0 vs NULL // Twitter @raysato

COMP201

Computer Systems & Programming

Lecture #10 – Arrays and Pointers

KOÇ UNIVERSITY

Aykut Erdem // Koç University // Fall 2020

Good news, everyone!

- No class on Wednesday (Oct 28)
- Lab 3 – C-Strings and Valgrind postponed to next week
- Lab 5 – Shell Tools and Scripting canceled
- Assignment 2 will be out on Oct 28 (due Nov 11)
- No office hour this week *(Republic Day)*

Image: Professor Farnsworth (Futurama)

Recap: Pointers

- A *pointer* is a variable that stores a memory address.
- Because there is no pass-by-reference in C like in C++, pointers let us pass around the address of one instance of memory, instead of making many copies.
- One (8 byte) pointer can represent any size memory location!
- Pointers are also essential for allocating memory on the heap, which we will cover later.
- Pointers also let us refer to memory generically, which we will cover later.

Recap: Pointers

- If you are performing an operation with some input and do not care about any changes to the input, **pass the data type itself**.
- If you are modifying a specific instance of some value, **pass the location** of what you would like to modify.
- If a function takes an address (pointer) as a parameter, it can *go to* that address if it needs the actual value.

Recap: Pointers

- **Tip:** setting a function parameter equal to a new value usually doesn't do what you want. Remember that this is setting the function's *own copy* of the parameter equal to some new value.

```
void doubleNum(int x) {
    x = x * x;     // modifies doubleNum's own copy!
}

void advanceStr(char *str) {
    str += 2;      // modifies advanceStr's own copy!
}
```

COMP201 Topic 4: How can we effectively manage all types of memory in our programs?

Plan for Today

- Pointers and Parameters (cont'd.)
- Double Pointers
- Arrays in Memory
- Arrays of Pointers

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

Lecture Plan

- Pointers and Parameters (cont'd.)
- Double Pointers
- Arrays in Memory
- Arrays of Pointers

C Parameters

When you pass a value as a parameter, C passes a copy of that value.

```
void myFunction(int x) {
    …
}

int main(int argc, char *argv[]) {
    int num = 4;
    myFunction(num);        // passes copy of 4
}
```

C Parameters

When you pass a value as a parameter, C passes a copy of that value.

```
void myFunction(int *x) {
    …
}

int main(int argc, char *argv[]) {
    int num = 4;
    myFunction(&num);       // passes copy of e.g. 0xffed63
}
```

C Parameters

If you are performing an operation with some input and do not care about any changes to the input, pass the data type itself.

```
void myFunction(char ch) {
    printf("%c", ch);
}

int main(int argc, char *argv[]) {
    char *myStr = "Hello!";
    myFunction(myStr[1]);        // prints 'e'
}
```

C Parameters

If you are modifying a specific instance of some value, pass the *location* of what you would like to modify.

Do I care about modifying *this* instance of my data? If so, I need to pass where that instance lives, as a parameter, so it can be modified.

`char *`

- A `char *` is technically a pointer to a **single character**.
- We commonly use `char *` as string by having the character it points to be followed by more characters and ultimately a null terminator.
- A `char *` could also just point to a single character (not a string).

Pointers

If you are modifying a specific instance of some value, pass the *location* of what you would like to modify.

```
void capitalize(char *ch) {
     // modifies what is at the address stored in ch
}

int main(int argc, char *argv[]) {
     char letter = 'h';
     /* We don’t want to capitalize any instance of 'h'.
      * We want to capitalize *this* instance of 'h'! */
     capitalize(&letter);
     printf("%c", letter);   // want to print 'H';
}
```

Pointers

If you are modifying a specific instance of some value, pass the *location* of what you would like to modify.

```
void doubleNum(int *x) {
     // modifies what is at the address stored in x
}

int main(int argc, char *argv[]) {
     int num = 2;
     /* We don’t want to double any instance of 2.
      * We want to double *this* instance of 2! */
     doubleNum(&num);
     printf("%d", num); // want to print 4;
}
```

Pointers

If a function takes an address (pointer) as a parameter, it can *go to* that address if it needs the actual value.

```
void capitalize(char *ch) {
     // *ch gets the character stored at address ch.
     char newChar = toupper(*ch);

     // *ch = goes to address ch and puts newChar there.
     *ch = newChar;
}
```

Pointers

If a function takes an address (pointer) as a parameter, it can *go to* that address if it needs the actual value.

```
void capitalize(char *ch) {
     /* go to address ch and put the capitalized version
      * of what is at address ch there. */
      *ch = toupper(*ch);
}
```

Pointers

If a function takes an address (pointer) as a parameter, it can *go to* that address if it needs the actual value.

```
void capitalize(char *ch) {
    // this capitalizes the address ch! ☹
    char newChar = toupper(ch);

    // this stores newChar in ch as an address! ☹
    ch = newChar;
}
```

Exercise 1

We want to write a function that prints out the square of a number. What should go in each of the blanks?

```
void printSquare(__?__) {
    int square = __?__ * __?__;
    printf("%d", square);
}

int main(int argc, char *argv[]) {
    int num = 3;
    printSquare(__?__);     // should print 9
}
```

Exercise 1

We want to write a function that prints out the square of a number. What should go in each of the blanks?

We are performing a calculation with some input and do not care about any changes to the input, so we pass the data type itself.

```
void printSquare(int x) {
    int square = x * x;
    printf("%d", square);
}

int main(int argc, char *argv[]) {
    int num = 3;
    printSquare(num);  // should print 9
}
```

Exercise 1

We want to write a function that prints out the square of a number. What should go in each of the blanks?

We are performing a calculation with some input and do not care about any changes to the input, so we pass the data type itself.

```
void printSquare(int x) {
    x = x * x;
    printf("%d", x);
}

int main(int argc, char *argv[]) {
    int num = 3;
    printSquare(num);  // should print 9
}
```

Exercise 2

We want to write a function that flips the case of a letter. What should go in each of the blanks?

```
void flipCase(__?__) {
      if (isupper(__?__)) {
            __?__ = __?__;
      } else if (islower(__?__)) {
            __?__ = __?__;
      }
}

int main(int argc, char *argv[]) {
      char ch = 'g';
      flipCase(__?__);
      printf("%c", ch);      // want this to print ‘G’
}
```

Exercise 2

We want to write a function that flips the case of a letter. What should go in each of the blanks?

```
void flipCase(char *letter) {
        if (isupper(*letter)) {
                *letter = tolower(*letter);
        } else if (islower(*letter)) {
                *letter = toupper(*letter);
        }
}

int main(int argc, char *argv[]) {
        char ch = 'g';
        flipCase(&ch);
        printf("%c", ch); // want this to print ‘G’

}
```

We are modifying a specific instance of the letter, so we pass the location of the letter we would like to modify.

Lecture Plan

- Pointers and Parameters (cont'd.)
- Double Pointers
- Arrays in Memory
- Arrays of Pointers

Exercise 3

Sometimes, we would like to modify a string's pointer itself, rather than just the characters it points to. E.g. we want to write a function **skipSpaces** that modifies a string pointer to skip past any initial spaces. What should go in each of the blanks?

```
void skipSpaces(__?__) {
    ...
}

int main(int argc, char *argv[]) {
    char *str = "    hello";
    skipSpaces(__?__);
    printf("%s", str);          // should print "hello"
}
```

Exercise 3

Sometimes, we would like to modify a string's pointer itself, rather than just the characters it points to. E.g. we want to write a function `skipSpaces` that modifies a string pointer to skip past any initial spaces. What should go in each of the blanks?

```
void skipSpaces(char **strPtr) {
    ...
}

int main(int argc, char *argv[]) {
    char *str = "    hello";
    skipSpaces(&str);
    printf("%s", str);          // should print "hello"
}
```

We are modifying a specific instance of the string pointer, so we pass the location of the string pointer we would like to modify.

Exercise 3

Sometimes, we would like to modify a string's pointer itself, rather than just the characters it points to. E.g. we want to write a function **`skipSpaces`** that modifies a string pointer to skip past any initial spaces. What should go in each of the blanks?

```
void skipSpaces(char *strPtr) {
     ...
}

int main(int argc, char *argv[]) {
     char *str = "    hello";
     skipSpaces(str);
     printf("%s", str);          // should print "hello"
}
```

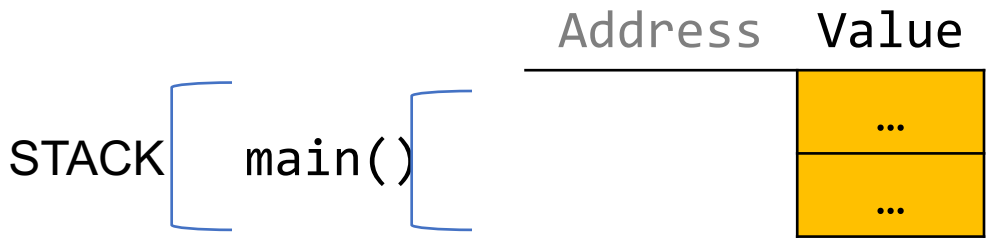
This advances `skipSpace`'s own copy of the string pointer, not the instance in main.

