

UPE Tutoring:

CS 31 Midterm 1 Review

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Libraries

- `#include` allows us to use a library
- `#include <iostream>` allows us to use things like:
 - `cin`
 - `cout`
 - `endl`
- *Note: `iostream` stands for input/output stream*



Namespaces

- `using namespace std;`
- A namespace is a collection of classes and functions
- If we don't call `using namespace ns_name`, we will have to specify the namespace of the function we want to call.
- e.g. `std::cout`, `std::string`, `std::isdigit`



Namespaces (cont.)

```
#include <iostream>

int main() {
    int age;
    std::cin >> age;
    std::cout << age;
    std::cout << std::endl;
}
```

```
#include <iostream>
using namespace std;

int main() {
    int age;
    cin >> age;
    cout << age;
    cout << endl;
}
```



Basic data types

- `int`, `double`, `char`
 - Declare variables to store values in memory
 - `int x; // Creates a variable x of type int`
 - `char y; // Creates a variable y of type char`
- Can initialize with value at declaration:
 - `int a = 5;`
 - `double z = 53.24324;`



Modifying variables

- The type of the variable must be specified only once, at the time of declaration

```
int x = 5;  
x = x + 5;  
x -= 6; // equivalent to x = x - 6;
```

```
double z;  
z = 53.234;  
z *= 5; // equivalent to z = z * 5;
```



Modifying variables (cont.)

- Integer division truncates after the decimal point
- The % (modulus) operator returns the remainder of integer division

```
int x = 5;  
int integerQuotient = x / 3; // integerQuotient equals 1  
int remainder = x % 3;      // remainder equals 2  
x %= 4;                     // same as x = x % 4, x now equals 1
```



Modifying variables (cont.)

- Double division
 - If at least one of the operands is a double, floating point division occurs.
 - If both values are integers, integer division occurs instead.

```
int x = 5;  
double unexpectedQuotient = x / 2;    // equals 2  
double expectedQuotient = x / 2.0;    // equals 2.5
```



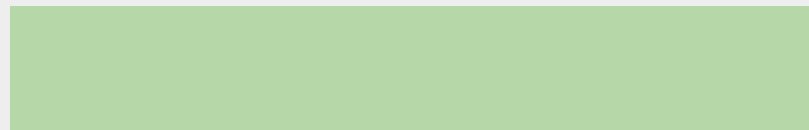
Input/output

```
#include <iostream>
using namespace std;
int main() {
    int age;
    cout << "How old are you? " << endl;
    cin >> age;
    cout << "You are " << age <<
        " years old" << endl;
}
```



Input/output

```
#include <iostream>
using namespace std;
int main() {
    int age;
    cout << "How old are you? " << endl;
    cin >> age;
    cout << "You are " << age <<
        " years old" << endl;
}
```



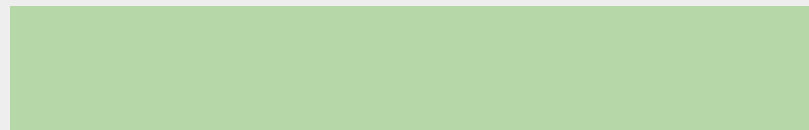
age



Input/output

```
#include <iostream>
using namespace std;
int main() {
    int age;
    cout << "How old are you? " << endl;
    cin >> age;
    cout << "You are " << age <<
        " years old" << endl;
}
```

> How old are you?



age



Input/output

```
#include <iostream>
using namespace std;
int main() {
    int age;
    cout << "How old are you? " << endl;
    cin >> age;
    cout << "You are " << age <<
        " years old" << endl;
}
```

> How old are you? 20

20

age



Input/output

```
#include <iostream>
using namespace std;
int main() {
    int age;
    cout << "How old are you? " << endl;
    cin >> age;
    cout << "You are " << age <<
        " years old" << endl;
}
```

```
> How old are you? 20
> You are 20 years old
```

20

age



Strings

- Used to store blocks of text
- Strings can be initialized from literals
 - `string x = "hello";`
- Individual characters can be accessed with the `[]` operator.
 - `char c = x[0]; // c == 'h'`



String operations

```
string x = "hello there";
```

- The `size()` method returns the number of characters in a string.
 - `int length = x.size(); // length equals 11`
- The `substr(startIndex, length)` method returns a substring *including* `startIndex` of length `length`.
 - `string sub = x.substr(3, 2); // sub equals "lo"`
- *Note: `substr` is not in the scope of the midterm.*



String operations

```
// The + operator is overloaded:  
// It appends to the end of strings.
```

```
int main() {  
    string x = "hello there";  
    x += ", my name is Mark";  
    cout << x << endl;  
}
```

hello there

x



String operations

```
// The + operator is overloaded:  
// It appends to the end of strings.
```

```
int main() {  
    string x = "hello there";  
    x += ", my name is Mark";  
    cout << x << endl;  
}
```

hello there, my name is Mark

x



String operations

```
// The + operator is overloaded:  
// It appends to the end of strings.
```

```
int main() {  
    string x = "hello there";  
    x += ", my name is Mark";  
    cout << x << endl;  
}
```

```
> hello there, my name is Mark
```

```
hello there, my name is Mark
```

```
x
```



String input

```
// getline(...) consumes characters from  
// the input until it encounters a '\n'.
```

```
int main() {  
    string x;  
    getline(cin, x);  
    cout << x << endl;  
}
```



String input

```
// getline(...) consumes characters from  
// the input until it encounters a '\n'.
```

```
int main() {  
    string x;  
    getline(cin, x);  
    cout << x << endl;  
}
```

> Why hello there!



String input

```
// getline(...) consumes characters from  
// the input until it encounters a '\n'.
```

```
int main() {  
    string x;  
    getline(cin, x);  
    cout << x << endl;  
}
```

```
> Why hello there!
```

```
> Why hello there!
```



Ignoring characters

- Undesirable characters are often left in the input buffer after using `cin`.
- `cin.ignore(int numChars, char delim)` can be used to “flush” out these undesired characters. It flushes up to the nearest `delim` or `numChar` characters, whichever comes first.
- `cin.ignore(...)` becomes necessary if after reading a number, the next thing you want to read is a string using `getline(...)`.



Ignoring characters

- Undesirable characters are often left in the input buffer after using `cin`.
- `cin.ignore(int numChars, char delim)` can be used to “flush” out these undesired characters. It flushes up to the nearest `delim` or `numChar` characters, whichever comes first.
- `cin.ignore(...)` becomes necessary if after reading a number, the next thing you want to read is a string using `getline(...)`.
- **Common question:** does `getline` consume `'\n'`?



Ignoring characters

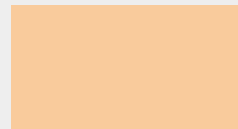
- Undesirable characters are often left in the input buffer after using `cin`.
- `cin.ignore(int numChars, char delim)` can be used to “flush” out these undesired characters. It flushes up to the nearest `delim` or `numChar` characters, whichever comes first.
- `cin.ignore(...)` becomes necessary if after reading a number, the next thing you want to read is a string using `getline(...)`.
- **Common question:** does `getline` consume `'\n'`?
If a newline is found, it is extracted and discarded (i.e. it is not stored and the next input operation will begin after it).



cin.ignore example

```
int main() {  
    cout << "How many Big Macs would you " <<  
        "like? ";  
    int bigMacs;  
    cin >> bigMacs;  
    cin.ignore(10000, '\n'); // Important!  
  
    cout << "What else would you like " <<  
        "with your order?";  
    string sides;  
    getline(cin, sides);  
}
```

> How many Big Macs would you like?



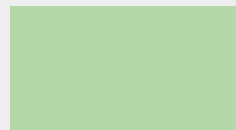
Input



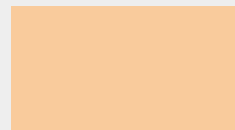
cin.ignore example

```
int main() {  
    cout << "How many Big Macs would you " <<  
        "like? ";  
    int bigMacs;  
    cin >> bigMacs;  
    cin.ignore(10000, '\n'); // Important!  
  
    cout << "What else would you like " <<  
        "with your order?";  
    string sides;  
    getline(cin, sides);  
}
```

> How many Big Macs would you like?



bigMacs



Input



cin.ignore example

```
int main() {  
    cout << "How many Big Macs would you " <<  
        "like? ";  
    int bigMacs;  
    cin >> bigMacs;  
    cin.ignore(10000, '\n'); // Important!  
  
    cout << "What else would you like " <<  
        "with your order?";  
    string sides;  
    getline(cin, sides);  
}
```

> How many Big Macs would you like? 1000

1000

bigMacs

\n

Input



cin.ignore example

```
int main() {  
    cout << "How many Big Macs would you " <<  
        "like? ";  
    int bigMacs;  
    cin >> bigMacs;  
    cin.ignore(10000, '\n'); // Important!  
  
    cout << "What else would you like " <<  
        "with your order?";  
    string sides;  
    getline(cin, sides);  
}
```

> How many Big Macs would you like? 1000

1000

bigMacs

Input



cin.ignore example

```
int main() {  
    cout << "How many Big Macs would you " <<  
        "like? ";  
    int bigMacs;  
    cin >> bigMacs;  
    cin.ignore(10000, '\n'); // Important!  
  
    cout << "What else would you like " <<  
        "with your order?";  
    string sides;  
    getline(cin, sides);  
}
```

- > How many Big Macs would you like? 1000
- > What else would you like with your order?

1000

bigMacs

Input



cin.ignore example

```
int main() {  
    cout << "How many Big Macs would you " <<  
        "like? ";  
    int bigMacs;  
    cin >> bigMacs;  
    cin.ignore(10000, '\n'); // Important!  
  
    cout << "What else would you like " <<  
        "with your order?";  
    string sides;  
    getline(cin, sides);  
}
```

- > How many Big Macs would you like? 1000
- > What else would you like with your order?

1000

bigMacs

sides

Input



cin.ignore example

```
int main() {  
    cout << "How many Big Macs would you " <<  
        "like? ";  
    int bigMacs;  
    cin >> bigMacs;  
    cin.ignore(10000, '\n'); // Important!  
  
    cout << "What else would you like " <<  
        "with your order?";  
    string sides;  
    getline(cin, sides);  
}
```

> How many Big Macs would you like? 1000
> What else would you like with your
order? Fries

1000

bigMacs

Fries

sides

Input



cin.ignore(...) example

- What will be stored in the string “a” in this example?
- Assume that input is newline terminated.

```
int x; string a;  
cout << "Enter an integer" << endl;  
cin >> x; // Assume the user enters "7"  
cout << "Enter a string" << endl;  
getline(cin, a); // Assume user enters "500"
```



cctype

- Useful shortcut methods for characters
- `#include<cctype>` gives you...
 - `isalpha('M')` // true, since 'M' is a letter
 - `isupper('M')` // true, since 'M' is an uppercase letter
 - `islower('r')` // true, since 'r' is a lowercase letter
 - `isdigit('5')` // true, since '5' is a digit character
 - `islower('M')` // false, since 'M' is not a lowercase letter
 - `isalpha(' ')` // false, since ' ' is not a letter
 - `isalpha('5')` // false, since '5' is not a letter



If statements

- if statements only run code if the condition is true
- *Note: any non-zero expression is considered true*

```
int age;  
cin >> age;  
if (age < 13) {  
    cout << "You are not yet a teenager!" << endl;  
}
```



If statements

- Without curly braces, only next statement is attached to the control statement.
- So, if you want multiple statements to be executed, use curly braces.
- *Note: this also applies to else and else-if statements*

```
if (cond1) {  
    statement1;  
    statement2;  
}
```



If statements (cont.)

```
int main() {  
    int x = 3;  
    if (x == 5)  
        cout << "x is 5" << endl;  
    cout << "In if" << endl; // Incorrectly  
                               // called!  
}
```

```
int main() {  
    int x = 5;  
    if (x == 5) {  
        cout << "x is 5" << endl;  
        cout << "In if" << endl;  
    }  
}
```



Else statements

- Performed when all if and else if conditions fail

```
int number;  
cin >> number;  
if (number % 2 == 0)  
    cout << "You gave an even number" << endl;  
else  
    cout << "You gave an odd number" << endl;
```



Else-if statements

- Allows us to check for more than the if condition and its complement

```
if (cond1)
    statement1;
else if (cond2)
    statement2;
else if (cond3)
    statement3;
else
    statement4;
```



Comparison pitfalls

- **Equals-equals (==) vs. Equals (=)**
- These operators are very different!

```
(x == y) // Returns true if x and y are equal
```

```
(x = y) // Assigns the value of y to x and returns the value  
        // ASSIGNED to x.
```



Conditional confusion?

- Does this output anything?

```
int age = 17;  
if (age) {  
    cout << "You are not 0 years old!" << endl;  
}
```



Conditional confusion?

- What does this output?

```
int age = 0;
if (age) {
    cout << "You are not 0 years old!" << endl;
} else {
    cout << "You are 0 years old!" << endl;
}
```



Switches

- Arguably a more compact alternative to long if/else if/else sequences
- The value tested must be an integral type or convertible to one
 - e.g. int, char, short, long, etc.
 - string is not a permitted type
- A break statement must be used to leave the switch. Otherwise execution will fall through to the next case.



