be changed, however.

```
// This function promises to not change str's characters
int countUppercase(const char *str) {
    int count = 0;
    for (int i = 0; i < strlen(str); i++) {
        if (isupper(str[i])) {
            count++;
        }
    }
    return count;
}
```

const

By definition, C gets upset when you set a **non-const** pointer equal to a **const** pointer. You need to be consistent with **const** to reflect what you cannot modify.

```
// This function promises to not change str's characters
int countUppercase(const char *str) {
      // compiler warning and error
     char *strToModify = str;
     strToModify[0] = …
}
```

const

By definition, C gets upset when you set a **non-const** pointer equal to a **const** pointer. You need to be consistent with **const** to reflect what you cannot modify. **Think of const as part of the variable type.**

```
// This function promises to not change str's characters
int countUppercase(const char *str) {
    const char *strToModify = str;
    strToModify[0] = …
}
```

const

const can be confusing to interpret in some variable types.

```
// cannot modify this char
const char c = 'h';

// cannot modify chars pointed to by str
const char *str = …

// cannot modify chars pointed to by *strPtr
const char **strPtr = …
```

Practice

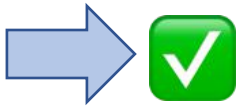
const

slido Event code: 73165

```
1    char buf[6];
2    strcpy(buf, "Hello");
3    const char *str = buf;
4    str[0] = 'M';
5    str = "Mello";
6    buf[0] = 'M';
```

Which lines (if any) above will cause an error due to violating `const`? Remember that `const char *` means that the characters at the location it stores cannot be changed.

const

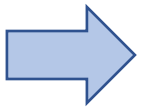


```
1    char buf[6];
2    strcpy(buf, "Hello");
3    const char *str = buf;
4    str[0] = 'M';
5    str = "Mello";
6    buf[0] = 'M';
```

Line 1 makes a typical modifiable character array of 6 characters.

Which lines (if any) above will cause an error due to violating `const`? Remember that `const char *` means that the characters at the location it stores cannot be changed.

const

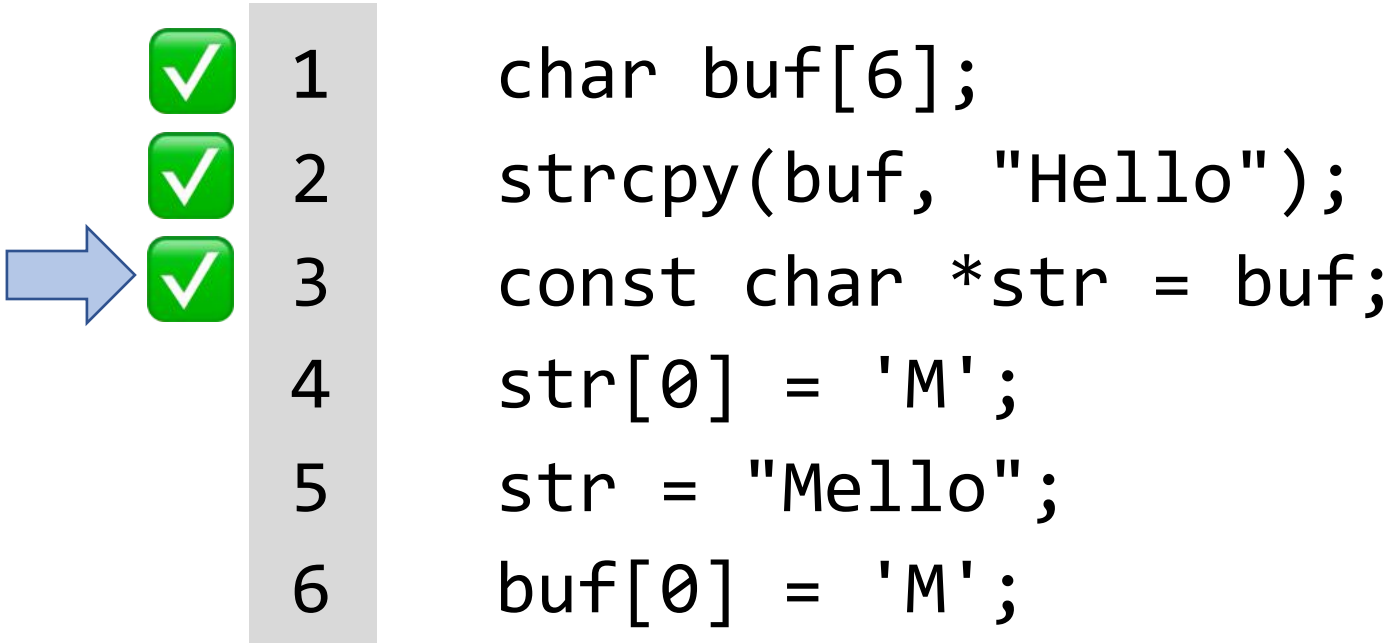


```
1    char buf[6];
2    strcpy(buf, "Hello");
3    const char *str = buf;
4    str[0] = 'M';
5    str = "Mello";
6    buf[0] = 'M';
```

Line 2 copies characters into this modifiable character array.