Demo: Skip Spaces

`skip_spaces.c`

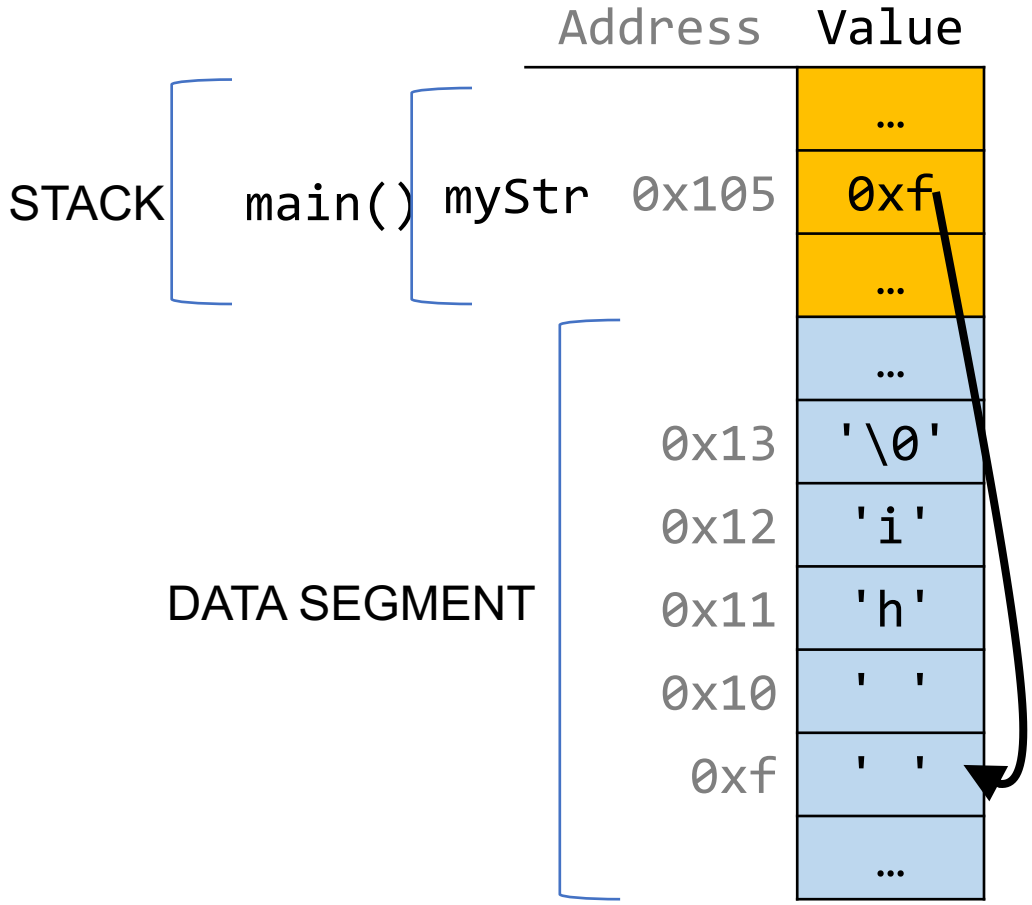
Pointers to Strings

```
void skipSpaces(char **strPtr) {
    int numSpaces = strspn(*strPtr, " ");
    *strPtr += numSpaces;
}

int main(int argc, char *argv[]) {
    char *myStr = "  hi";
    skipSpaces(&myStr);
    printf("%s\n", myStr);       // hi
    return 0;
}
```



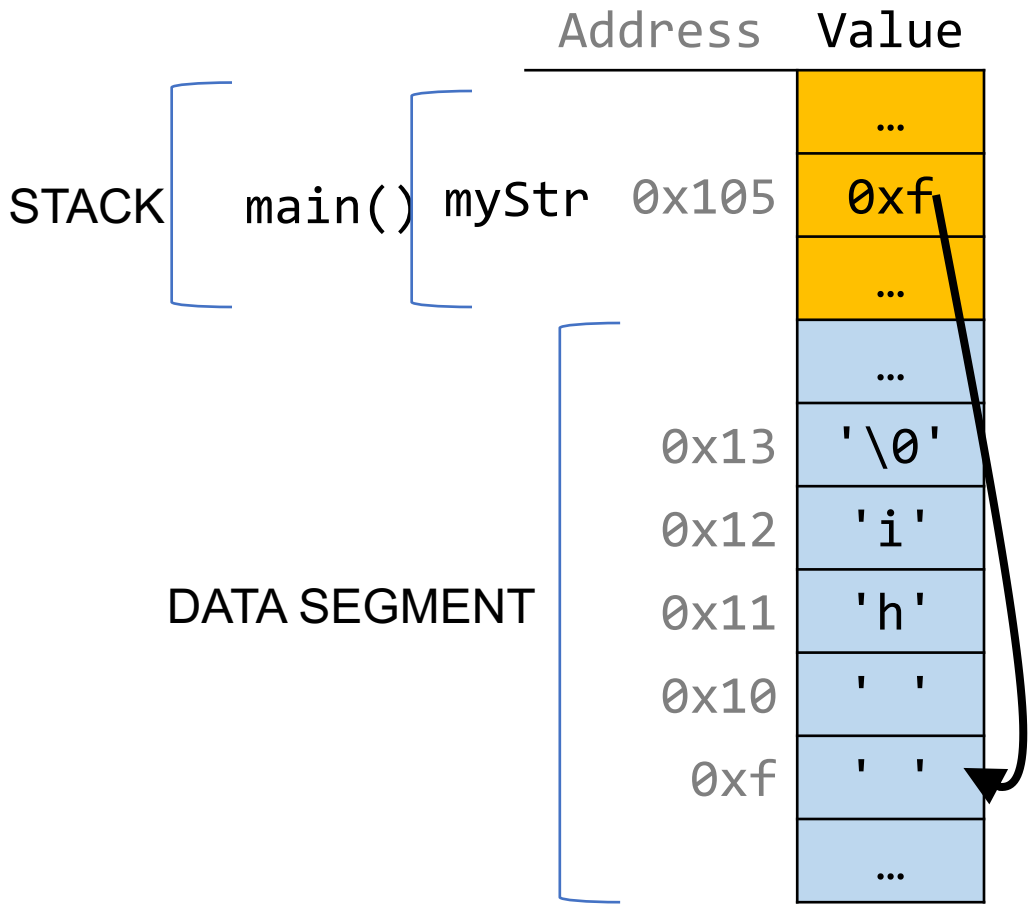
Pointers to Strings

```
void skipSpaces(char **strPtr) {
    int numSpaces = strspn(*strPtr, " ");
    *strPtr += numSpaces;
}

int main(int argc, char *argv[]) {
    char *myStr = "  hi";
    skipSpaces(&myStr);
    printf("%s\n", myStr);        // hi
    return 0;
}
```



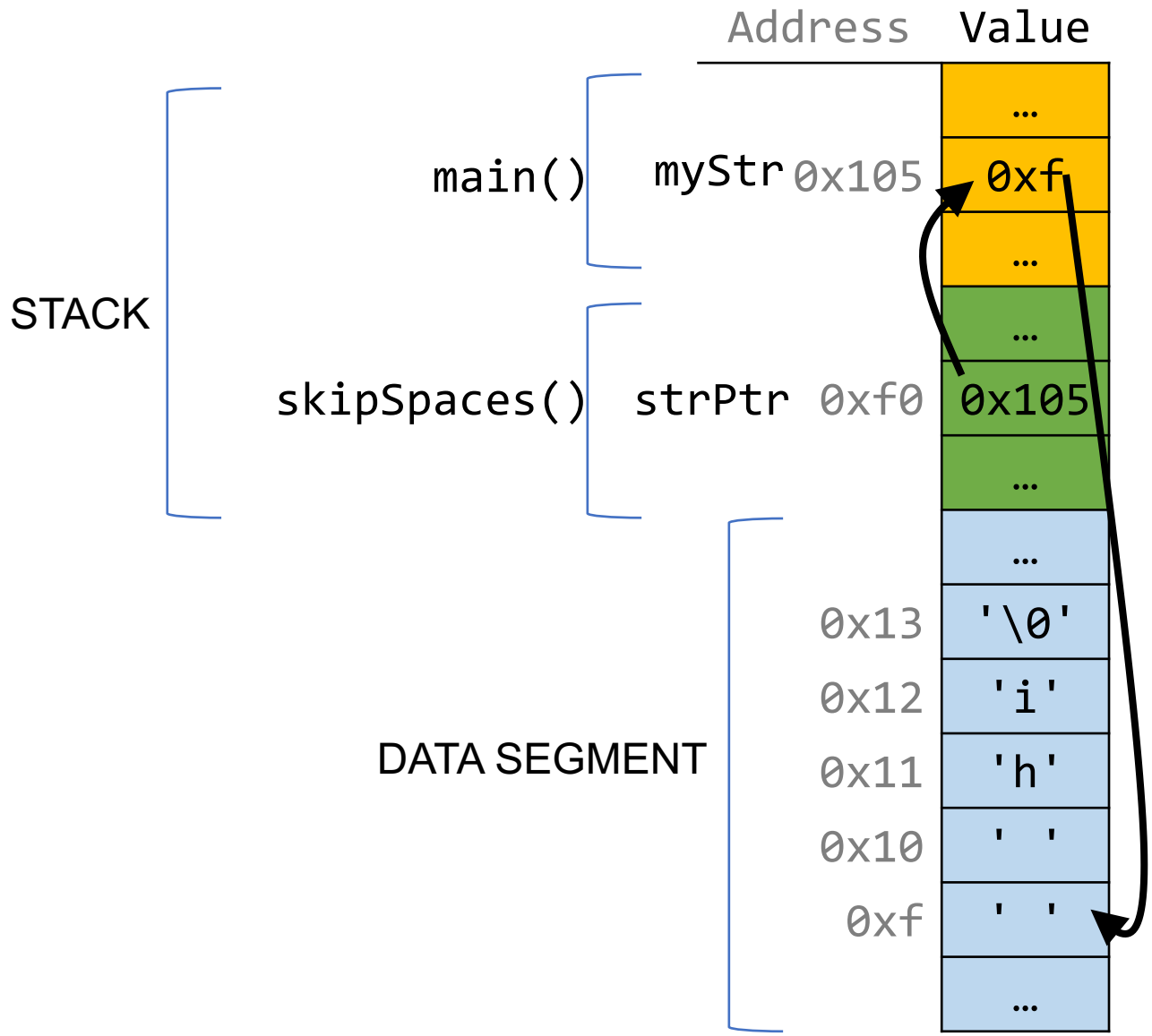
Pointers to Strings

```
void skipSpaces(char **strPtr) {
    int numSpaces = strspn(*strPtr, " ");
    *strPtr += numSpaces;
}

int main(int argc, char *argv[]) {
    char *myStr = "  hi";
    skipSpaces(&myStr);
    printf("%s\n", myStr);       // hi
    return 0;
}
```