Switches (cont.)

```
string value; int number;
cin >> number;
switch (number) {
    case 0:  // Fall-through to Case 2.
    case 2:
        value = "Good";
        break; // Remember to break!
    case 3:
        value = "Bad";
        break;
    default:
        value = "Ugly";
        break;
}
```

Common question 1: is a break statement required for the default case?



Switches (cont.)

```
string value; int number;
cin >> number;
switch (number) {
    case 0: // Fall-through to Case 2.
    case 2:
        value = "Good";
        break; // Remember to break!
    case 3:
        value = "Bad";
        break;
    default:
        value = "Ugly";
        break;
}
```

Common question 1: is a break statement required for the default case?

No, if the default case is at the end. However, we recommend that you put one anyways. This allows the default case to appear in a different order, and not necessarily at the end of the switch statement.



Switches (cont.)

```
string value; int number;
cin >> number;
switch (number) {
    case 0: // Fall-through to Case 2.
    case 2:
        value = "Good";
        break; // Remember to break!
    case 3:
        value = "Bad";
        break;
    default:
        value = "Ugly";
        break;
}
```

Common question 1: is a break statement required for the default case?

No if the default case is at the end. However, we recommend that you put one anyways. This allows the default case to appear in a different order, and not necessarily at the end of the switch statement.

Common question 2: do I need a default statement?



Switches (cont.)

```
string value; int number;
cin >> number;
switch (number) {
    case 0: // Fall-through to Case 2.
    case 2:
        value = "Good";
        break; // Remember to break!
    case 3:
        value = "Bad";
        break;
    default:
        value = "Ugly";
        break;
}
```

Common question 1: is a break statement required for the default case?

No if the default case is at the end. However, we recommend that you put one anyways. This allows the default case to appear in a different order, and not necessarily at the end of the switch statement.

Common question 2: do I need a default statement?

No, but it is good to have to catch unexpected cases. You should leave a //comment if you don't have a default to explain why!



While loops

- while loops run code until the condition is false

```
int count;  
cin >> count;  
while (count >= 0) {  
    cout << "Countdown: " << count << endl;  
    count--;  
}
```



While loops

```
int main() {  
    int x = 0;  
    while (x < 2) {  
        cout << x << endl;  
        x++;  
    }  
    cout << "Done!" << endl;  
}
```

0

x



While loops

```
int main() {  
    int x = 0;  
    while (x < 2) {  
        cout << x << endl;  
        x++;  
    }  
    cout << "Done!" << endl;  
}
```

> 0

0

x



While loops

```
int main() {  
    int x = 0;  
    while (x < 2) {  
        cout << x << endl;  
        x++;  
    }  
    cout << "Done!" << endl;  
}
```

> 0

1

x



While loops

```
int main() {  
    int x = 0;  
    while (x < 2) {  
        cout << x << endl;  
        x++;  
    }  
    cout << "Done!" << endl;  
}
```

> 0

1

x



While loops

```
int main() {  
    int x = 0;  
    while (x < 2) {  
        cout << x << endl;  
        x++;  
    }  
    cout << "Done!" << endl;  
}
```

> 0

> 1

1

x



While loops

```
int main() {  
    int x = 0;  
    while (x < 2) {  
        cout << x << endl;  
        x++;  
    }  
    cout << "Done!" << endl;  
}
```

> 0

> 1

2

x



While loops

```
int main() {  
    int x = 0;  
    while (x < 2) {  
        cout << x << endl;  
        x++;  
    }  
    cout << "Done!" << endl;  
}
```

> 0

> 1

2

x



While loops

```
int main() {  
    int x = 0;  
    while (x < 2) {  
        cout << x << endl;  
        x++;  
    }  
    cout << "Done!" << endl;  
}
```

> 0
> 1
> Done!

2

x



Do-while loops

- Same as while loops, except the first iteration always runs.

```
statement1;  
do {  
    statement2;  
} while (cond1); // Don't forget the semicolon!  
  
statement3;
```



For loops

- Declaration is run once before anything else
- Condition is evaluated before the code block is executed
- Action is run after the code block is executed

```
for (declaration; condition; action) {  
    statement1;  
    statement2;  
}
```

Note: all of the three sections of the for loop are optional; all that is required is the semicolon. If condition is empty, it defaults to always true. Example: `for(int i = 0;;i++) { //infinite loop }`



For loops

```
int main() {  
    for (int i = 0; i < 2; i++) {  
        cout << "i is now equal to: " << i <<  
            endl;  
    }  
  
    // Note that i is now out of scope.  
    cout << "Done!" << endl;  
}
```



For loops

```
int main() {  
    for (int i = 0; i < 2; i++) {  
        cout << "i is now equal to: " << i <<  
            endl;  
    }  
  
    // Note that i is now out of scope.  
    cout << "Done!" << endl;  
}
```

0

i



For loops

```
int main() {  
    for (int i = 0; i < 2; i++) {  
        cout << "i is now equal to: " << i <<  
            endl;  
    }  
  
    // Note that i is now out of scope.  
    cout << "Done!" << endl;  
}
```

> i is now equal to: 0

0

i



For loops

```
int main() {  
    for (int i = 0; i < 2; i++) {  
        cout << "i is now equal to: " << i <<  
            endl;  
    }  
  
    // Note that i is now out of scope.  
    cout << "Done!" << endl;  
}
```

> i is now equal to: 0

1

i



For loops

```
int main() {  
    for (int i = 0; i < 2; i++) {  
        cout << "i is now equal to: " << i <<  
            endl;  
    }  
  
    // Note that i is now out of scope.  
    cout << "Done!" << endl;  
}
```

> i is now equal to: 0

1

i



For loops

```
int main() {  
    for (int i = 0; i < 2; i++) {  
        cout << "i is now equal to: " << i <<  
            endl;  
    }  
  
    // Note that i is now out of scope.  
    cout << "Done!" << endl;  
}
```

> i is now equal to: 0

> i is now equal to: 1

1

i



For loops

```
int main() {  
    for (int i = 0; i < 2; i++) {  
        cout << "i is now equal to: " << i <<  
            endl;  
    }  
  
    // Note that i is now out of scope.  
    cout << "Done!" << endl;  
}
```

> i is now equal to: 0

> i is now equal to: 1

2

i



For loops

```
int main() {  
    for (int i = 0; i < 2; i++) {  
        cout << "i is now equal to: " << i <<  
            endl;  
    }  
  
    // Note that i is now out of scope.  
    cout << "Done!" << endl;  
}
```

> i is now equal to: 0

> i is now equal to: 1

2

i



For loops

```
int main() {  
    for (int i = 0; i < 2; i++) {  
        cout << "i is now equal to: " << i <<  
            endl;  
    }  
  
    // Note that i is now out of scope.  
    cout << "Done!" << endl;  
}
```

```
> i is now equal to: 0  
> i is now equal to: 1  
> Done!
```



Nested loops

```
for (int i = 1; i <= 10; i++) {  
    for (int j = 1; j <= 10; j++) {  
        cout << (i * j) << "\t";  
    }  
    cout << endl;  
}
```



Quick Question - Breaking the Outer Loop

- What happens when you break inside nested loops?



Quick Question - Breaking the Outer Loop

- What happens when you break inside nested loops?
 - Only the loop that contains the break statement is broken out of.



Quick Question - Breaking the Outer Loop

- What happens when you break inside nested loops?
 - Only the loop that contains the break statement is broken out of.
- Solution: use a boolean variable (a *flag*) in your loop's statements and change the boolean from true to false when you want to break out of a nested loop.

```
bool keepLoopingI = true;
for (int i = 1; i <= 100; i++) {
    for (int j = 1; j <= 200; j++) {
        if (i+j > 250) keepLoopingI = false;
        cout << i << ", " << j << endl;
    }
    if (!keepLoopingI) break;
}
```

What does this print?



Practice Question: Pile of Money

Print a pile of money n stacks high, leaning up on the right against your mansion's wall.

Example for $n=4$:

```
$|  
$$|  
$$$|  
$$$$|
```

(Contributed by Matthew Wong)



Solution: Pile of Money

```
int n = 5; // Or any positive integer value

// Loop through all n rows
for (int i = 1; i <= n; i++) {
    // print the spaces preceding the dollar signs
    for (int spaces = 0; spaces < n - i; spaces++)
        cout << " ";

    // print the i dollar signs for the row
    for (int money = 0; money < i; money++)
        cout << "$";

    // print the wall and move to the next line
    cout << "|" << endl;
}
```



Practice Question: String to Int

Convert a variable of type string into the integer represented by that string.

Example, convert:

```
string number = "125"      into
int numberAsInt // holding the value 125 as an integer
```

Hints:

```
// string name = "Daniel";
```

```
// name[0] is 'D'
```

```
// name.size() is 6
```

```
// '8' - '0' (the character eight minus the character zero) is 8 (the integer eight)
```

(Contributed by Katie Luangkote)



Solution: String to Int

```
string number = "125"; // or let the user cin their own string
int result = 0;
int multiplier = 1;
for (int i = number.size() - 1; i >= 0; i--) {
    result += (number[i] - '0') * multiplier;
    multiplier *= 10;
}
int numberAsInt = result;
```

// "125" becomes $5 + 2 \times 10 + 1 \times 100 = 125$

// Any other way to do this?



Practice Question: isPalindrome

Write a function `is_palindrome` that takes a string as an argument and returns true if the string is a **palindrome** and false if it is not. A palindrome is a string that is read backwards the same way as it is forwards. For example "racecar" backwards is "racecar".



Solution: isPalindrome

Start by checking that the first and the last letters in the string are equal, then move inward until we reach the middle of the string. Note: This only requires $n / 2$ iterations of the for-loop. Also, this code works even when n is **odd**. Trace through an example by hand to see why!

```
bool is_palindrome(string s) {
    int n = s.size();
    for (int i = 0; i < n / 2; i++) {
        int j = (n - 1) - i;
        if (s[i] != s[j]) return false;
    }
    return true;
}
```



Practice Question: Get “Switchy”

```
int main() {  
    string morty;  
    int rick = 5;  
    rick = (rick + 2 * 5) / 10;  
    switch (rick) {  
        case 1:  
            morty = “lubba”;  
            break;  
        case 3:  
            morty = “aw geez”;  
            break;  
        default:  
            morty = “oh man”;  
            break;  
    }  
    ...  
}
```

```
...  
morty += morty;  
morty[0] = ‘w’;  
  
for (int i = 0; i < 2; i++)  
    morty += “dub”;  
  
cout << morty << endl;  
}
```

What is the output of this code?



Solution: Get “Switchy”

```
int main() {  
    string morty;  
    int rick = 5;  
    rick = (rick + 2 * 5) / 10; rick = 1  
    switch (rick) {  
        case 1:  
            morty = “lubba”; morty = “lubba”  
            break;  
        case 3:  
            morty = “aw geez”;  
            break;  
        default:  
            morty = “oh man”;  
            break;  
    }  
    ...  
}
```

```
...  
morty += morty; morty = “lubbalubba”  
morty[0] = ‘w’; morty = “wubbalubba”  
  
for (int i = 0; i < 2; i++)  
    morty += “dub”; morty = “wubbalubbadubdub”  
  
cout << morty << endl;  
}
```

Output: wubbalubbadubdub

Translation: I am in great pain please help me



Scoping

- Variables only exist within the curly brackets or the implied curly brackets that they were written in.

```
if (cond1) {  
    statement1;  
}
```



Scoping (cont.)

```
if (cond1) {  
    int x = 5;  
    cout << x << endl; // No error  
}
```

```
cout << x << endl; // Error!! x doesn't exist  
                  // outside the if statement
```



Scoping (cont.)

```
int x = 1;
if (cond1) {
    x = 5;
    cout << x << endl; // No error
}

cout << x << endl; // No error here either!
```



Scoping (cont.)

```
string s1 = "bonjour";  
for (int i = 0; i < s1.size(); i++) {  
    char lastChar = s1[i];  
}
```

```
// Both i and lastChar don't exist here!  
cout << i << " " << lastChar << endl; // Error!
```



Scoping (cont.)

```
string s1 = "bonjour";  
int i; char lastChar;  
for (i = 0; i < s1.size(); i++) {  
    lastChar = s1[i];  
}
```

```
// Now both i and lastChar exist here  
cout << i << " " << lastChar << endl;
```



Scoping: Switch Statements

```
int main() {  
    int n;  
    cin >> n;  
    switch (n) {  
        case 1:  
            int x = 10;  
            cout << "You entered 1! 1 times 10 is " << x << endl;  
            break;  
        default:  
            int x = 5;  
            cout << "You didn't enter 1" << endl;  
    }  
}
```



Scoping: Switch Statements

Warning: the cases of a switch statement share the same scope!

```
int main() {  
    int n;  
    cin >> n;  
    switch (n) {  
        case 1:  
            int x = 10;  
            cout << "You entered 1! 1 times 10 is " << x << endl;  
            break;  
        default:  
            int x = 5; // This is an error! Compiler says "error: redefinition of 'x'"  
            cout << "You didn't enter 1" << endl;  
    }  
}
```



Scoping: Switch Statements

Warning: the cases of a switch statement share the same scope!

```
int main() {  
    int n;  
    cin >> n;  
    switch (n) {  
        case 1:  
            int x = 10;  
            cout << "You entered 1! 1 times 10 is " << x << endl;  
            break;  
        default:  
            // Does x exist here? It's within the switch's curly braces, but "int x = 10" was never executed?!  
            cout << "You didn't enter 1" << endl;  
    }  
}
```