Which lines (if any) above will cause an error due to violating `const`? Remember that `const char *` means that the characters at the location it stores cannot be changed.

const

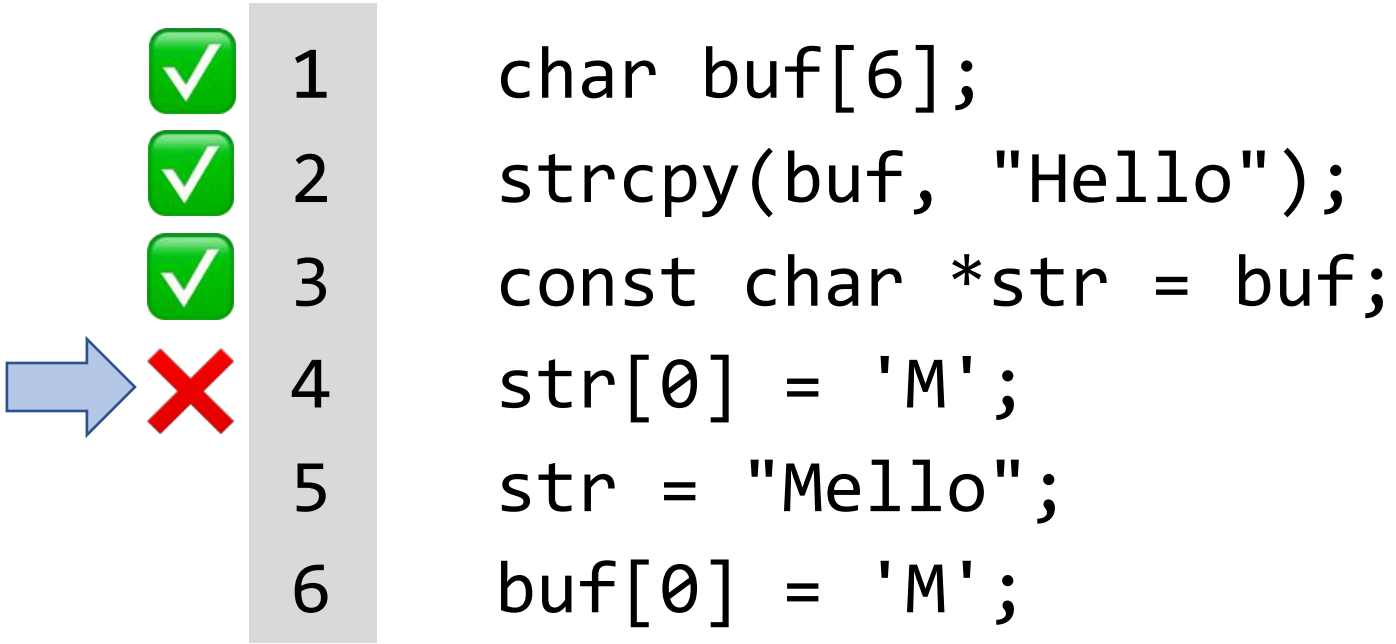


```
1    char buf[6];
2    strcpy(buf, "Hello");
3    const char *str = buf;
4    str[0] = 'M';
5    str = "Mello";
6    buf[0] = 'M';
```

Line 3 makes a `const` pointer that points to the first element of `buf`. We cannot use `str` to change the characters it points to because it is `const`.

Which lines (if any) above will cause an error due to violating `const`? Remember that `const char *` means that the characters at the location it stores cannot be changed.