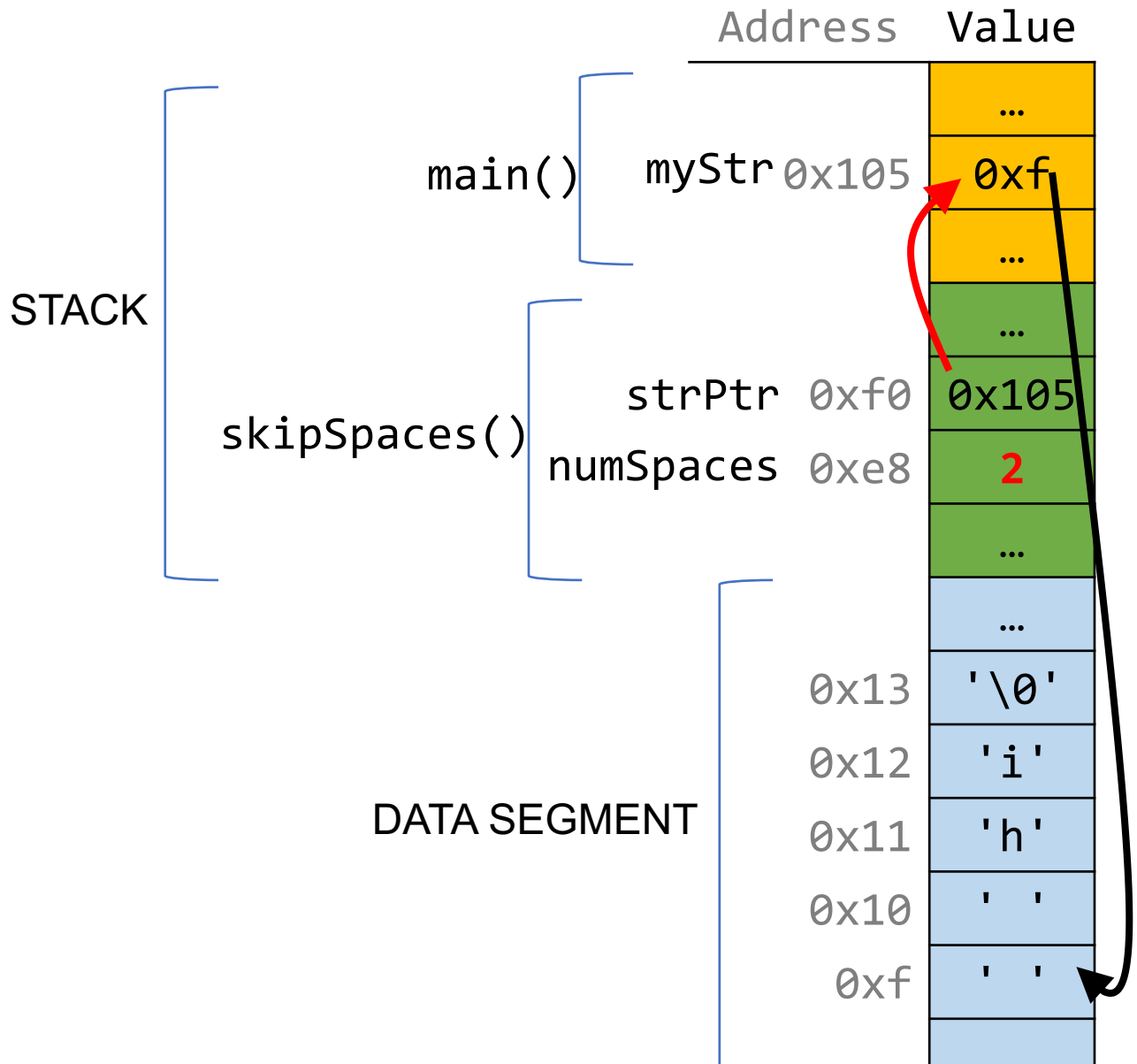
Pointers to Strings

```
void skipSpaces(char **strPtr) {
    int numSpaces = strspn(*strPtr, " ");
    *strPtr += numSpaces;
}

int main(int argc, char *argv[]) {
    char *myStr = "  hi";
    skipSpaces(&myStr);
    printf("%s\n", myStr);       // hi
    return 0;
}
```



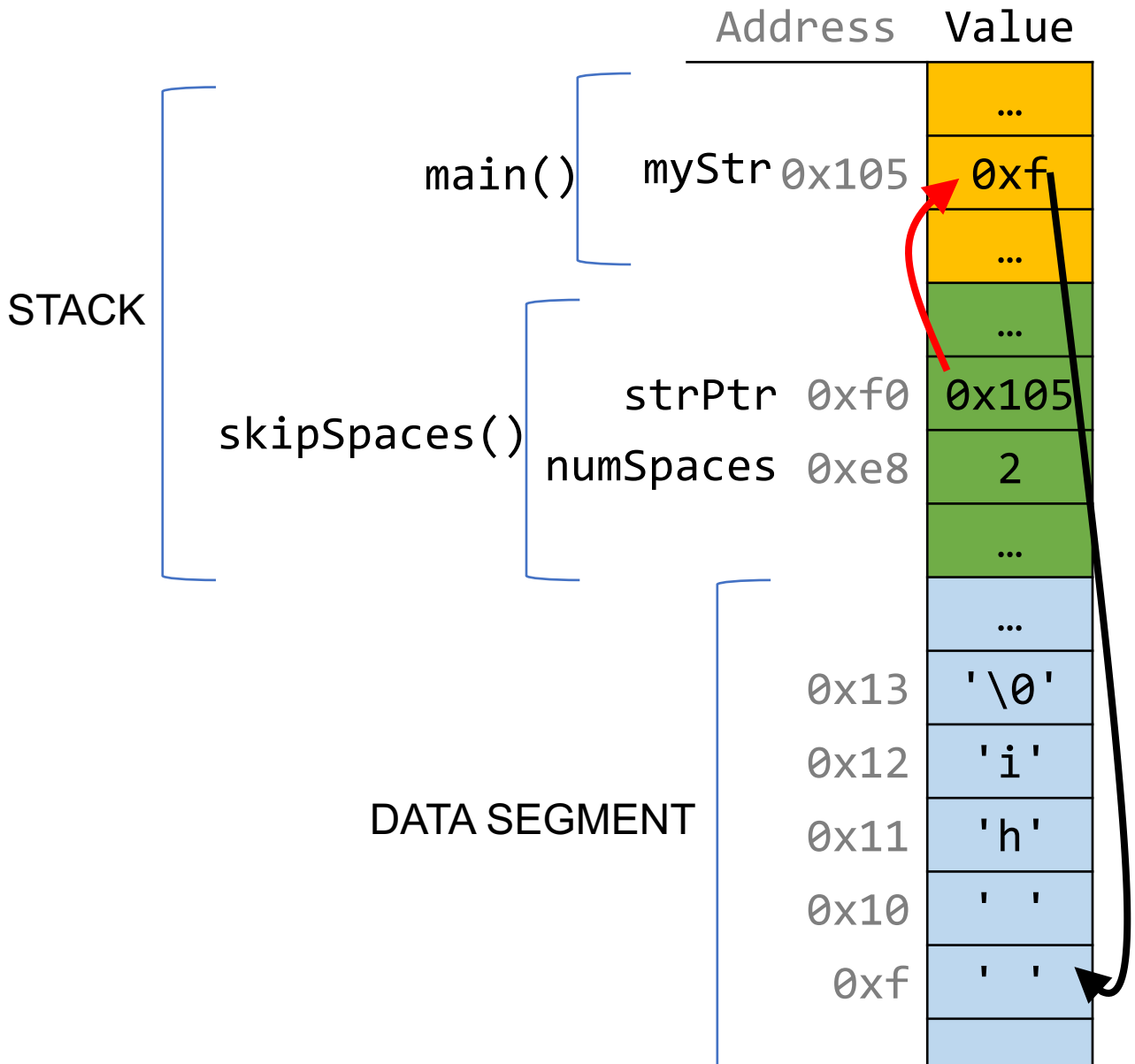
Pointers to Strings

```
void skipSpaces(char **strPtr) {
    int numSpaces = strspn(*strPtr, " ");
    *strPtr += numSpaces;
}

int main(int argc, char *argv[]) {
    char *myStr = "  hi";
    skipSpaces(&myStr);
    printf("%s\n", myStr);       // hi
    return 0;
}
```



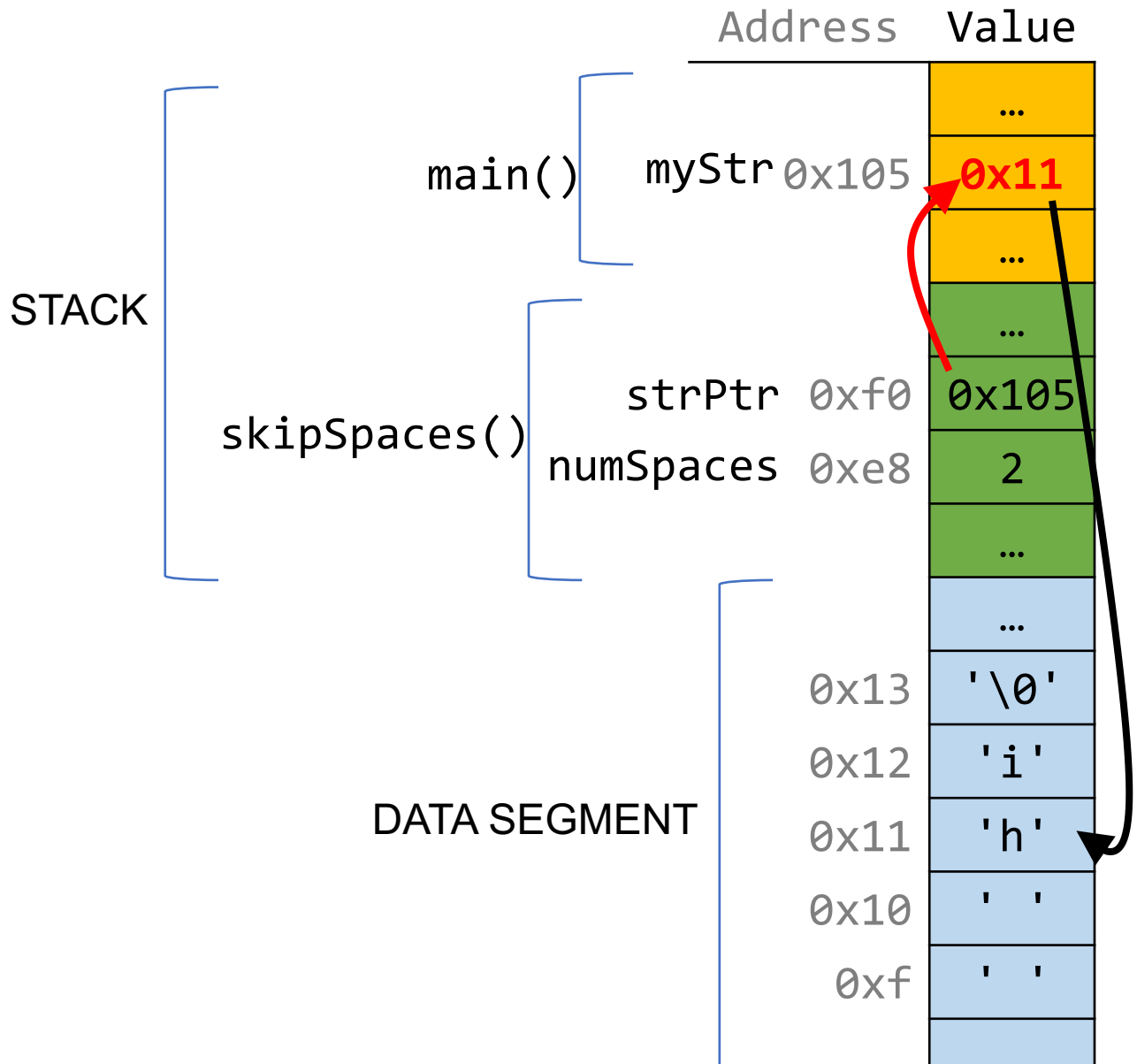
Pointers to Strings

```
void skipSpaces(char **strPtr) {
    int numSpaces = strspn(*strPtr, " ");
    *strPtr += numSpaces;
}

int main(int argc, char *argv[]) {
    char *myStr = "  hi";
    skipSpaces(&myStr);
    printf("%s\n", myStr);        // hi
    return 0;
}
```