Scoping: Switch Statements

Warning: the cases of a switch statement share the same scope!

```
int main() {  
    int n;  
    cin >> n;  
    switch (n) {  
        case 1:  
            int x = 10;  
            cout << "You entered 1! 1 times 10 is " << x << endl;  
            break;  
        default:  
            // So, this is also an error! Compiler says "note: jump bypasses variable initialization"  
            cout << "You didn't enter 1" << endl;  
    }  
}
```



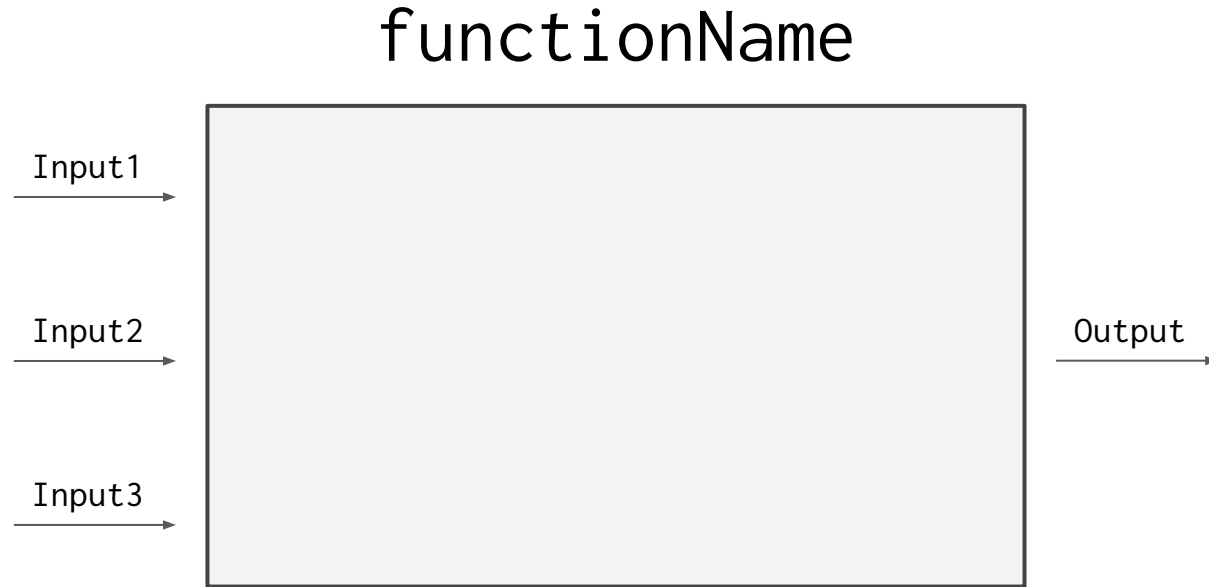
Scoping: Switch Statements

Warning: the cases of a switch statement share the same scope!

```
int main() {  
    int n;  
    cin >> n;  
    switch (n) {  
        case 1: {  
            int x = 10; // Now x is only known to the scope of this case  
            cout << "You entered 1! 1 times 10 is " << x << endl;  
            break;  
        }  
        default:  
            cout << "You didn't enter 1" << endl;  
    }  
}
```



Functions: The Box Model



Functions: Simple Example

```
#include <iostream>
using namespace std;

int hypotenuse(int side1, int side2) {
    /* Function body */
    /* We don't need to know how the function is implemented */
    ...
}

int main() {
    int x = hypotenuse(3,4);
}
```



Functions: Mathematical Example

- $f(x, y, z) = x - y - z$;
- $f(10, 5, 4) = 10 - 5 - 4 = 1$
- $f(3, 5, 4) = 3 - 5 - 4 = -6$

- Symbolically, x , y , and z are input1 , input2 , and input3



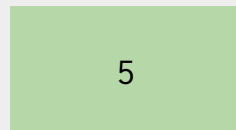
Math Example (cont.)

Suppose we define $f(x, y, z) = x - y - z$.

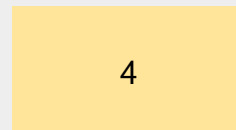
```
int main() {  
    int b = 5;  
    int a = 4;  
    int c = 6;  
    cout << f(c,b,a) << endl;  
}
```

Then for some variables a, b, c , we have $f(c, b, a) = c - b - a = 6 - 5 - 4 = -3$.

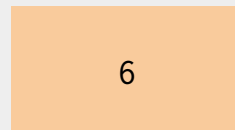
> -3



b



a



c



Mathematical Example (cont.)

```
#include <iostream>
using namespace std;
int functionName(int num1, int num2, int num3) {
    return num1 - num2 - num3;
}
```

- $f(x, y, z)$ becomes `functionName(num1, num2, num3)`
- `functionName(10, 5, 4) = 10 - 5 - 4 = 1;`
- `functionName(3, 5, 4) = 3 - 5 - 4 = -6;`



Functions: Scoping

- Variables declared outside the function do not exist inside the function unless they are global variables

```
const int foo = 6;
string functionName(int a, int b) {
    cout << x << endl; // x does not exist here, so this is an ERROR.
    int y = 5 + foo;    // This is okay because foo is global.
    return y + a + b;
}
```



Functions: Scoping (cont.)

Variables declared inside the function do not exist outside the function

```
int main() {  
    int x = 4;  
    cout << functionName(4,5) << endl;  
    cout << y << endl; // y does not exist here, so this is an error!  
}
```



Functions: Nested Loops Example

Problem: Find the first character in `string1` that exists in `string2`, or return the null byte if no such character is found.

Examples:

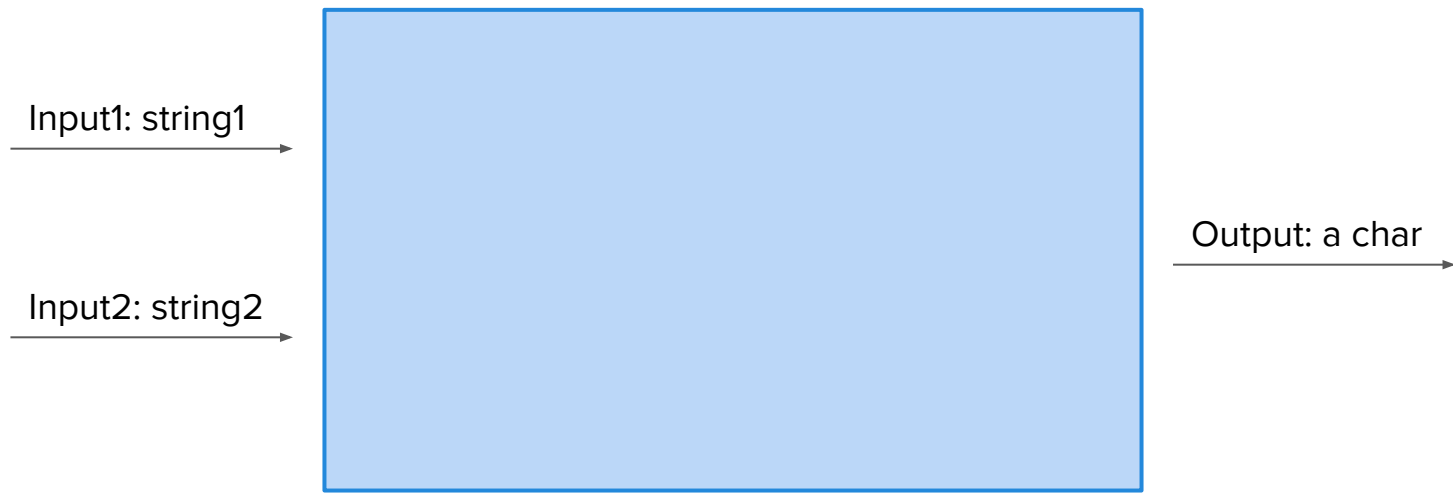
- `string1 = "hello", string2 = "there", result = 'h'`
- `string1 = "aabc", string2 = "xyzab", result = 'a'`
- `string1 = "aabc", string2 = "xyzzb", result = 'b'`
- `string1 = "abcd", string2 = "wxyz", result = '\0'`



Functions: The Box Model

```
char firstChar(string string1, string string2);
```

firstChar



Functions: Nested Loops Solution

```
char firstChar(string string1, string string2) {  
    for (int i = 0; i < string1.size(); i++)  
        for (int j = 0; j < string2.size(); j++)  
            if (string1[i] == string2[j])  
                return string1[i];  
    return '\0';  
}
```



Functions: Calling the firstChar Function

```
int main() {  
    cout << firstChar("hello", "there") << endl;  
    cout << firstChar("aabc", "xyzab") << endl;  
    cout << firstChar("aabc", "xyzzb") << endl;  
}
```



Walkthrough

```
char firstChar(string string1,  
               string string2) {  
    for (int i=0; i < string1.size(); i++)  
        for (int j=0; j < string2.size(); j++)  
            if (string1[i] == string2[j])  
                return string1[i];  
    return '\\0';  
}
```

```
int main() {  
    cout << firstChar("hello", "there");  
}
```



Walkthrough

```
char firstChar(string string1,
               string string2) {
    for (int i=0; i < string1.size(); i++)
        for (int j=0; j < string2.size(); j++)
            if (string1[i] == string2[j])
                return string1[i];
    return '\0';
}

int main() {
    cout << firstChar("hello", "there");
}
```



Walkthrough

```
char firstChar(string string1,  
               string string2) {  
    for (int i=0; i < string1.size(); i++)  
        for (int j=0; j < string2.size(); j++)  
            if (string1[i] == string2[j])  
                return string1[i];  
    return '\\0';  
}  
  
int main() {  
    cout << firstChar("hello", "there");  
}
```

"hello"

string1

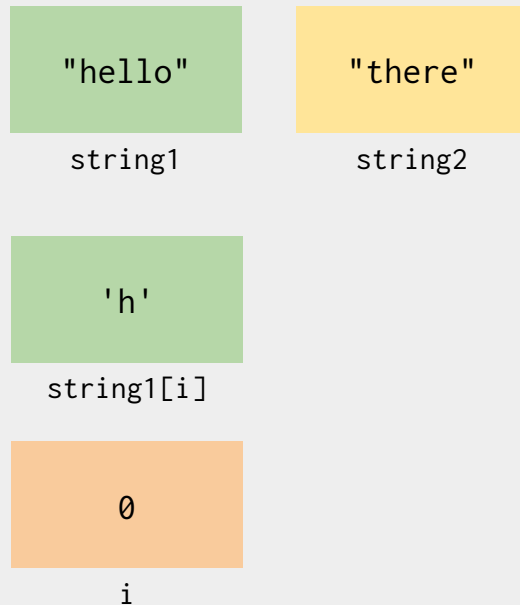
"there"

string2



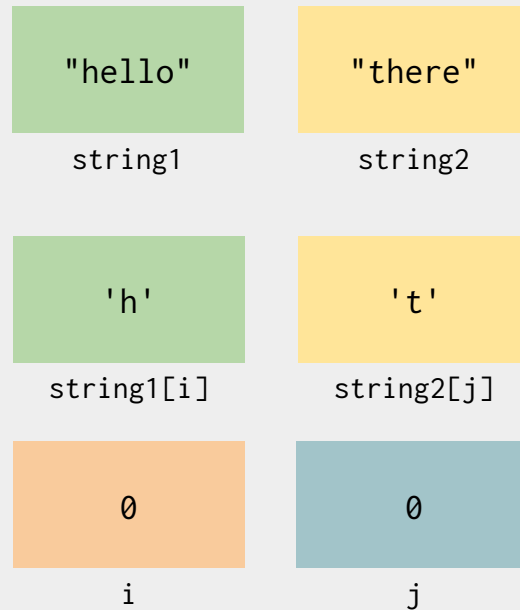
Walkthrough

```
char firstChar(string string1,  
               string string2) {  
    for (int i=0; i < string1.size(); i++)  
        for (int j=0; j < string2.size(); j++)  
            if (string1[i] == string2[j])  
                return string1[i];  
    return '\\0';  
}  
  
int main() {  
    cout << firstChar("hello", "there");  
}
```



Walkthrough

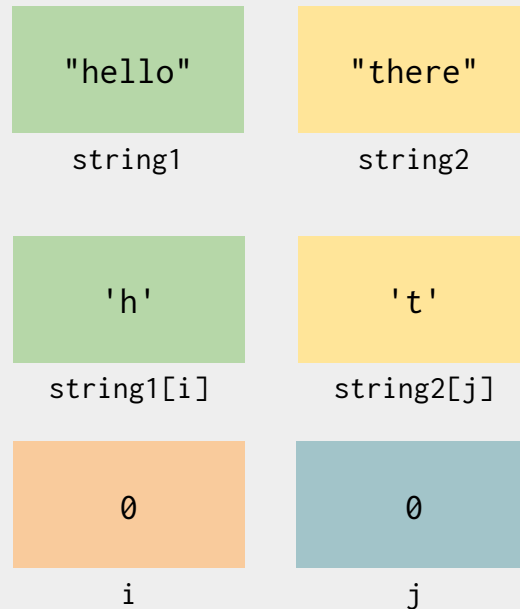
```
char firstChar(string string1,  
               string string2) {  
    for (int i=0; i < string1.size(); i++)  
        for (int j=0; j < string2.size(); j++)  
            if (string1[i] == string2[j])  
                return string1[i];  
    return '\\0';  
}  
  
int main() {  
    cout << firstChar("hello", "there");  
}
```