const

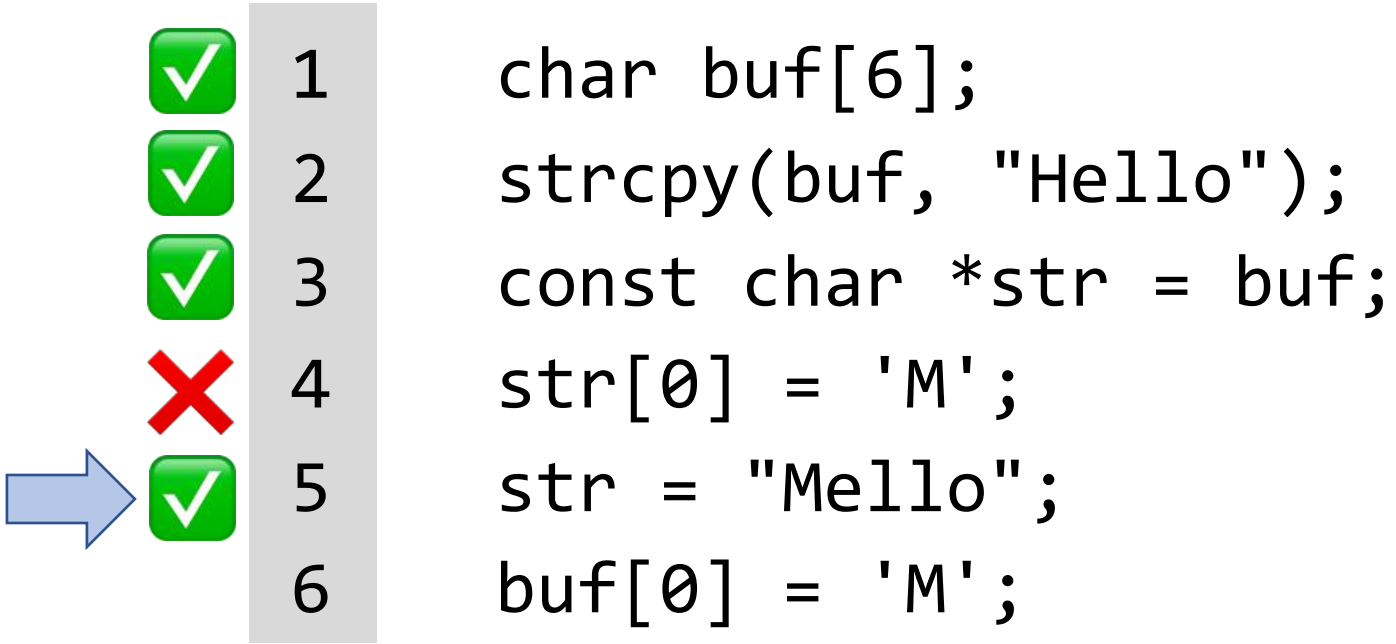


```
1    char buf[6];
2    strcpy(buf, "Hello");
3    const char *str = buf;
4    str[0] = 'M';
5    str = "Mello";
6    buf[0] = 'M';
```

Line 4 is not allowed – it attempts to use a const pointer to characters to modify those characters.

Which lines (if any) above will cause an error due to violating `const`? Remember that `const char *` means that the characters at the location it stores cannot be changed.

const

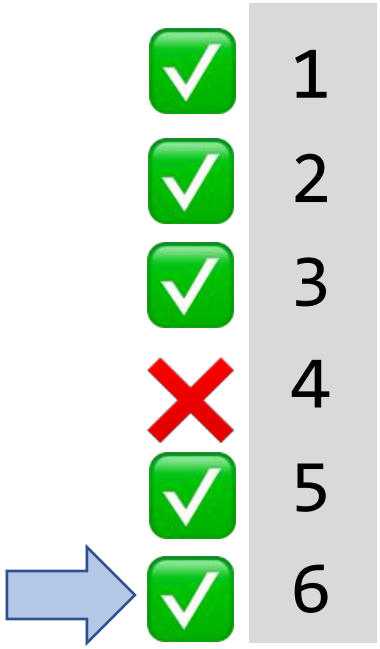


```
1    char buf[6];
2    strcpy(buf, "Hello");
3    const char *str = buf;
4    str[0] = 'M';
5    str = "Mello";
6    buf[0] = 'M';
```

Line 5 is ok – `str`'s type means that while you cannot change the characters at which it points, you can change `str` itself to point somewhere else. `str` is not `const` – its characters are.

Which lines (if any) above will cause an error due to violating `const`? Remember that `const char *` means that the characters at the location it stores cannot be changed.

const



```
1    char buf[6];
2    strcpy(buf, "Hello");
3    const char *str = buf;
4    str[0] = 'M';
5    str = "Mello";
6    buf[0] = 'M';
```

Line 6 is ok – `buf` is a modifiable char array, and we can use it to change its characters. Declaring `str` as `const` doesn't mean that place in memory is not modifiable at all – it just means that you cannot modify it using `str`.

Which lines (if any) above will cause an error due to violating `const`? Remember that `const char *` means that the characters at the location it stores cannot be changed.

Recap

- Function Pointers (cont'd.)
- `const`

Next Time: Structs