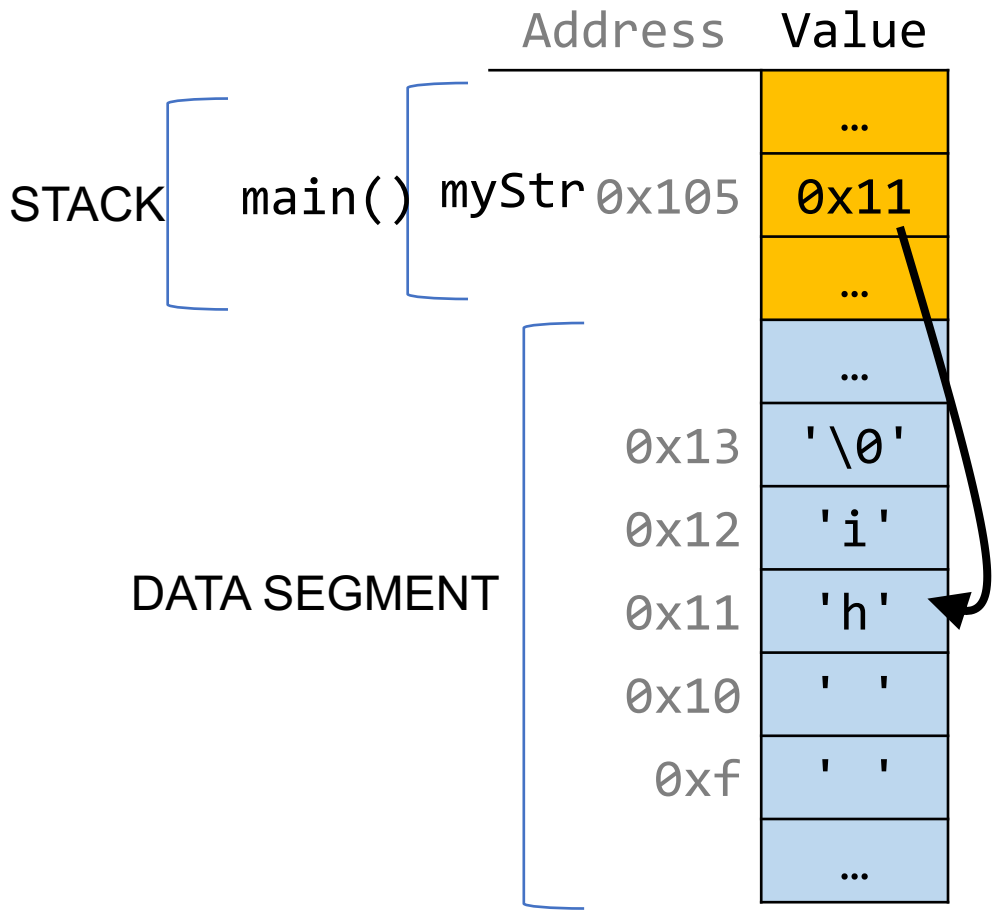
Pointers to Strings

```
void skipSpaces(char **strPtr) {
    int numSpaces = strspn(*strPtr, " ");
    *strPtr += numSpaces;
}

int main(int argc, char *argv[]) {
    char *myStr = "  hi";
    skipSpaces(&myStr);
    printf("%s\n", myStr);       // hi
    return 0;
}
```



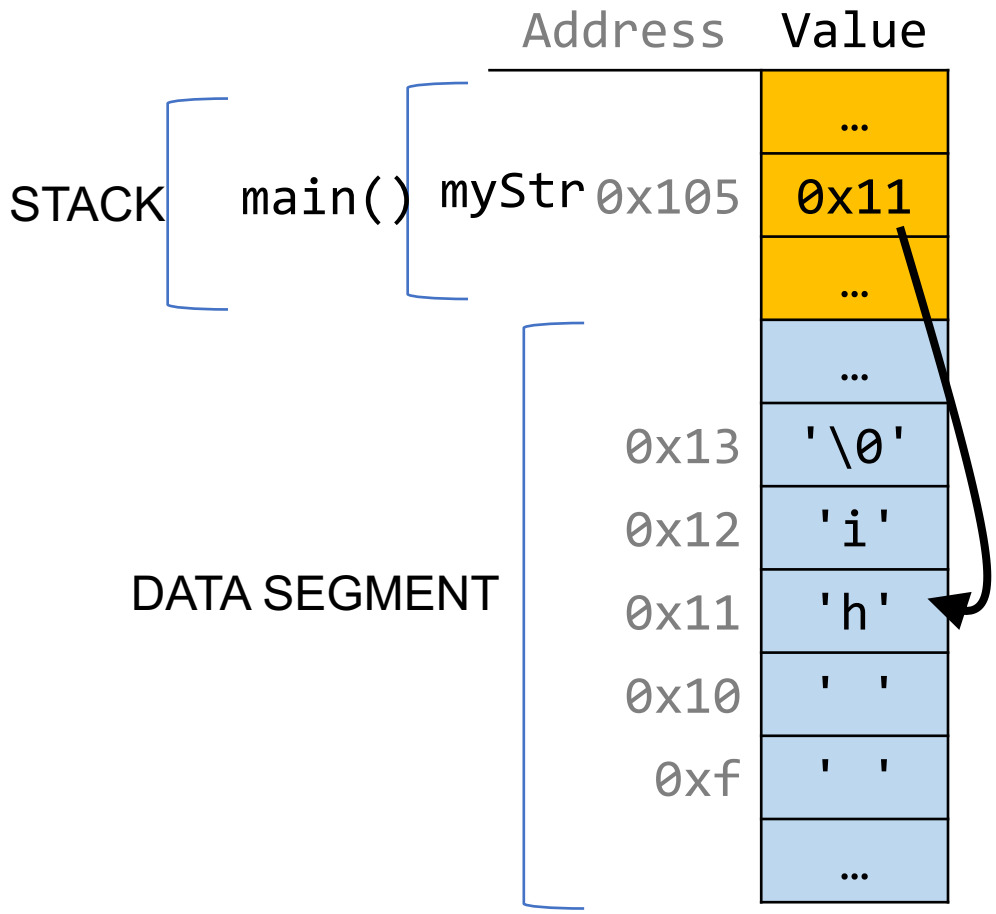
Pointers to Strings

```
void skipSpaces(char **strPtr) {
    int numSpaces = strspn(*strPtr, " ");
    *strPtr += numSpaces;
}

int main(int argc, char *argv[]) {
    char *myStr = "  hi";
    skipSpaces(&myStr);
    printf("%s\n", myStr);       // hi
    return 0;
}
```