Walkthrough

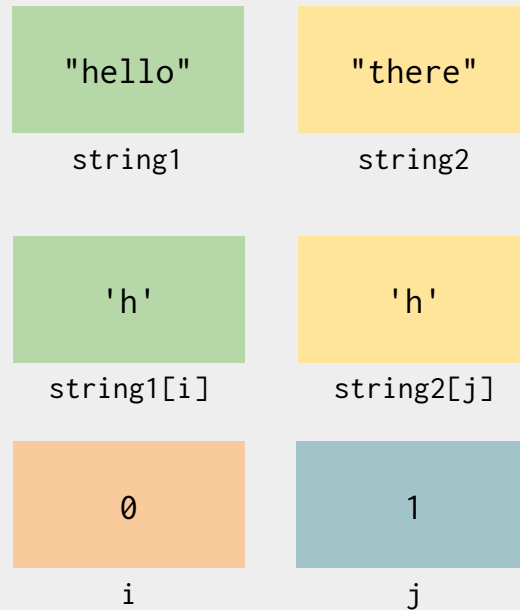
```
char firstChar(string string1,
                string string2) {
    for (int i=0; i < string1.size(); i++)
        for (int j=0; j < string2.size(); j++)
            if (string1[i] == string2[j])
                return string1[i];
    return '\0';
}

int main() {
    cout << firstChar("hello", "there");
}
```



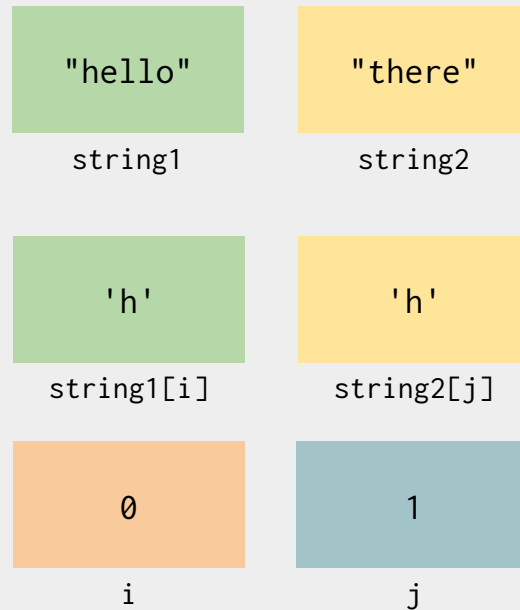
Walkthrough

```
char firstChar(string string1,  
               string string2) {  
    for (int i=0; i < string1.size(); i++)  
        for (int j=0; j < string2.size(); j++)  
            if (string1[i] == string2[j])  
                return string1[i];  
    return '\\0';  
}  
  
int main() {  
    cout << firstChar("hello", "there");  
}
```



Walkthrough

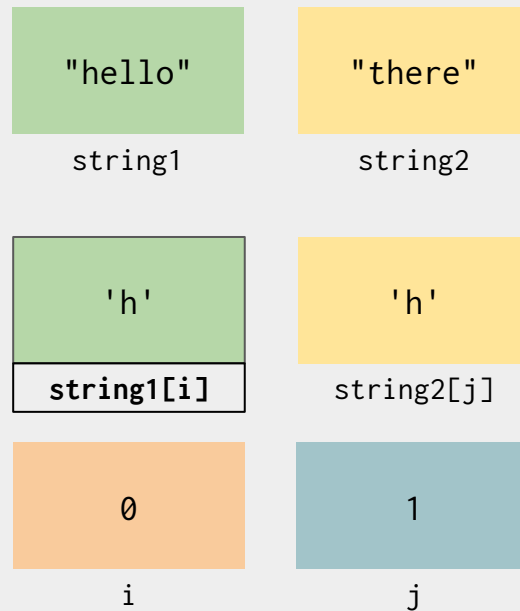
```
char firstChar(string string1,  
               string string2) {  
    for (int i=0; i < string1.size(); i++)  
        for (int j=0; j < string2.size(); j++)  
            if (string1[i] == string2[j])  
                return string1[i];  
    return '\\0';  
}  
  
int main() {  
    cout << firstChar("hello", "there");  
}
```



Walkthrough

```
char firstChar(string string1,
                string string2) {
    for (int i=0; i < string1.size(); i++)
        for (int j=0; j < string2.size(); j++)
            if (string1[i] == string2[j])
                return string1[i];
    return '\\0';
}

int main() {
    cout << firstChar("hello", "there");
}
```



Walkthrough

```
char firstChar(string string1,  
               string string2) {  
    for (int i=0; i < string1.size(); i++)  
        for (int j=0; j < string2.size(); j++)  
            if (string1[i] == string2[j])  
                return string1[i];  
    return '\\0';  
}
```

```
int main() {  
    cout << firstChar("hello", "there");  
}
```

> h



Walkthrough

```
char firstChar(string string1,  
               string string2) {  
    for (int i=0; i < string1.size(); i++)  
        for (int j=0; j < string2.size(); j++)  
            if (string1[i] == string2[j])  
                return string1[i];  
    return '\\0';  
}
```

```
int main() {  
    cout << firstChar("hello", "there");  
}
```

> h



Functions: Parameters

- The types, modifiers, order, and number of parameters are all important in a function declaration
 - types: `string`, `int`, `bool`, etc.
 - modifiers: `&`, `const`, `*`, etc.
 - number: how many parameters are passed to a particular function?
- Function call **must** match the pattern of the declaration



Will this compile?

```
// Assume this function is defined later.
bool isEqual(string s1, string s2, int position);

int main() {
    string s1 = "hello";
    string s2 = "there";
    int position = 1;
    string x = isEqual(s1,s2, position);
}
```



Will this compile?

```
// Assume this function is defined later.  
bool isEqual(string s1, string s2, int position);
```

```
int main() {  
    string s1 = "hello";  
    string s2 = "there";  
    int position = 1;  
    string x = isEqual(s1,s2, position);  
}
```

No. The return type is boolean.



Will this compile?

```
// Assume this function is defined later.  
bool isEqual(string s1, string s2, int position);
```

```
int main() {  
    string s1 = "hello";  
    string s2 = "there";  
    int position = 1;  
    bool x = isEqual(s1,s2);  
}
```



Will this compile?

```
// Assume this function is defined later.  
bool isEqual(string s1, string s2, int position);
```

```
int main() {  
    string s1 = "hello";  
    string s2 = "there";  
    int position = 1;  
    bool x = isEqual(s1,s2);  
}
```

No. The number of arguments doesn't match.



Will this compile?

```
// Assume this function is defined later.
bool isEqual(string s1, string s2, int position);

int main() {
    string s1 = "hello";
    string s2 = "there";
    int position = 1;
    bool x = isEqual(position, s1, s2);
}
```



Will this compile?

```
// Assume this function is defined later.  
bool isEqual(string s1, string s2, int position);
```

```
int main() {  
    string s1 = "hello";  
    string s2 = "there";  
    int position = 1;  
    bool x = isEqual(position, s1, s2);  
}
```

No. The order of arguments doesn't match.



Will this compile?

```
// Assume this function is defined later.  
bool isEqual(string s1, string s2, int position);
```

```
int main() {  
    string s1 = "hello";  
    string s2 = "there";  
    int position = 1;  
    bool x = isEqual(s1, s2, position);  
}
```



Will this compile?

```
// Assume this function is defined later.  
bool isEqual(string s1, string s2, int position);
```

```
int main() {  
    string s1 = "hello";  
    string s2 = "there";  
    int position = 1;  
    bool x = isEqual(s1, s2, position);  
}
```

Yes.



Will this compile?

```
// Assume this function is defined later.  
bool isEqual(const string& s1, const string& s2, int position);  
  
int main() {  
    string s1 = "hello";  
    string s2 = "there";  
    int position = 1;  
    bool x = isEqual(s1, s2, position);  
}
```



Will this compile?

```
// Assume this function is defined later.  
bool isEqual(const string& s1, const string& s2, int position);  
  
int main() {  
    string s1 = "hello";  
    string s2 = "there";  
    int position = 1;  
    bool x = isEqual(s1, s2, position);  
}
```

Yes. Notice the argument passing syntax is identical for pass by reference.



Functions: Pass by Value

- By default, all parameters in C++ are pass by value.
- Every pass by value parameter is **copied** into the function

```
bool containsLowerCase(string s);
```

```
int main() {  
    string s1 = "really long string";  
    containsLowerCase(s1);    // a copy of s1 is made and  
}  
                             // passed to containsLowerCase
```



Functions: Pass by Reference

- A **reference** to a variable is passed to the function instead of a copy of the variable
- Syntax: add an & between parameter type and name
 - `int& x`, `bool& b`, `string& s`
- If these variables are **changed inside** the function, then they will also be **changed outside**.



Functions: swap

- Does this function properly swap the two variables passed to it?

```
void swap(int x, int y) {  
    int temp = x;  
    x = y;  
    y = temp;  
}
```



Functions: swap

- Does this function properly swap the two variables passed to it?

```
void swap(int x, int y) {  
    int temp = x;  
    x = y;  
    y = temp;  
}
```

No, it only swaps local copies! We need to use pass by reference.



Functions: swap

```
void swap (int& x, int& y);
```

swap

Input1: integer x
→

Input2: integer y
→



→ Output: nothing???

Functions: swap #2

- Does this function properly swap the two variables passed to it?

```
void swap(int& x, int& y) {  
    int temp = x;  
    x = y;  
    y = temp;  
}
```



Functions: swap #2

- Does this function properly swap the two variables passed to it?

```
void swap(int& x, int& y) {  
    int temp = x;  
    x = y;  
    y = temp;  
}
```

Yes, because we are using the & modifier on the parameters to pass by reference.



Functions: Const Variables

- A parameter with the const modifier **cannot be modified** within the function. For example, we cannot change the value of num from within the body of the function isPrime.

```
bool isPrime(const int& num) {  
    // Cannot change value of num here.  
    ...  
}
```



Functions: Const Variables

- Why are they useful?
 - Gives assurance the the caller of a function that the argument they pass in won't be modified
 - Makes convoluted functions easier to understand if we know a certain variable can't be modified
- These are usually **passed by reference**. *(It's a little weird to use it with pass by value.)*



Functions: Passing by Constant Reference

- The purpose of passing by reference is to save memory or allow modifications by the function.
- What if we want to avoid copying but don't want to allow functions to modify the variables we pass in?



Functions: Passing by Constant Reference

- If we pass by **const reference** we can:
 - avoid the cost of copying
 - prevent our variables from being modified by the function
- Essentially a free performance gain
- You'll run into const reference often in CS32



Practice Question: Pass By Reference

Assume that `foo` and `foo2` are implemented identically as follows:

```
int foo(int x, int& y, int& z,  
        string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z <<  
        endl;
```

```
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;
```

```
    if (arr[x-1] == "Sup")  
        return 1;  
    else {  
        return 0;  
    }
```



Practice Question: Pass By Reference

What does this program print out?

```
int main() {  
    int x = 1, y = 2, z = 3;  
    string arr[] = {"Sup", "Hi", "Hey"};  
  
    // Print values before the call to foo  
    cout << x << " " << y << " " << z << endl;  
    // Print the return value of foo  
    cout << foo(x, y, z, arr) << endl;  
    // Print values after the call to foo  
    cout << x << " " << y << " " << z << endl;  
}
```



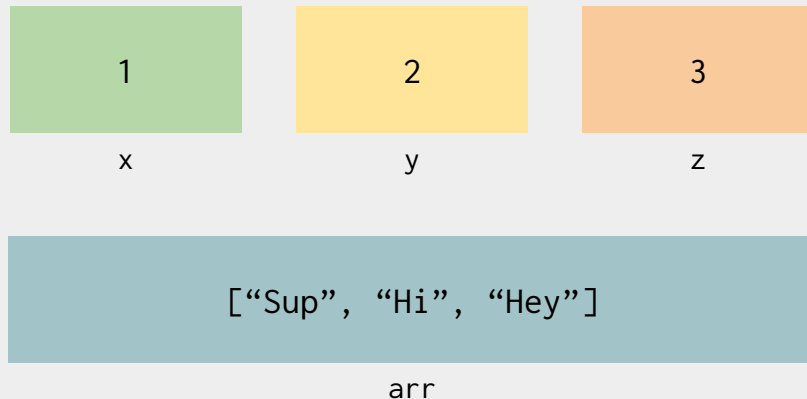
Walkthrough

```
int main() {  
    int x = 1, y = 2, z = 3;  
    string arr[] = {"Sup", "Hi", "Hey"};  
  
    // Print values before the call to foo  
    cout << x << " " << y << " " << z << endl;  
    // Print the return value of foo  
    cout << foo(x, y, z, arr) << endl;  
    // Print values after the call to foo  
    cout << x << " " << y << " " << z <<  
        endl;  
}
```



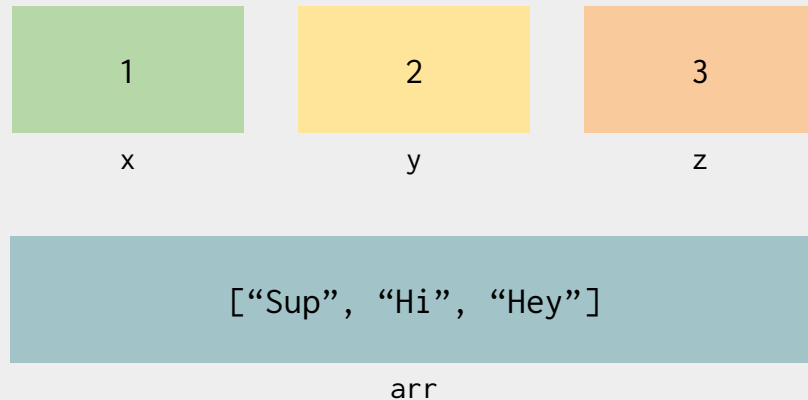
Walkthrough

```
int main() {  
    int x = 1, y = 2, z = 3;  
    string arr[] = {"Sup", "Hi", "Hey"};  
  
    // Print values before the call to foo  
    cout << x << " " << y << " " << z << endl;  
    // Print the return value of foo  
    cout << foo(x, y, z, arr) << endl;  
    // Print values after the call to foo  
    cout << x << " " << y << " " << z <<  
        endl;  
}
```



Walkthrough

```
int main() {  
    int x = 1, y = 2, z = 3;  
    string arr[] = {"Sup", "Hi", "Hey"};  
  
    // Print values before the call to foo  
    cout << x << " " << y << " " << z << endl;  
    // Print the return value of foo  
    cout << foo(x, y, z, arr) << endl;  
    // Print values after the call to foo  
    cout << x << " " << y << " " << z <<  
        endl;  
}
```

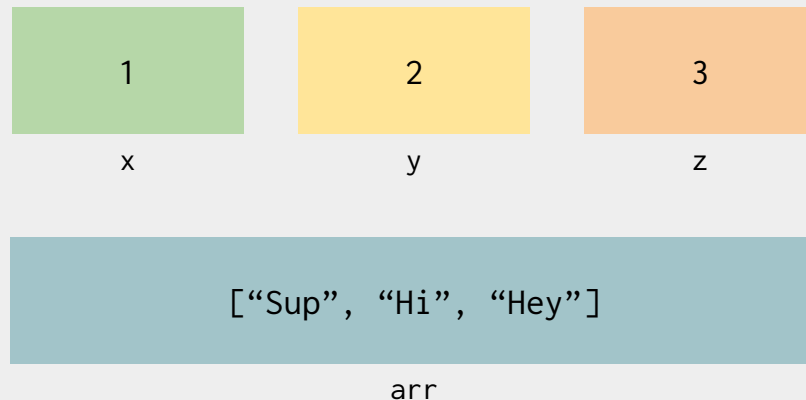


> 1 2 3



Walkthrough

```
int main() {  
    int x = 1, y = 2, z = 3;  
    string arr[] = {"Sup", "Hi", "Hey"};  
  
    // Print values before the call to foo  
    cout << x << " " << y << " " << z << endl;  
    // Print the return value of foo  
    cout << foo(x, y, z, arr) << endl;  
    // Print values after the call to foo  
    cout << x << " " << y << " " << z <<  
        endl;  
}
```

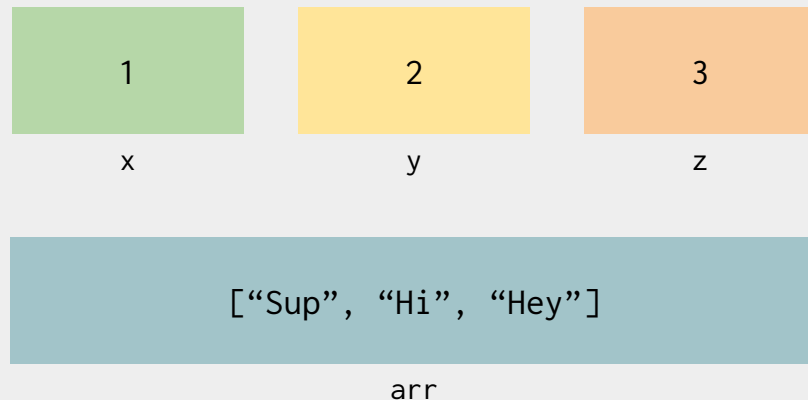


> 1 2 3



Walkthrough

```
int foo(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;  
  
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;  
  
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```

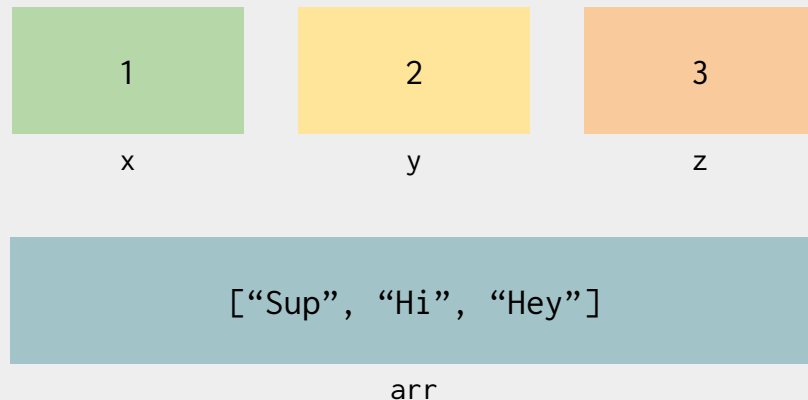


> 1 2 3



Walkthrough

```
int foo(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;  
  
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;  
  
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```

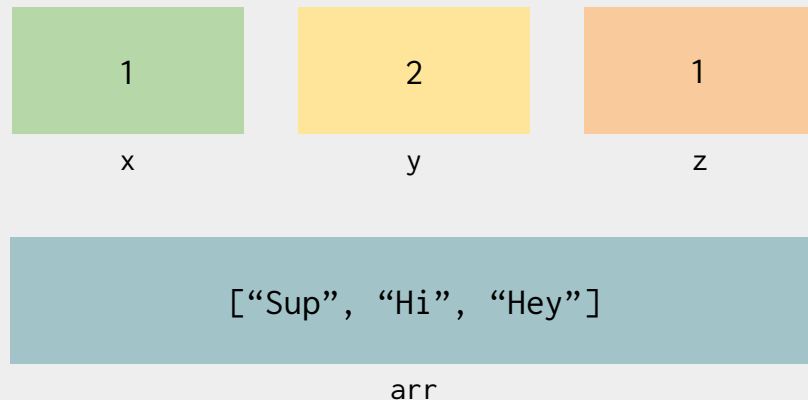


> 1 2 3



Walkthrough

```
int foo(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;  
  
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;  
  
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```

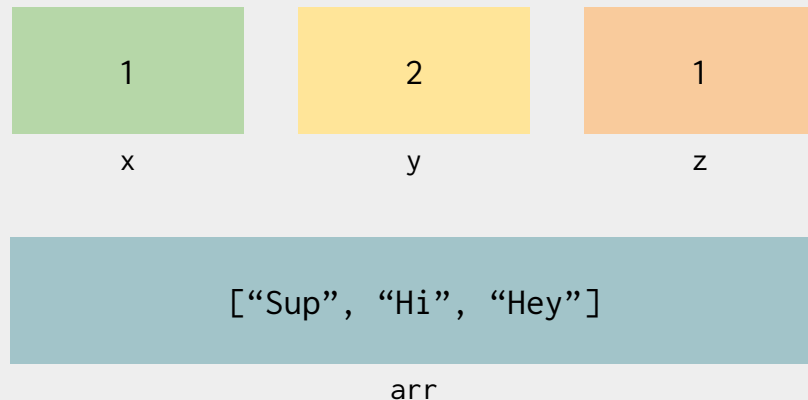


> 1 2 3



Walkthrough

```
int foo(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;  
  
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;  
  
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```



```
> 1 2 3  
> 1 2 1
```

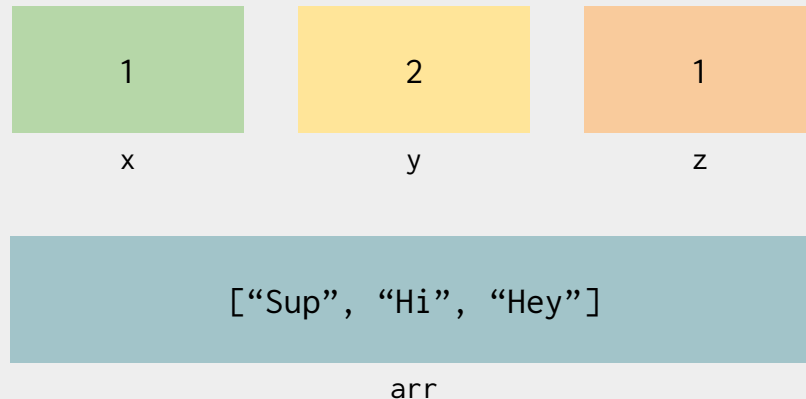


Walkthrough

```
int foo(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;
```

```
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;
```

```
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```

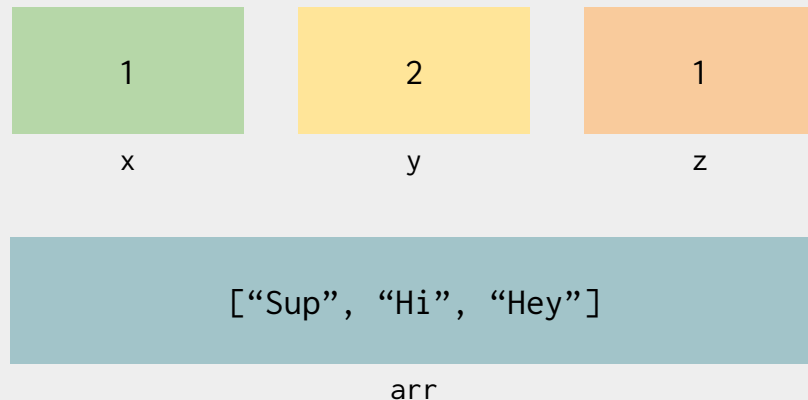


```
> 1 2 3  
> 1 2 1
```



Walkthrough

```
int foo(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;  
  
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;  
  
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```

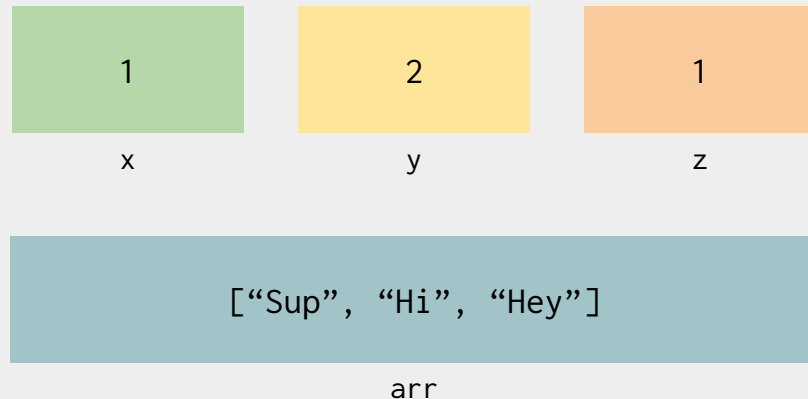


```
> 1 2 3  
> 1 2 1
```



Walkthrough

```
int foo2(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;  
  
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;  
  
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```

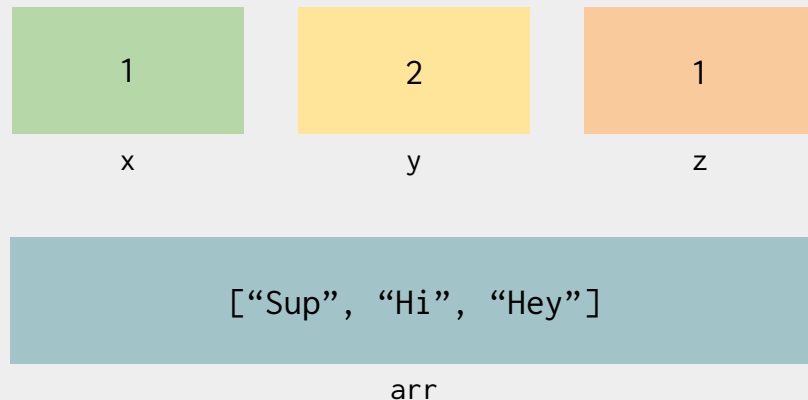


```
> 1 2 3  
> 1 2 1
```



Walkthrough

```
int foo2(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;  
  
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;  
  