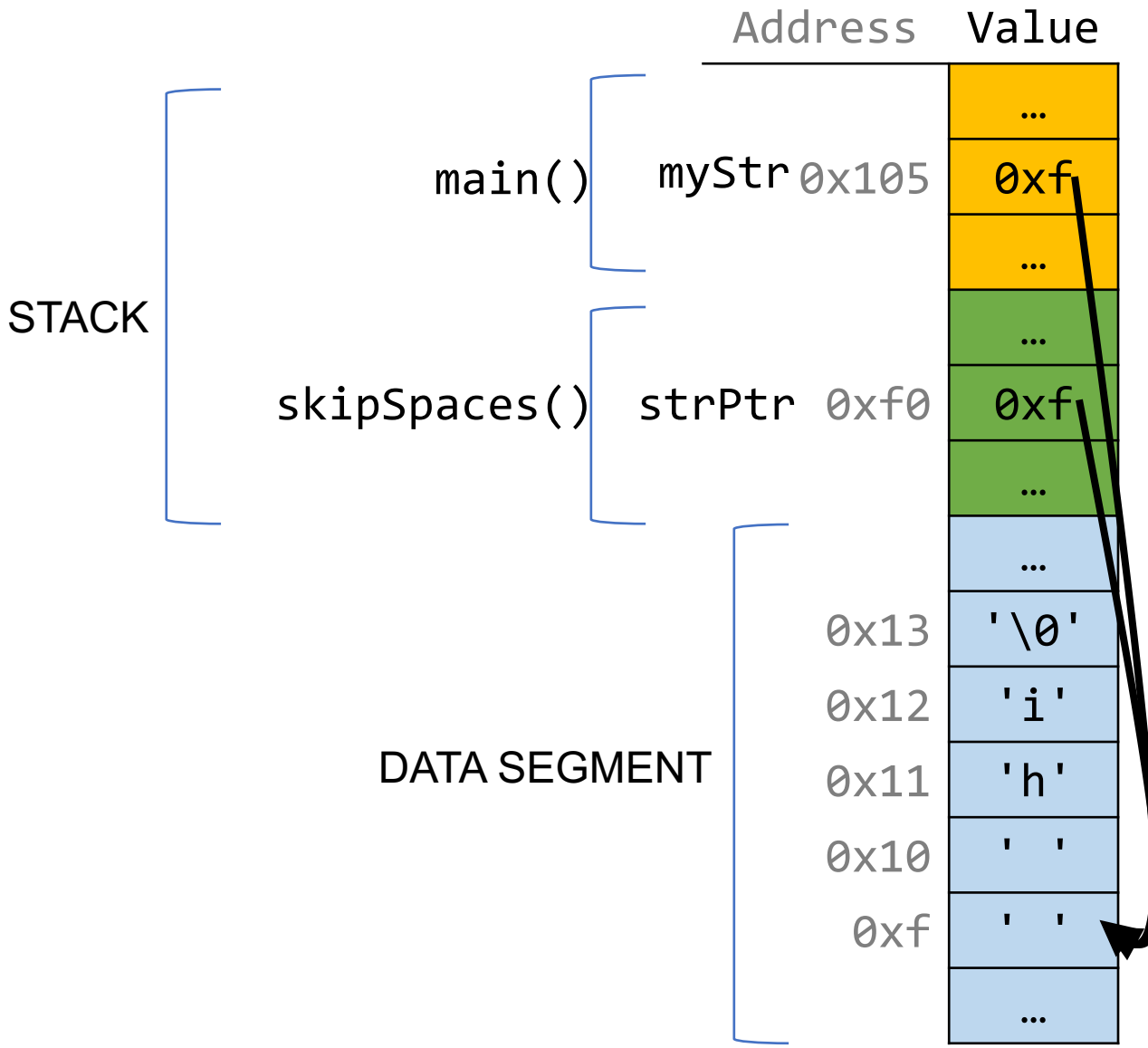
Pointers to Strings

```
void skipSpaces(char **strPtr) {
    int numSpaces = strspn(*strPtr, " ");
    *strPtr += numSpaces;
}

int main(int argc, char *argv[]) {
    char *myStr = "  hi";
    skipSpaces(&myStr);
    printf("%s\n", myStr);       // hi
    return 0;
}
```



Making Copies

```
void skipSpaces(char *strPtr) {
    int numSpaces = strspn(strPtr, " ");
    strPtr += numSpaces;
}

int main(int argc, char *argv[]) {
    char *myStr = "  hi";
    skipSpaces(myStr);
    printf("%s\n", myStr);        //   hi
    return 0;
}
```

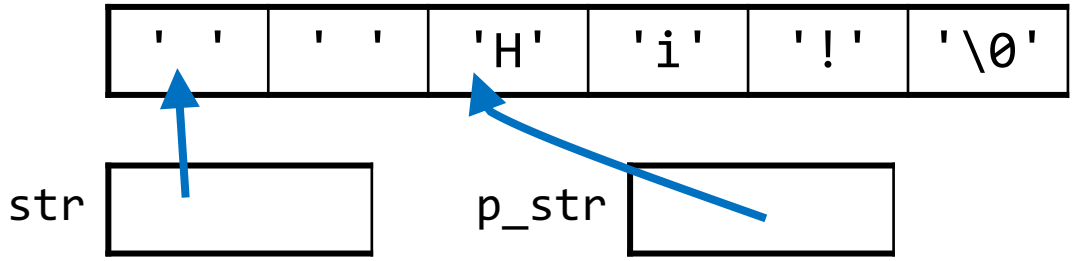


Skip spaces

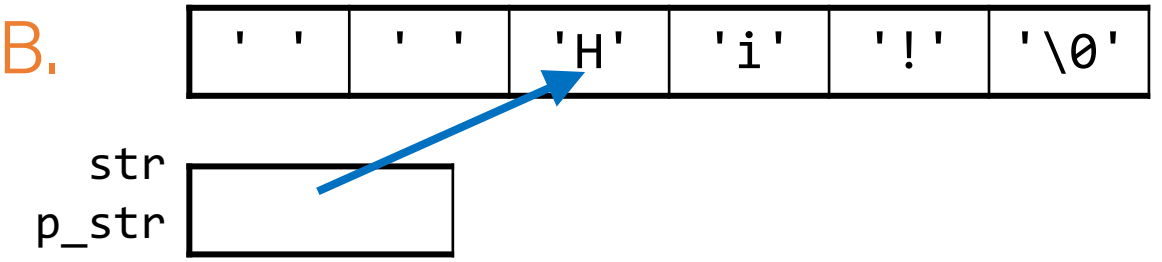
```
1  void skip_spaces(char **p_str) {
2    int num = strspn(*p_str, " ");
3    *p_str = *p_str + num;
4  }
5  int main(int argc, char *argv[]){
6    char *str = "  Hi!";
7    skip_spaces(&str);
8    printf("%s", str); // "Hi!"
9    return 0;
10 }
```

What diagram most accurately depicts program state at Line 4 (before `skip_spaces` returns to `main`)?

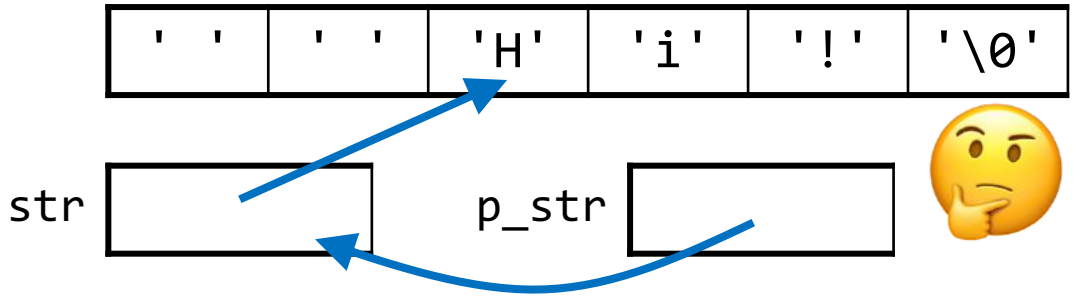
A.



B.



C.

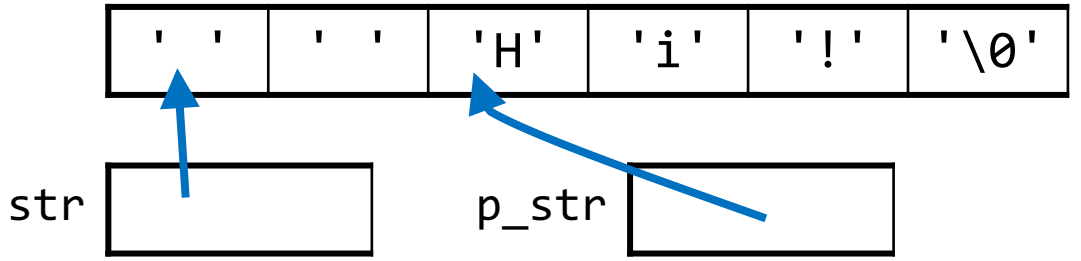


Skip spaces

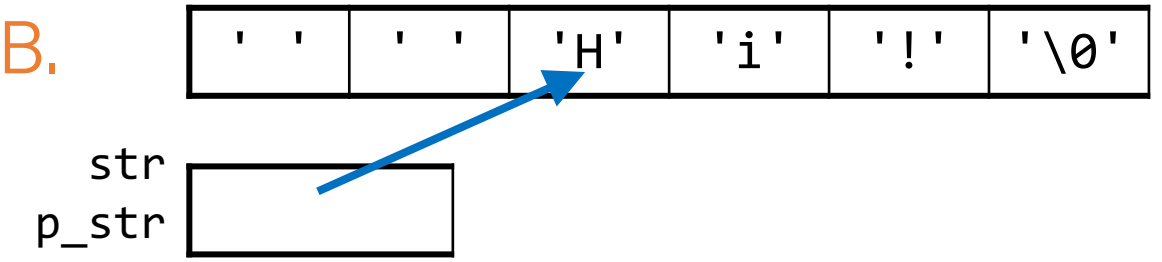
```
1  void skip_spaces(char **p_str) {
2    int num = strspn(*p_str, " ");
3    *p_str = *p_str + num;
4  }
5  int main(int argc, char *argv[]){
6    char *str = "  Hi!";
7    skip_spaces(&str);
8    printf("%s", str); // "Hi!"
9    return 0;
10 }
```

What diagram most accurately depicts program state at Line 4 (before `skip_spaces` returns to `main`)?

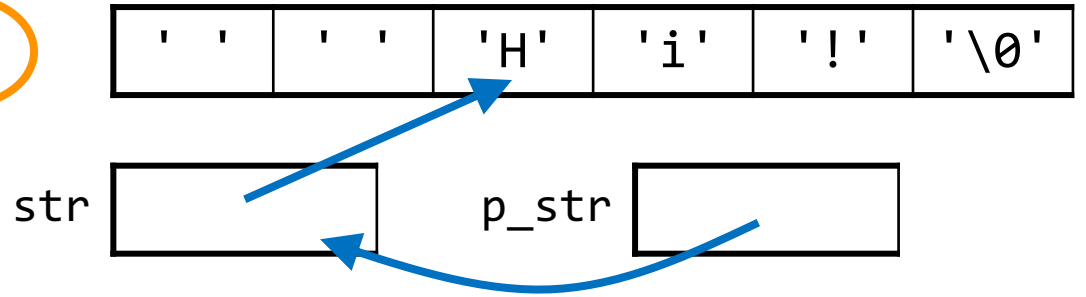
A.



B.



C.