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```

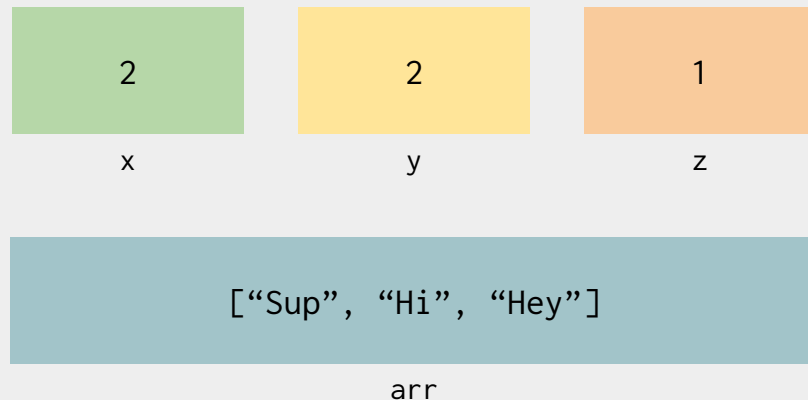


```
> 1 2 3  
> 1 2 1
```



Walkthrough

```
int foo2(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;  
  
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;  
  
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```

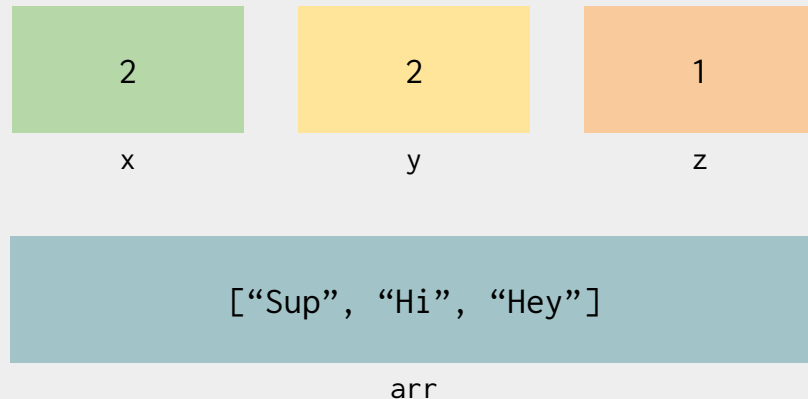


```
> 1 2 3  
> 1 2 1
```



Walkthrough

```
int foo2(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;  
  
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;  
  
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```

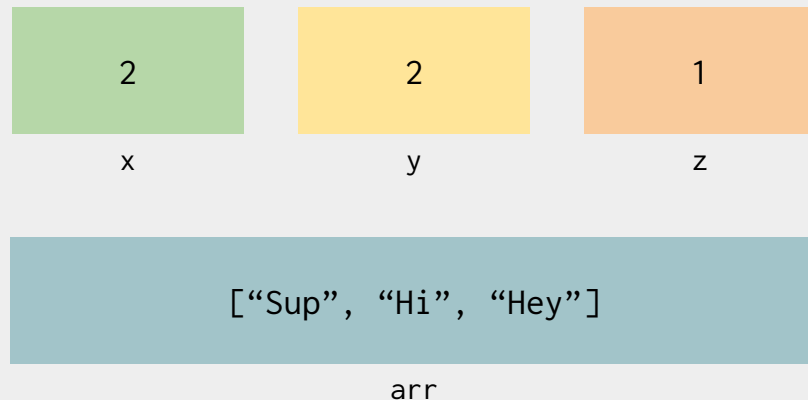


```
> 1 2 3  
> 1 2 1  
> 2 2 1
```



Walkthrough

```
int foo2(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;  
  
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;  
  
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```

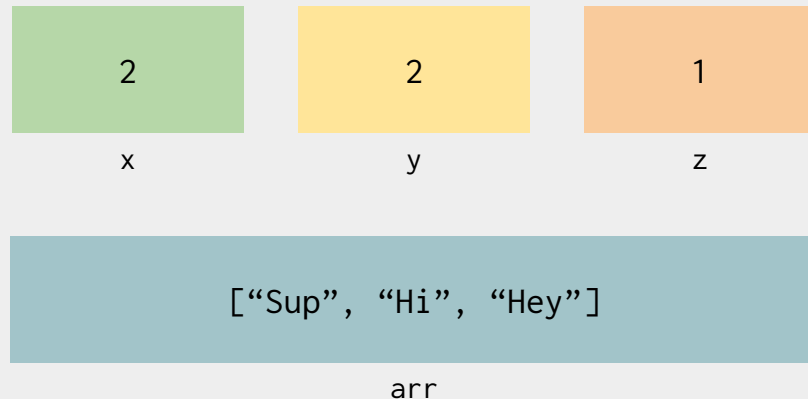


```
> 1 2 3  
> 1 2 1  
> 2 2 1
```



Walkthrough

```
int foo2(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;  
  
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;  
  
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```

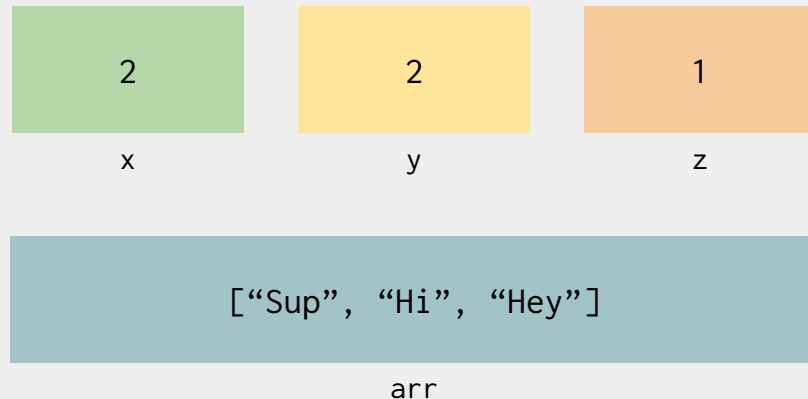


```
> 1 2 3  
> 1 2 1  
> 2 2 1
```



Walkthrough

```
int foo2(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;  
  
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;  
  
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```

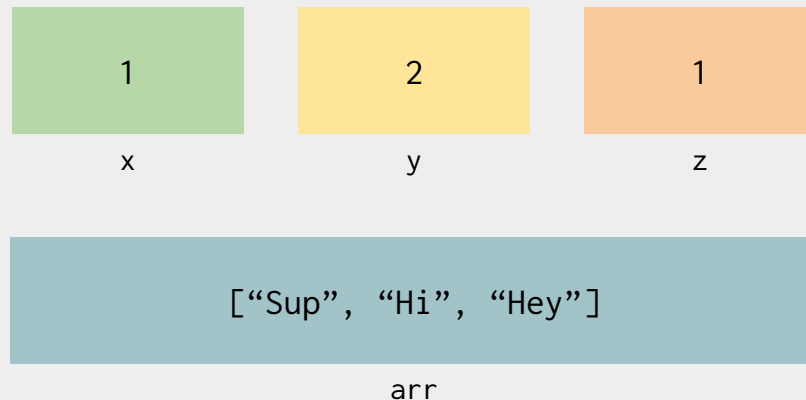


```
> 1 2 3  
> 1 2 1  
> 2 2 1
```



Walkthrough

```
int foo(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;  
  
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;  
  
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```

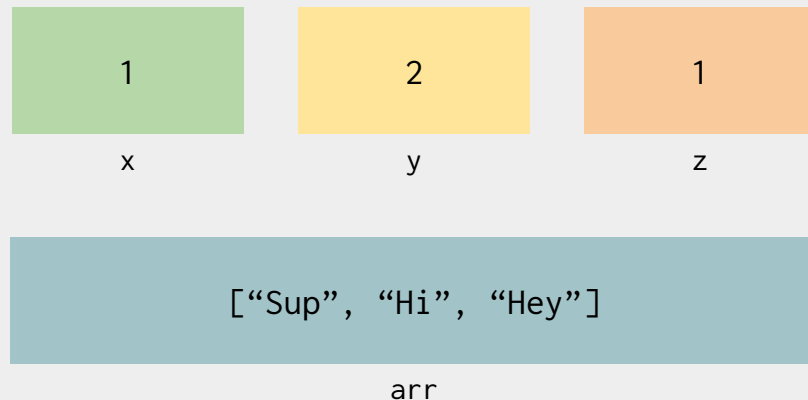


```
> 1 2 3           > 0  
> 1 2 1  
> 2 2 1
```



Walkthrough

```
int foo(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;  
  
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;  
  
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```

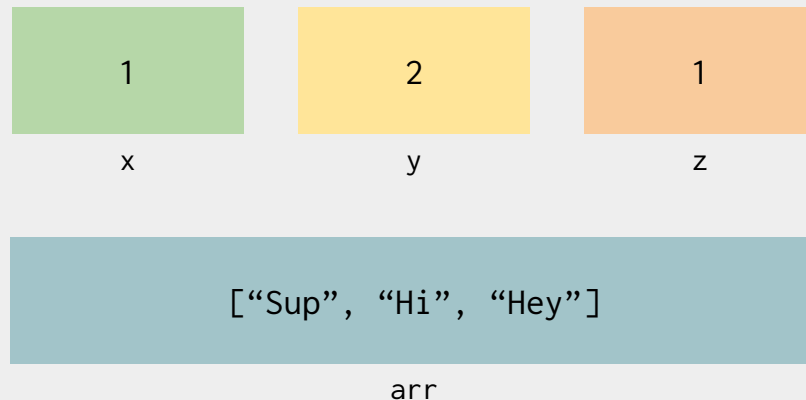


```
> 1 2 3          > 0  
> 1 2 1  
> 2 2 1
```



Walkthrough

```
int foo(int x, int& y, int& z, string arr[]) {  
    if (x == z)  
        x = y;  
    else  
        z = x;  
    cout << x << " " << y << " " << z << endl;  
  
    if (x != y)  
        cout << foo2(x, y, z, arr) << endl;  
  
    if (arr[x-1] == "Sup")  
        return 1;  
    else  
        return 0;  
}
```

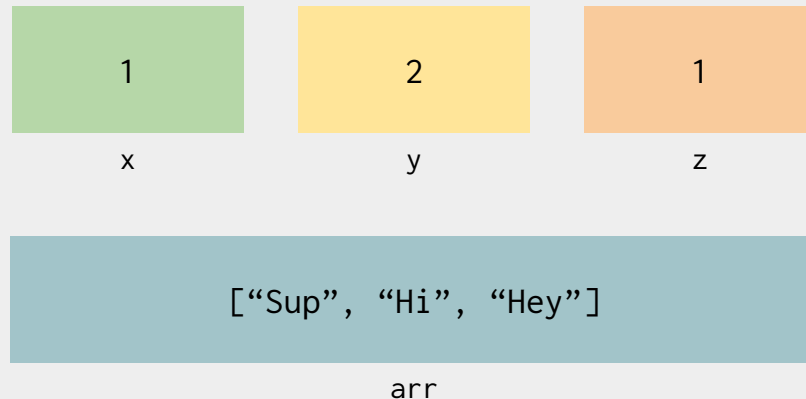


```
> 1 2 3          > 0  
> 1 2 1  
> 2 2 1
```



Walkthrough

```
int main() {  
    int x = 1, y = 2, z = 3;  
    string arr[] = {"Sup", "Hi", "Hey"};  
  
    // Print values before the call to foo  
    cout << x << " " << y << " " << z << endl;  
    // Print the return value of foo  
    cout << foo(x, y, z, arr) << endl;  
    // Print values after the call to foo  
    cout << x << " " << y << " " << z <<  
        endl;  
}
```

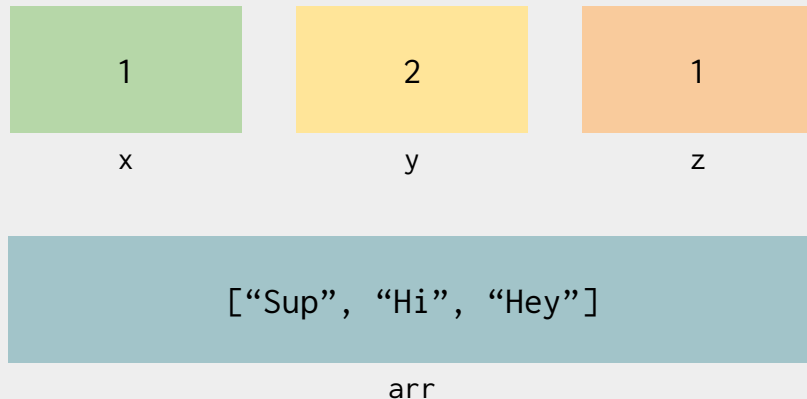


```
> 1 2 3          > 0  
> 1 2 1          > 1  
> 2 2 1
```



Walkthrough

```
int main() {  
    int x = 1, y = 2, z = 3;  
    string arr[] = {"Sup", "Hi", "Hey"};  
  
    // Print values before the call to foo  
    cout << x << " " << y << " " << z << endl;  
    // Print the return value of foo  
    cout << foo(x, y, z, arr) << endl;  
    // Print values after the call to foo  
    cout << x << " " << y << " " << z <<  
        endl;  
}
```



> 1 2 3	> 0
> 1 2 1	> 1
> 2 2 1	> 1 2 1



Arrays

- Valid declarations:

```
int arr[10];
```

```
bool list[5];
```

```
const int MAX_SIZE = 10;  
string words[MAX_SIZE];
```

```
int arr[] = {1, 2, 3};
```



Arrays (cont.)

- Rules for specifying size:
 - **Must** be included in the brackets
 - **Cannot** involve a variable unless it is a constant known at compile time
 - The only time size can be left out is when a list of its contents is included
- Not allowed in C++:
 - `int arr[]; // Size not included.`
 - `/****** Use of non-const variable. *****/`
`int x;`
`cin >> x;`
`char buffer[x];`



Passing Arrays to Functions

- Parameter Syntax
 - `(..., type name[], ...)`
- Arrays are default passed by reference
 - Any changes made to the array will be retained outside of the function scope



Passing Arrays to Functions (cont.)

- Size of array should be passed to the function
- Call to the function just passes in array name

```
// arr is the array itself, n is the size.  
int firstOdd(int arr[], int n) {  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1)  
            return i;  
    }  
    return n; // If no odd number found.  
}
```



What does this print?