Lecture Plan

- Pointers and Parameters (cont'd.)
- Double Pointers
- Arrays in Memory
- Arrays of Pointers

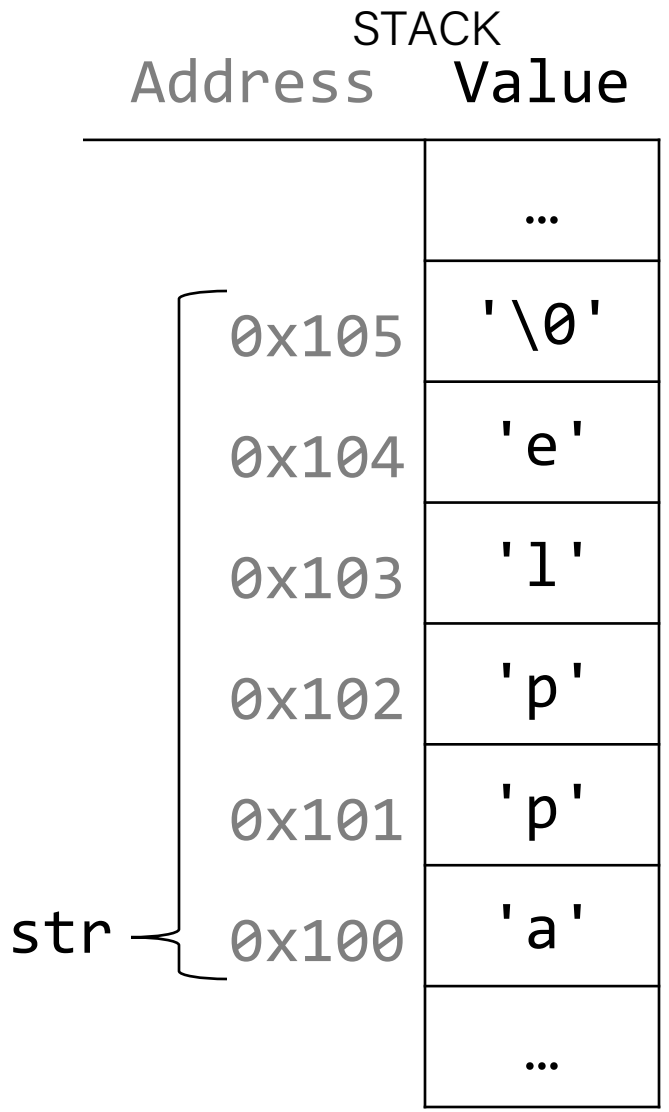
Arrays

When you declare an array, contiguous memory is allocated on the stack to store the contents of the entire array.

```
char str[6];
strcpy(str, "apple");
```

The array variable (e.g. **`str`**) is not a pointer; it refers to the entire array contents. In fact, **`sizeof`** returns the size of the entire array!

```
int arrayBytes = sizeof(str);    // 6
```



Arrays

An array variable refers to an entire block of memory. You cannot reassign an existing array to be equal to a new array.

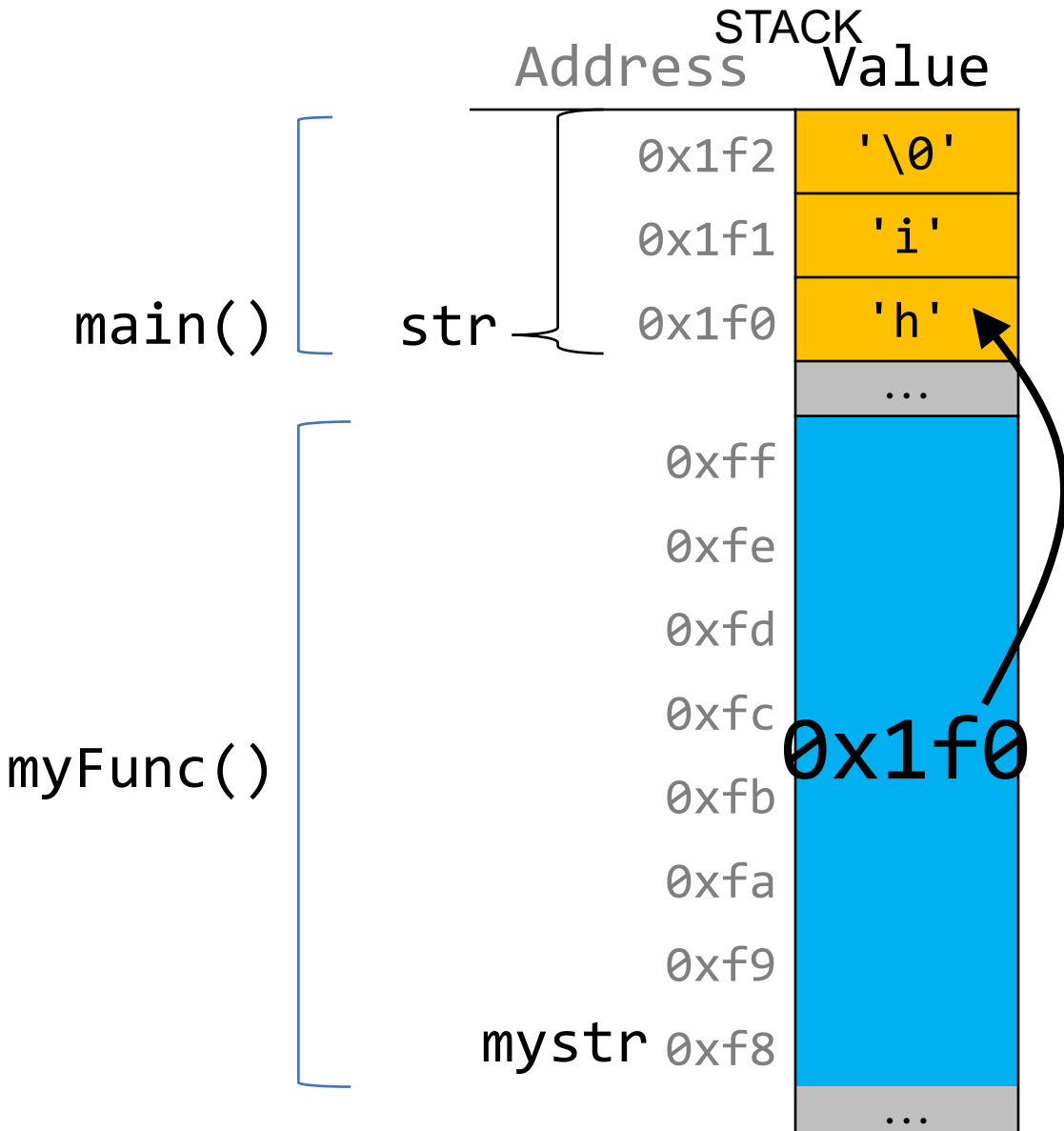
```
int nums[] = {1, 2, 3};
int nums2[] = {4, 5, 6, 7};
nums = nums2; // not allowed!
```

An array's size cannot be changed once you create it; you must create another new array instead.

Arrays as Parameters

When you pass an **array** as a parameter, C makes a *copy of the address of the first array element*, and passes it (a pointer) to the function.

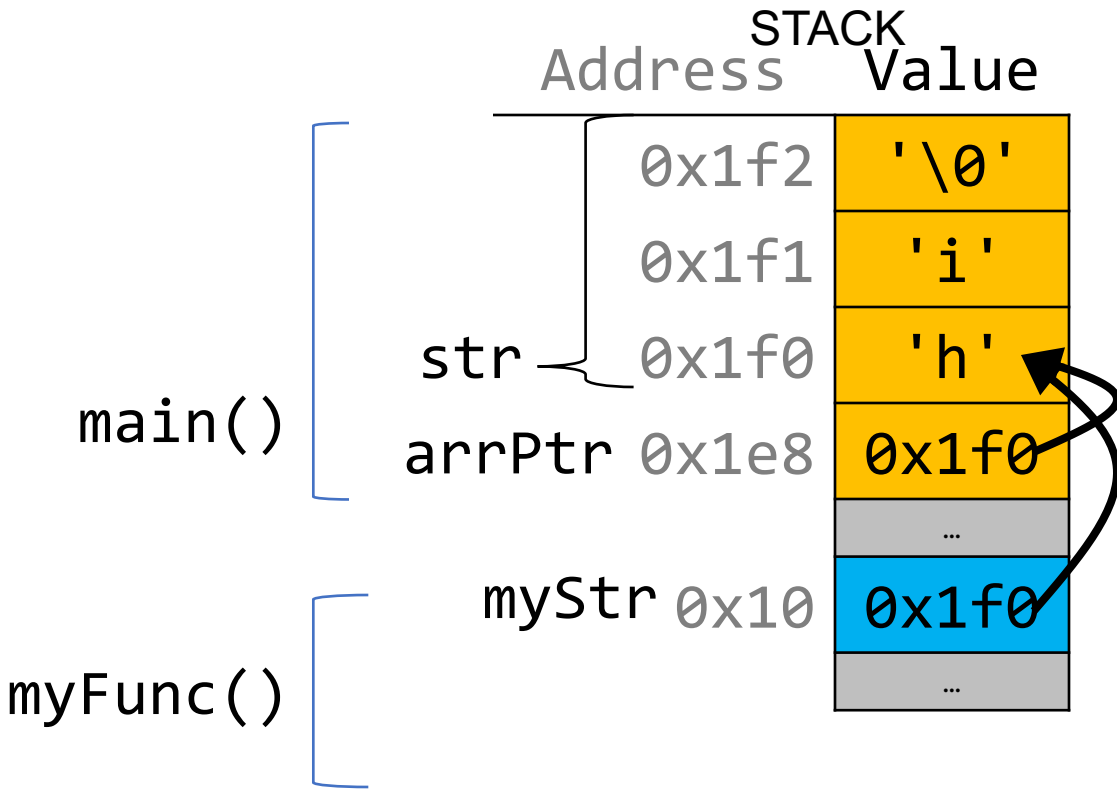
```
void myFunc(char *myStr) {
      ...
}

int main(int argc, char *argv[]) {
      char str[3];
      strcpy(str, "hi");
      myFunc(str);
      ...
}
```



Arrays as Parameters

When you pass an **array** as a parameter, C makes a *copy of the address of the first array element and* passes it (a pointer) to the function.