```
// arr is the array itself, n is the size.
int changeOdd(int arr[], int n) {
    int count = 0;
    for (int i = 0; i < n; i++) {
        if (arr[i] % 2 == 1) {
            arr[i]--;
            count++;
        }
    }
    n++;
    return count;
}

int main() {
    int n = 5;
    int arr[5] = {2, 6, 3, 5, 10};
    cout << changeOdd(arr, n) << endl;
}
```



What does this print?

```
// arr is the array itself, n is the size.
int changeOdd(int arr[], int n) {
    int count = 0;
    for (int i = 0; i < n; i++) {
        if (arr[i] % 2 == 1) {
            arr[i]--;
            count++;
        }
    }
    n++;
    return count;
}

int main() {
    int n = 5;
    int arr[5] = {2, 6, 3, 5, 10};
    cout << changeOdd(arr, n) << endl;
}
```

5

n



What does this print?

// **arr** is the array itself, **n** is the size.

```
int changeOdd(int arr[], int n) {
    int count = 0;
    for (int i = 0; i < n; i++) {
        if (arr[i] % 2 == 1) {
            arr[i]--;
            count++;
        }
    }
    n++;
    return count;
}

int main() {
    int n = 5;
    int arr[5] = {2, 6, 3, 5, 10};
    cout << changeOdd(arr, n) << endl;
}
```

5

n

[2, 6, 3, 5, 10]

arr



What does this print?

// **arr** is the array itself, **n** is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1) {  
            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

n

[2, 6, 3, 5, 10]

arr

5

n

0

count



What does this print?

// **arr** is the array itself, **n** is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1) {  
            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

n

[2, 6, 3, 5, 10]

arr

5

n

0

count

0

i



What does this print?

// `arr` is the array itself, `n` is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1) {  
            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 3, 5, 10]

`arr`

5

`n`

0

`count`

0

`i`



What does this print?

// `arr` is the array itself, `n` is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1) {  
            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 3, 5, 10]

`arr`

5

`n`

0

`count`

1

`i`



What does this print?

// **arr** is the array itself, **n** is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1) {  
            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

n

[2, 6, 3, 5, 10]

arr

5

n

0

count

1

i



What does this print?

// `arr` is the array itself, `n` is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1) {  
            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 3, 5, 10]

`arr`

5

`n`

0

`count`

1

`i`



What does this print?

// `arr` is the array itself, `n` is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1) {  
            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 3, 5, 10]

`arr`

5

`n`

0

`count`

2

`i`



What does this print?

// **arr** is the array itself, **n** is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1) {  
            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

n

[2, 6, 3, 5, 10]

arr

5

n

0

count

2

i



What does this print?

// `arr` is the array itself, `n` is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
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            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 3, 5, 10]

`arr`

5

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0

`count`

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What does this print?

// `arr` is the array itself, `n` is the size.

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            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
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}  
  
int main() {  
    int n = 5;  
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    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 2, 5, 10]

`arr`

5

`n`

0

`count`

2

`i`



What does this print?

// `arr` is the array itself, `n` is the size.

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int changeOdd(int arr[], int n) {
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            arr[i]--;
            count++;
        }
    }
    n++;
    return count;
}

int main() {
    int n = 5;
    int arr[5] = {2, 6, 3, 5, 10};
    cout << changeOdd(arr, n) << endl;
}
```

5

`n`

[2, 6, 2, 5, 10]

`arr`

5

`n`

1

`count`

2

`i`



What does this print?

// `arr` is the array itself, `n` is the size.

```
int changeOdd(int arr[], int n) {  
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}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 2, 5, 10]

`arr`

5

`n`

1

`count`

3

`i`



What does this print?

// `arr` is the array itself, `n` is the size.

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int changeOdd(int arr[], int n) {  
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int main() {  
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    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 2, 5, 10]

`arr`

5

`n`

1

`count`

3

`i`



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```

5

`n`

[2, 6, 2, 5, 10]

`arr`

5

`n`

1

`count`

3

`i`



What does this print?

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int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 2, 4, 10]

`arr`

5

`n`

1

`count`

3

`i`



What does this print?

// `arr` is the array itself, `n` is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
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            arr[i]--;  
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    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 2, 4, 10]

`arr`

5

`n`

2

`count`

3

`i`



What does this print?

// `arr` is the array itself, `n` is the size.

```
int changeOdd(int arr[], int n) {  
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int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 2, 4, 10]

`arr`

5

`n`

2

`count`

4

`i`



What does this print?

// **arr** is the array itself, **n** is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1) {  
            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

n

[2, 6, 2, 4, 10]

arr

5

n

2

count

4

i



What does this print?

// `arr` is the array itself, `n` is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
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            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 2, 4, 10]

`arr`

5

`n`

2

`count`

4

`i`



What does this print?

// `arr` is the array itself, `n` is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1) {  
            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 2, 4, 10]

`arr`

5

`n`

2

`count`

5

`i`



What does this print?

// **arr** is the array itself, **n** is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1) {  
            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

n

[2, 6, 2, 4, 10]

arr

5

n

2

count

5

i



What does this print?

// `arr` is the array itself, `n` is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1) {  
            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 2, 4, 10]

`arr`

6

`n`

2

`count`

5

`i`



What does this print?

// `arr` is the array itself, `n` is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1) {  
            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 2, 4, 10]

`arr`

6

`n`

2

`count`

5

`i`



What does this print?

// `arr` is the array itself, `n` is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1) {  
            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 2, 4, 10]

`arr`



What does this print?

// `arr` is the array itself, `n` is the size.

```
int changeOdd(int arr[], int n) {  
    int count = 0;  
    for (int i = 0; i < n; i++) {  
        if (arr[i] % 2 == 1) {  
            arr[i]--;  
            count++;  
        }  
    }  
    n++;  
    return count;  
}  
  
int main() {  
    int n = 5;  
    int arr[5] = {2, 6, 3, 5, 10};  
    cout << changeOdd(arr, n) << endl;  
}
```

5

`n`

[2, 6, 2, 4, 10]

`arr`

> 2



Printing Arrays

- To print an array, we need to use a loop to print each element.
- Printing the name will just print the starting address of the array

```
string arr[] = {"Smallberg", "CS31", "Midterm"};
for (int i = 0; i < 3; ++i) {
    cout << arr[i];
}
```



Out of Bounds Errors

- Occur anytime you can access memory past the end (or beginning) of an array
 - Only certain spaces in memory have useful data
 - Anything outside is essentially garbage
 - Hard to debug. C++ doesn't do bounds checking on array access so out of bounds accesses can often go unnoticed.

```
string array[3] = {"CS31", "Smallberg", "Midterm"};  
cout << array[3] << endl; // Out of bounds error!
```



Out of Bounds Example

Do we have an out of bounds memory access here?

```
// Assume arr only contains n elements.
int countFives(int arr[], int n) {
    int count = 0;
    for (int i = 0; i <= n; ++i) {
        if (arr[i] == 5) {
            count++;
        }
    }
    return count;
}
```



Out of Bounds Example

Do we have an out of bounds memory access here?

```
// Assume arr only contains n elements
int countFives(int arr[], int n) {
    int count = 0;
    for (int i = 0; i <= n; ++i) {
        if (arr[i] == 5) {
            count++;
        }
    }
    return count;
}
```

Yes! The for loop will access the element at the **nth** index.



Practice Question: Index of First Repeated

Given an array of integers and the size of the array, write a function `firstRepeat` that returns the index of the first repeated element. You may assume that there will be at least one duplicate element in the array.

Input: `int arr[] = {1, 2, 3, 2, 4}; int size = 5;`

Output: 3

Input: `int arr[] = {1, 2, 3, 7, 0, 2, 7, 3, 1}; int size = 9;`

Output: 5

(Contributed by Carter Wu)



Solution: Index of First Repeated

We use two for loops to check every character. Once we find a repeated character, we update the index only if it is less than minIndex, which is initiated to the value $n - 1$ which is the largest possible value.

```
int firstRepeat(int arr[], int n) {  
    int minIndex = n - 1;  
    for (int i = 0; i < n; i++)  
        for (int j = i + 1; j < n; j++)  
            if (arr[i] == arr[j] && j < minIndex)  
                minIndex = j;  
    return minIndex;  
}
```



Practice Question: What Makes CS Beautiful

```
int main() {
    string oneD[] = {"Zayn", "Louis", "Harry", "Niall", "Liam"};
    int size = 5;

    for (int i = 0; i < size; i++) {
        int min = i;
        for (int j = i + 1; j < size; j++)
            if (oneD[j] < oneD[min])
                min = j;
        string temp = oneD[i];
        oneD[i] = oneD[min];
        oneD[min] = temp;
    }
    oneD[4] = "RIP" + oneD[4];
}
```

What does the string array contain after this code is executed?



Walkthrough

```
string oneD[] = {....};
```

```
int size = 5;
```

```
for (int i = 0; i < size; i++) {  
    int min = i;  
    for (int j = i + 1; j < size; j++)  
        if (oneD[j] < oneD[min])  
            min = j;  
    string temp = oneD[i];  
    oneD[i] = oneD[min];  
    oneD[min] = temp;  
}  
oneD[4] = "RIP" + oneD[4];
```

["Zayn", "Louis", "Harry", "Niall", "Liam"]

oneD

5

size

0

i



Walkthrough

```
string oneD[] = {....};  
int size = 5;  
  
for (int i = 0; i < size; i++) {  
    int min = i;  
    for (int j = i + 1; j < size; j++)  
        if (oneD[j] < oneD[min])  
            min = j;  
    string temp = oneD[i];  
    oneD[i] = oneD[min];  
    oneD[min] = temp;  
}  
oneD[4] = "RIP" + oneD[4];
```

["Zayn", "Louis", "Harry", "Niall", "Liam"]

oneD

5

size

0

i

0

min



Walkthrough

```
string oneD[] = {....};  
int size = 5;  
  
for (int i = 0; i < size; i++) {  
    int min = i;  
    for (int j = i + 1; j < size; j++)  
        if (oneD[j] < oneD[min])  
            min = j;  
    string temp = oneD[i];  
    oneD[i] = oneD[min];  
    oneD[min] = temp;  
}  
oneD[4] = "RIP" + oneD[4];
```

["Zayn", "Louis", "Harry", "Niall", "Liam"]

oneD

5

size

0

i

1

j

0

min



Walkthrough

```
string oneD[] = {....};  
int size = 5;  
  
for (int i = 0; i < size; i++) {  
    int min = i;  
    for (int j = i + 1; j < size; j++)  
        if (oneD[j] < oneD[min])  
            min = j;  
    string temp = oneD[i];  
    oneD[i] = oneD[min];  
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oneD[4] = "RIP" + oneD[4];
```

["Zayn", "Louis", "Harry", "Niall", "Liam"]

oneD

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Walkthrough

```
string oneD[] = {....};
int size = 5;

for (int i = 0; i < size; i++) {
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        if (oneD[j] < oneD[min])
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    oneD[i] = oneD[min];
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}
oneD[4] = "RIP" + oneD[4];
```

["Zayn", "Louis", "Harry", "Niall", "Liam"]

oneD

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Walkthrough

```
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for (int i = 0; i < size; i++) {  
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    string temp = oneD[i];  
    oneD[i] = oneD[min];  
    oneD[min] = temp;  
}  
oneD[4] = "RIP" + oneD[4];
```

["Zayn", "Louis", "Harry", "Niall", "Liam"]

oneD

5

size

0

i

2

j

1

min



Walkthrough

```
string oneD[] = {....};  
int size = 5;  
  
for (int i = 0; i < size; i++) {  
    int min = i;  
    for (int j = i + 1; j < size; j++)  
        if (oneD[j] < oneD[min])  
            min = j;  
    string temp = oneD[i];  
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```

["Zayn", "Louis", "Harry", "Niall", "Liam"]

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Walkthrough

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string oneD[] = {....};  
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["Zayn", "Louis", "Harry", "Niall", "Liam"]

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Walkthrough

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    string temp = oneD[i];  
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["Zayn", "Louis", "Harry", "Niall", "Liam"]

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["Zayn", "Louis", "Harry", "Niall", "Liam"]

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Walkthrough

```
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    int min = i;  
    for (int j = i + 1; j < size; j++)  
        if (oneD[j] < oneD[min])  
            min = j;  
    string temp = oneD[i];  
    oneD[i] = oneD[min];  
    oneD[min] = temp;  
}  
oneD[4] = "RIP" + oneD[4];
```

["Zayn", "Louis", "Harry", "Niall", "Liam"]

oneD

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Walkthrough

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oneD[4] = "RIP" + oneD[4];
```

["Zayn", "Louis", "Harry", "Niall", "Liam"]

oneD

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size

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Walkthrough

```
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    for (int j = i + 1; j < size; j++)
        if (oneD[j] < oneD[min])
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}

oneD[4] = "RIP" + oneD[4];
```