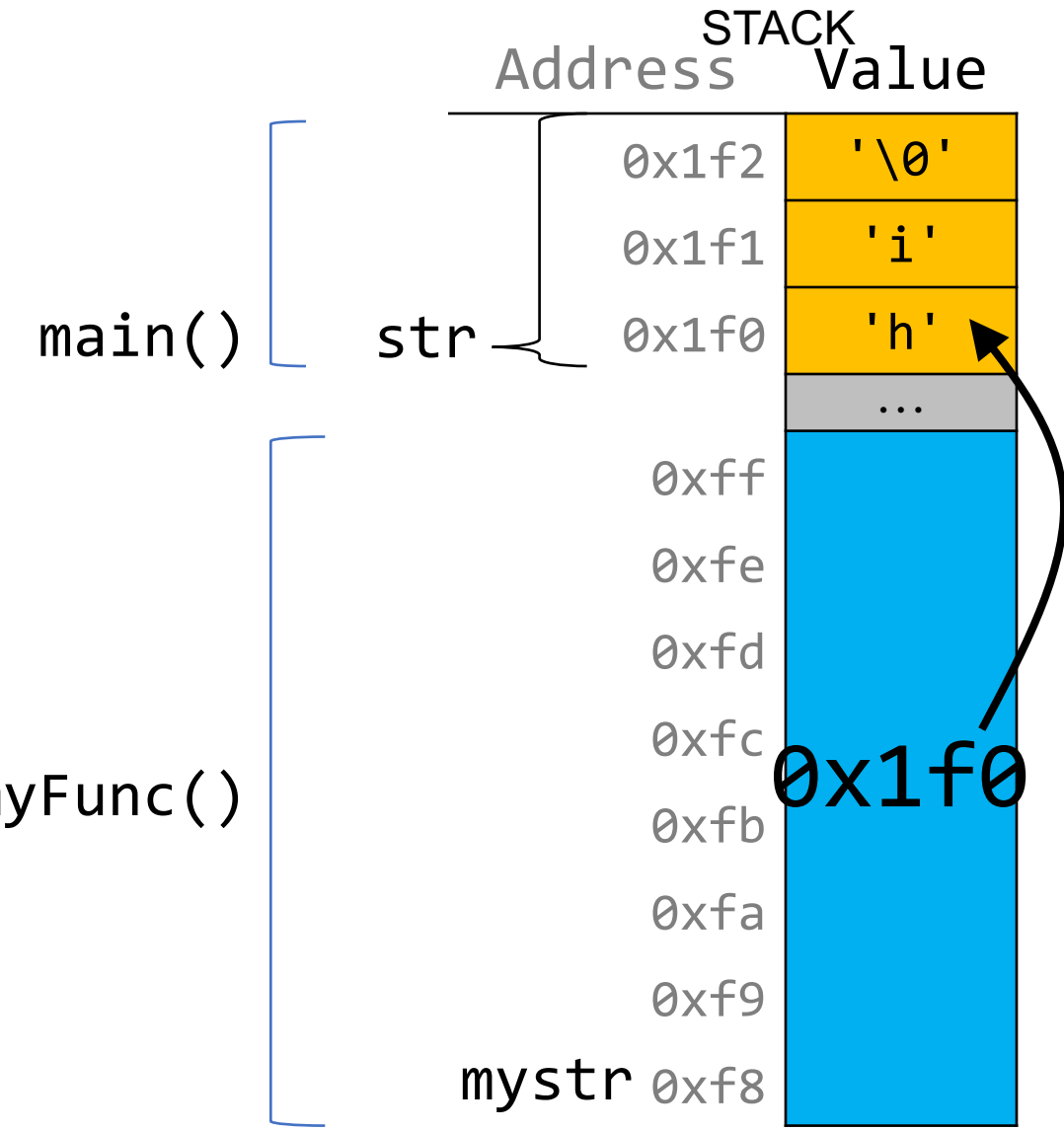
```
void myFunc(char *myStr) {
      …
}

int main(int argc, char *argv[]) {
      char str[3];
      strcpy(str, "hi");
      // equivalent
      char *arrPtr = str;
      myFunc(arrPtr);
      ...
}
```



Arrays as Parameters

This also means we can no longer get the full size of the array using **`sizeof`**, because now it is just a pointer.

```
void myFunc(char *myStr) {
      int size = sizeof(myStr); // 8
}

int main(int argc, char *argv[]) {
      char str[3];
      strcpy(str, "hi");
      int size = sizeof(str);   // 3
      myFunc(str);
      ...
}
```

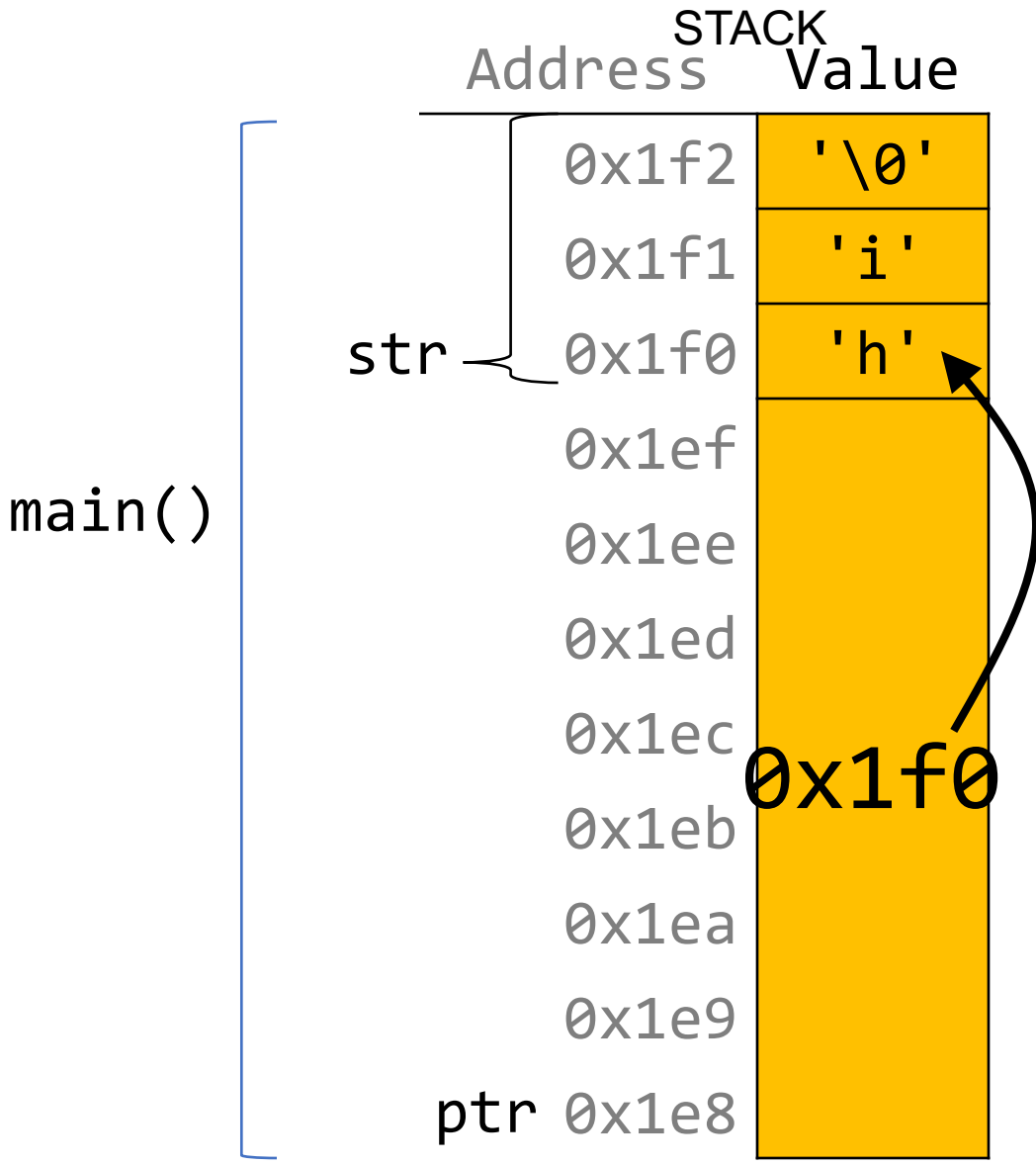


`sizeof` returns the size of an array, or 8 for a pointer. Therefore, when we pass an array as a parameter, we can no longer use **`sizeof`** to get its full size.

Arrays and Pointers

You can also make a pointer equal to an array; it will point to the first element in that array.

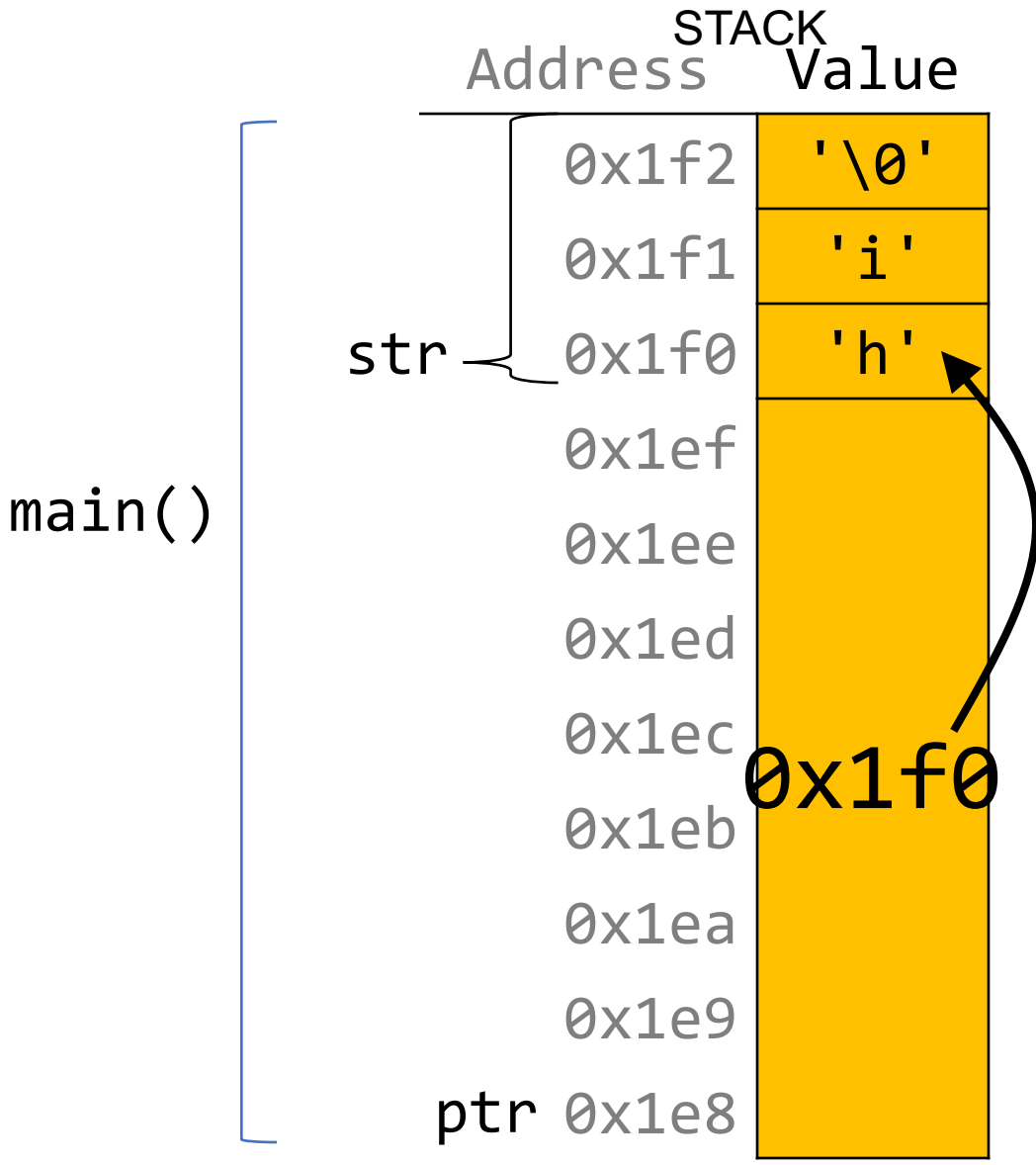
```
int main(int argc, char *argv[]) {
      char str[3];
      strcpy(str, "hi");
      char *ptr = str;
      ...
}
```



Arrays and Pointers

You can also make a pointer equal to an array; it will point to the first element in that array.

```
int main(int argc, char *argv[]) {
      char str[3];
      strcpy(str, "hi");
      char *ptr = str;

      // equivalent
      char *ptr = &str[0];

      // equivalent, but avoid
      char *ptr = &str;
      ...
}
```



Lecture Plan

- Pointers and Parameters (cont'd.)
- Double Pointers
- Arrays in Memory
- Arrays of Pointers

Arrays Of Pointers

You can make an array of pointers to e.g. group multiple strings together:

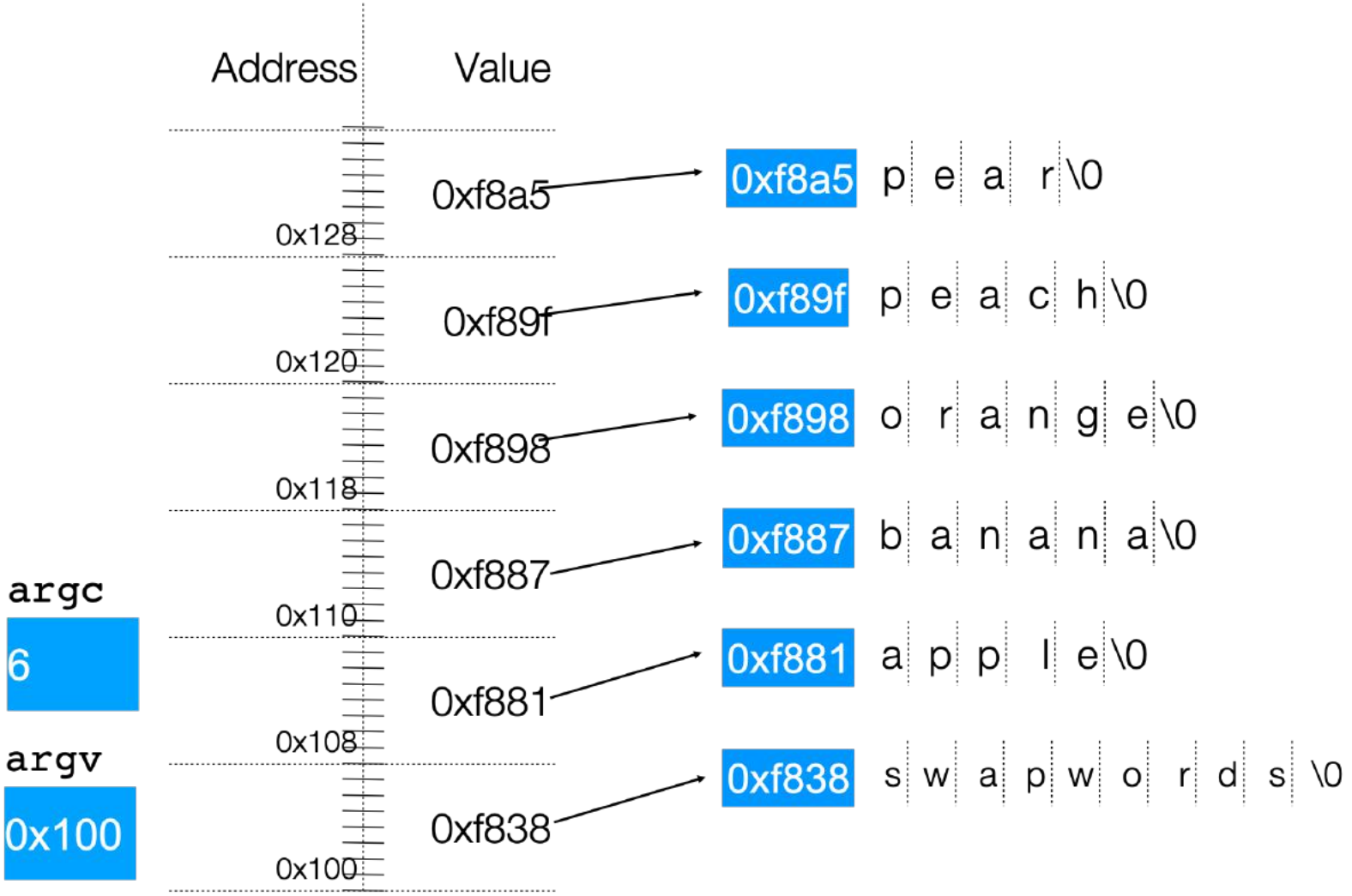
```
char *stringArray[5];   // space to store 5 char *s
```

This stores 5 **char *s**, *not* all of the characters for 5 strings!

```
char *str0 = stringArray[0];      // first char *
```

Arrays Of Pointers

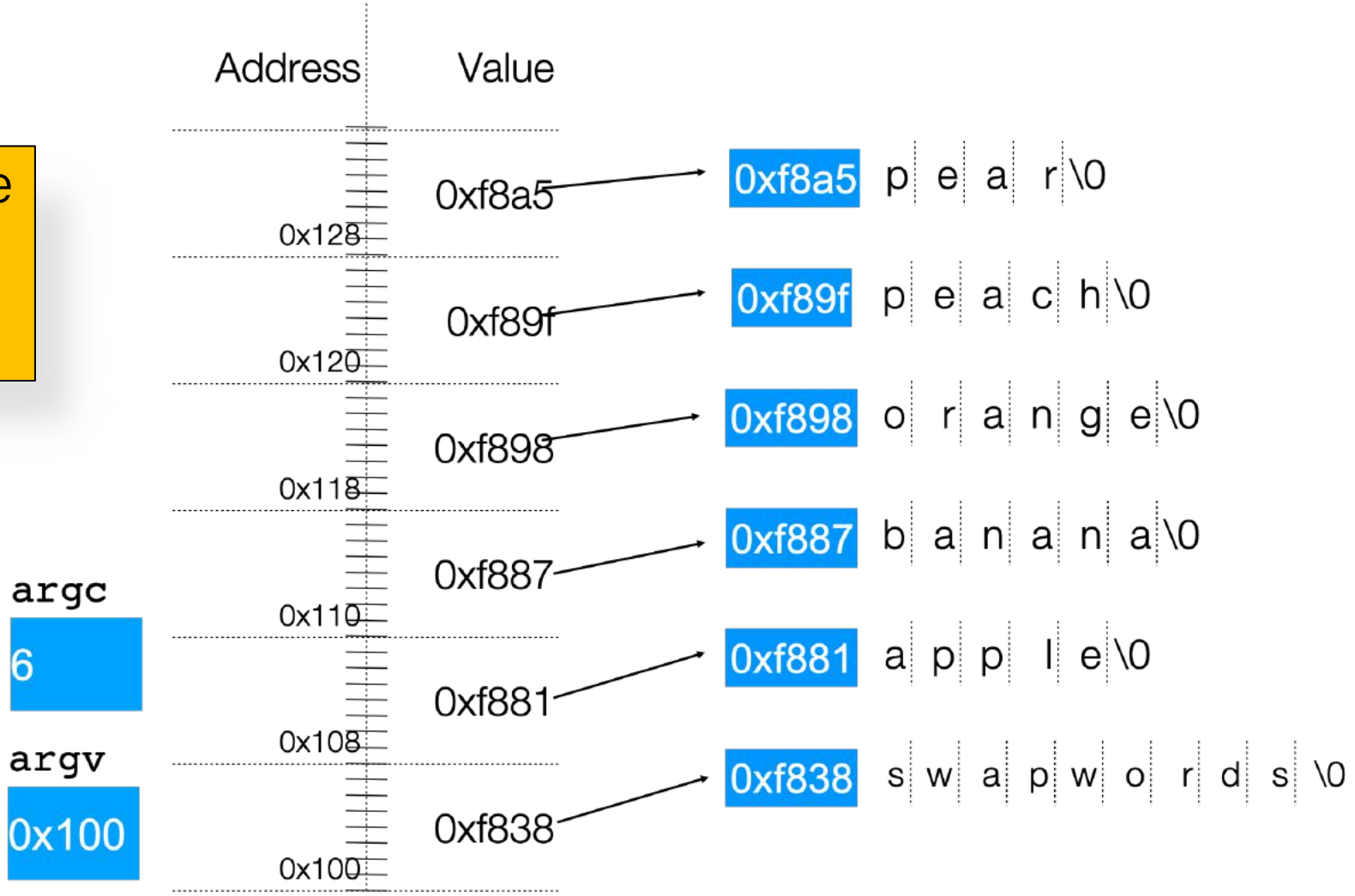
```
./swapwords apple banana orange peach pear
```



Arrays Of Pointers

```
./swapwords apple banana orange peach pear
```

What is the value of `argv[2]` in this diagram?



Recap

- Pointers and Parameters
- Double Pointers
- Arrays in Memory
- Arrays of Pointers

Next Time: pointer arithmetic, dynamically allocated memory