["Zayn", "Louis", "Harry", "Niall", "Liam"]

oneD

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size

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5

j

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min



Walkthrough

```
string oneD[] = {....};
int size = 5;

for (int i = 0; i < size; i++) {
    int min = i;
    for (int j = i + 1; j < size; j++)
        if (oneD[j] < oneD[min])
            min = j;
    string temp = oneD[i];
    oneD[i] = oneD[min];
    oneD[min] = temp;
}

oneD[4] = "RIP" + oneD[4];
```

["Zayn", "Louis", "Harry", "Niall", "Liam"]

oneD

5

size

0

i

2

min

"Zayn"

temp



Walkthrough

```
string oneD[] = {....};
int size = 5;

for (int i = 0; i < size; i++) {
    int min = i;
    for (int j = i + 1; j < size; j++)
        if (oneD[j] < oneD[min])
            min = j;
    string temp = oneD[i];
    oneD[i] = oneD[min];
    oneD[min] = temp;
}

oneD[4] = "RIP" + oneD[4];
```

["Harry", "Louis", "Harry", "Niall", "Liam"]

oneD

5

size

0

i

2

min

"Zayn"

temp



Walkthrough

```
string oneD[] = {....};  
int size = 5;  
  
for (int i = 0; i < size; i++) {  
    int min = i;  
    for (int j = i + 1; j < size; j++)  
        if (oneD[j] < oneD[min])  
            min = j;  
    string temp = oneD[i];  
    oneD[i] = oneD[min];  
    oneD[min] = temp;  
}  
oneD[4] = "RIP" + oneD[4];
```

["Harry", "Louis", "Zayn", "Niall", "Liam"]

oneD

5

size

0

i

2

min

"Zayn"

temp



Walkthrough

```
string oneD[] = {....};
```

```
int size = 5;
```

```
for (int i = 0; i < size; i++) {  
    int min = i;  
    for (int j = i + 1; j < size; j++)  
        if (oneD[j] < oneD[min])  
            min = j;  
    string temp = oneD[i];  
    oneD[i] = oneD[min];  
    oneD[min] = temp;  
}  
oneD[4] = "RIP" + oneD[4];
```

["Harry", "Louis", "Zayn", "Niall", "Liam"]

oneD

5

size

1

i



Walkthrough

```
string oneD[] = {....};  
int size = 5;  
  
for (int i = 0; i < size; i++) {  
    int min = i;  
    for (int j = i + 1; j < size; j++)  
        if (oneD[j] < oneD[min])  
            min = j;  
    string temp = oneD[i];  
    oneD[i] = oneD[min];  
    oneD[min] = temp;  
}  
oneD[4] = "RIP" + oneD[4];
```

["Harry", "Louis", "Zayn", "Niall", "Liam"]

oneD

5

size

1

i

1

min



Walkthrough

```
string oneD[] = {....};
int size = 5;

for (int i = 0; i < size; i++) {
    int min = i;
    for (int j = i + 1; j < size; j++)
        if (oneD[j] < oneD[min])
            min = j;
    string temp = oneD[i];
    oneD[i] = oneD[min];
    oneD[min] = temp;
}
oneD[4] = "RIP" + oneD[4];
```

["Harry", "Louis", "Zayn", "Niall", "Liam"]

oneD

5

size

1

i

2

j

1

min



Walkthrough

```
string oneD[] = {....};
int size = 5;

for (int i = 0; i < size; i++) {
    int min = i;
    for (int j = i + 1; j < size; j++)
        if (oneD[j] < oneD[min])
            min = j;
    string temp = oneD[i];
    oneD[i] = oneD[min];
    oneD[min] = temp;
}

oneD[4] = "RIP" + oneD[4];
```

["Harry", "Louis", "Zayn", "Niall", "Liam"]

oneD

5

size

1

i

2

j

1

min



Walkthrough

```
string oneD[] = {....};  
int size = 5;  
  
for (int i = 0; i < size; i++) {  
    int min = i;  
    for (int j = i + 1; j < size; j++)  
        if (oneD[j] < oneD[min])  
            min = j;  
    string temp = oneD[i];  
    oneD[i] = oneD[min];  
    oneD[min] = temp;  
}  
oneD[4] = "RIP" + oneD[4];
```

["Harry", "Louis", "Zayn", "Niall", "Liam"]

oneD

5

size

1

i

3

j

1

min



Walkthrough

```
string oneD[] = {....};
int size = 5;

for (int i = 0; i < size; i++) {
    int min = i;
    for (int j = i + 1; j < size; j++)
        if (oneD[j] < oneD[min])
            min = j;
    string temp = oneD[i];
    oneD[i] = oneD[min];
    oneD[min] = temp;
}

oneD[4] = "RIP" + oneD[4];
```

["Harry", "Louis", "Zayn", "Niall", "Liam"]

oneD

5

size

1

i

3

j

1

min



Walkthrough

```
string oneD[] = {....};  
int size = 5;  
  
for (int i = 0; i < size; i++) {  
    int min = i;  
    for (int j = i + 1; j < size; j++)  
        if (oneD[j] < oneD[min])  
            min = j;  
    string temp = oneD[i];  
    oneD[i] = oneD[min];  
    oneD[min] = temp;  
}  
oneD[4] = "RIP" + oneD[4];
```

["Harry", "Louis", "Zayn", "Niall", "Liam"]

oneD

5

size

1

i

4

j

1

min



Walkthrough

```
string oneD[] = {....};  
int size = 5;  
  
for (int i = 0; i < size; i++) {  
    int min = i;  
    for (int j = i + 1; j < size; j++)  
        if (oneD[j] < oneD[min])  
            min = j;  
    string temp = oneD[i];  
    oneD[i] = oneD[min];  
    oneD[min] = temp;  
}  
oneD[4] = "RIP" + oneD[4];
```

["Harry", "Louis", "Zayn", "Niall", "Liam"]

oneD

5

size

1

i

4

j

1

min



Walkthrough

```
string oneD[] = {....};  
int size = 5;  
  
for (int i = 0; i < size; i++) {  
    int min = i;  
    for (int j = i + 1; j < size; j++)  
        if (oneD[j] < oneD[min])  
            min = j;  
    string temp = oneD[i];  
    oneD[i] = oneD[min];  
    oneD[min] = temp;  
}  
oneD[4] = "RIP" + oneD[4];
```

["Harry", "Louis", "Zayn", "Niall", "Liam"]

oneD

5

size

1

i

4

j

4

min



Walkthrough

```
string oneD[] = {....};
int size = 5;

for (int i = 0; i < size; i++) {
    int min = i;
    for (int j = i + 1; j < size; j++)
        if (oneD[j] < oneD[min])
            min = j;
    string temp = oneD[i];
    oneD[i] = oneD[min];
    oneD[min] = temp;
}
oneD[4] = "RIP" + oneD[4];
```

["Harry", "Louis", "Zayn", "Niall", "Liam"]

oneD

5

size

1

i

5

j

4

min



Walkthrough

```
string oneD[] = {....};  
int size = 5;  
  
for (int i = 0; i < size; i++) {  
    int min = i;  
    for (int j = i + 1; j < size; j++)  
        if (oneD[j] < oneD[min])  
            min = j;  
    string temp = oneD[i];  
    oneD[i] = oneD[min];  
    oneD[min] = temp;  
}  
oneD[4] = "RIP" + oneD[4];
```

["Harry", "Louis", "Zayn", "Niall", "Liam"]

oneD

5

size

1

i

4

min

"Louis"

temp



Walkthrough

```
string oneD[] = {....};
int size = 5;

for (int i = 0; i < size; i++) {
    int min = i;
    for (int j = i + 1; j < size; j++)
        if (oneD[j] < oneD[min])
            min = j;
    string temp = oneD[i];
    oneD[i] = oneD[min];
    oneD[min] = temp;
}

oneD[4] = "RIP" + oneD[4];
```

["Harry", "Liam", "Zayn", "Niall", "Liam"]

oneD

5

size

1

i

4

min

"Louis"

temp



Walkthrough

```
string oneD[] = {....};
int size = 5;

for (int i = 0; i < size; i++) {
    int min = i;
    for (int j = i + 1; j < size; j++)
        if (oneD[j] < oneD[min])
            min = j;
    string temp = oneD[i];
    oneD[i] = oneD[min];
    oneD[min] = temp;
}

oneD[4] = "RIP" + oneD[4];
```

["Harry", "Liam", "Zayn", "Niall", "Louis"]

oneD

5

size

1

i

4

min

"Louis"

temp



Solution: What Makes CS Beautiful

After walking through two iterations of the outer for loop, we notice that the loops are sorting the array into alphabetical order!

(this is called Selection Sort, but don't worry about it for now) https://en.wikipedia.org/wiki/Selection_sort

Initial: ["Zayn", "Louis", "Harry", "Niall", "Liam"]

i = 0: ["Harry", "Louis", "Zayn", "Niall", "Liam"]

i = 1: ["Harry", "Liam", "Zayn", "Niall", "Louis"]

i = 2: ["Harry", "Liam", "Louis", "Niall", "Zayn"]

i = 3: ["Harry", "Liam", "Louis", "Niall", "Zayn"]

i = 4: ["Harry", "Liam", "Louis", "Niall", "Zayn"]

Final Answer: ["Harry", "Liam", "Louis", "Niall", "RIPZayn"]



Practice Question: Transpose

Implement a function that takes in a pointer to an $n \times n$ 2d array of ints and transposes it. That is, the rows should become the columns and vice versa.

```
void transpose(int** matrix, int n);
```

Example: 1 2 3 ($n = 3$) \rightarrow 1 4 7
 4 5 6 2 5 8
 7 8 9 3 6 9



Solution: Transpose

```
void transpose(int** matrix, int n) {  
    for (int i = 0; i < n; i++) {  
        for (int j = 0; j < i; j++) {  
            int temp = matrix[i][j];  
            matrix[i][j] = matrix[j][i];  
            matrix[j][i] = temp;  
        }  
    }  
}
```



Practice Question: Resolve Merge Issues

```
// Assume arr1 and arr2 are ordered from least to
// greatest and have size n1 and n2, respectively.
// Also assume arr3 has size n1 + n2.
void merge(int arr1[], int n1, int arr2[], int n2,
           int arr3[]) {
    int i1 = 0, i2 = 0, i3 = 0;
    while (i3 < n1 + n2) {
        if (arr1[i1] < arr2[i2]) {
            arr3[i3] = arr1[i1];
            i1++;
        } else if (arr2[i2] < arr1[i1]) {
            arr3[i3] = arr2[i2];
            i2++;
        }
        i3++;
    }
}
```

This function attempts to merge two arrays arr1 and arr2 that are ordered from least to greatest into a third array arr3, so that arr3 contains the contents of both arr1 and arr2 ordered from least to greatest.

Example: arr1 = {1, 2, 5}, arr2 = {2, 4, 6}
→ arr3 = {1, 2, 2, 4, 5, 6}

Can you find and fix the bugs in this function so that it performs correctly?



Practice Question: Resolve Merge Issues

```
// Assume arr1 and arr2 are ordered from least to
// greatest and have size n1 and n2, respectively.
// Also assume arr3 has size n1 + n2.
void merge(int arr1[], int n1, int arr2[], int n2,
           int arr3[]) {
    int i1 = 0, i2 = 0, i3 = 0;
    while (i3 < n1 + n2) {
        if (arr1[i1] < arr2[i2]) { // what if i1>=n1
            arr3[i3] = arr1[i1]; // or i2 >= n2??
            i1++;
        } else if (arr2[i2] < arr1[i1]) { // same!
            arr3[i3] = arr2[i2];
            i2++;
        } // what do we do if arr1[i1] == arr2[i2]?
        i3++;
    }
}
```

This function attempts to merge two arrays arr1 and arr2 that are ordered from least to greatest into a third array arr3, so that arr3 contains the contents of both arr1 and arr2 ordered from least to greatest.

Example: arr1 = {1, 2, 5}, arr2 = {2, 4, 6}
→ arr3 = {1, 2, 2, 4, 5, 6}

Can you find and fix the bugs in this function so that it performs correctly?



Solution: Resolve Merge Issues

```
void merge(int arr1[], int n1, int arr2[], int n2,
           int arr3[]) {
    int i1 = 0, i2 = 0, i3 = 0;
    while (i1 < n1 && i2 < n2) {
        if (arr1[i1] < arr2[i2]) {
            arr3[i3] = arr1[i1];
            i1++;
        } else if (arr2[i2] <= arr1[i1]) {
            arr3[i3] = arr2[i2];
            i2++;
        }
        i3++;
    }
    // continued...
```

```
    while (i1 < n1) { // only one of these will run
        arr3[i3] = arr1[i1];
        i1++;
        i3++;
    }
    while (i2 < n2) {
        arr3[i3] = arr2[i2];
        i2++;
        i3++;
    }
}
```



Good luck!

Sign-in <https://forms.gle/ita7uaMBtCTjcnmx9>

Slides <https://shorturl.at/tNSW9>

Practice <https://github.com/uclaupe-tutoring/practice-problems/wiki>

Questions? Need more help?

- Come up and ask us! We'll try our best.
- UPE offers daily computer science tutoring:
 - Location: ACM/UPE Clubhouse (Boelter 2763)
 - Schedule: <https://upe.seas.ucla.edu/tutoring/>
- You can also post on the Facebook event page.

