CS106L Lecture 3:
Initialization & References 

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Attendance

A quick recap

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1. **`auto:`** a keyword that tells the compiler to deduce the type of an object or variable
    a. Use at your discretion
    b. Typically, when the type is ***annoyingly*** verbose to write out

```cpp
#include <iostream>
#include <string>
#include <map>
#include <unordered_map>
#include <vector>

int main()
{
    std::map<std::string, std::vector<std::pair<int, std::unordered_map<char, double>>>>
    complexType;

    /// confusing iterator type (We'll find out what this is in the iterators lecture!)
    std::map<std::string,std::vector<std::pair<int,std::unordered_map<char,double>>>>::iterator
    it = complexType.begin();

    // clear(er) iterator type!
    auto it = complexType.begin();

    return 0;
}
```

A quick recap

1. `auto:` a keyword that tells the compiler to deduce the type of an object or variable
    a. Use at your discretion
    b. Typically, when the type is ***annoyingly*** verbose to write out

2. **Structs** are a way to bundle many variables into one type

Plan

1. Initialization
2. References
3. L-values vs R-values
4. Const
5. Compiling C++ programs

Initialization

What?: “Provides initial values at the time of construction” - *cppreference.com*

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How? 🤔:

1. Direct initialization
2. Uniform initialization
3. Structured Binding

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How? 🤔:

1. Direct initialization

2. Uniform initialization

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Direct initialization

```cpp
#include <iostream>

int main() {
    int numOne = 12.0;
    int numTwo(12.0);

    std::cout << "numOne is: " << numOne << std::endl;
    std::cout << "numTwo is: " << numTwo << std::endl;

    return 0;
}
```

Notice!!:

is 12.0 an int?

Direct initialization

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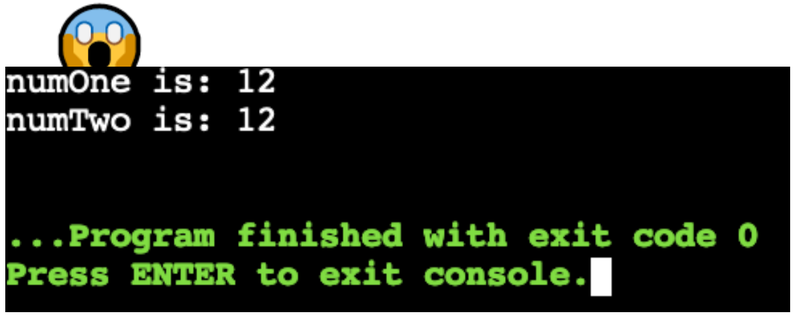
    return 0;
}
```

Notice!!:

is 12.0 an int?

NO

C++ Doesn't Care



Problem? 🧐

```
void checkCool() {
    if (temperature > 100.0) {
        std::cout << "Emergency cooling activated!" << std::endl;
    } else {
        std::cout << "Temperature normal. No emergency cooling required.";
    }
}

int ma
    in
    Reactor reactor(criticalTemperature);
    reactor.checkCool();

    return 0;
}
```

```
~/Doc/St/Te/cs106L/cs106l-lecture-code/lecture03 git lectu
re03 *2 !7 ?4 ./a.out ✔ system 05:20:48 PM
Temperature is normal. No emergency cooling required
```

Recall

```cpp
#include <iostream>

int main() {
    int numOne = 12.0;
    int numTwo(12.0);

    std::cout << "numOne is: " << numOne << std::endl;
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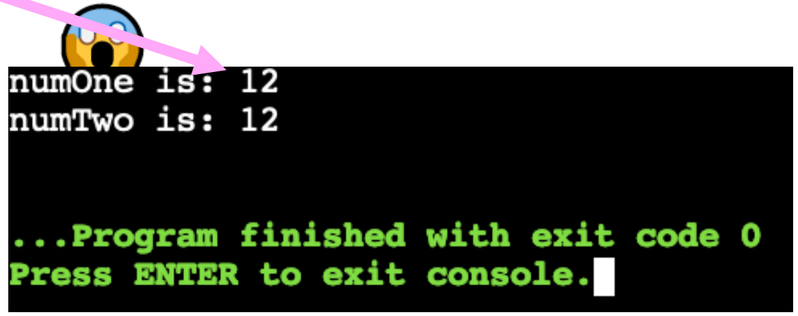

What happened?

```
void checkCool() {
    if (temperature > 100.0) {
        std::cout << "Emergency cooling activated!" << std::endl;
    } else {
        std::cout << "Temperature normal. No emergency cooling required.";
    }
}

int main() {
    int criticalTemperature(100.8);
    Reactor reactor(criticalTemperature);
    reactor.checkCool();

    return 0;
}
```

C++ doesn't care in this case, it doesn't type check with direct initialization

What happened?

```
void checkCool() {
    if (temperature > 100.0) {
        std::cout << "Emergency cooling activated!" << std::endl;
    } else {
        std::cout << "Temperature normal. No emergency cooling required.";
    }
}

int main() {
    int criticalTemperature(100.8);
    Reactor reactor(criticalTemperature);
    reactor.checkCool();

    return 0;
}
```

So C++ said “Meh, I’ll store 100.8 as an int,” and we possibly now have an error. This is commonly called a **narrowing conversion**

Initialization

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How? 🤔:

1. Direct initialization
2. **Uniform initialization**
3. Structured Binding

Uniform initialization (C++11)

```cpp
#include <iostream>

int main() {
    // Notice the brackets
    int numOne{12.0};
    float numTwo{12.0};

    std::cout << "numOne is: " << numOne << std::endl;
    std::cout << "numTwo is: " << numTwo << std::endl;

    return 0;
}
```

Notice!!:

the curly braces!

With uniform initialization C++ ***does*** care about types!

Uniform initialization (C++11)

```cpp
#include <iostream>

int main() {
    // Notice the brackets
    int numOne{12.0};
    float numTwo{12.0};

    std::cout << "numOne is: " << numOne << std::endl;
    std::cout << "numTwo is: " << numTwo << std::endl;

}
```

```
narrowing_conversion.cpp:5:16: error: type 'double' cannot be narrowed to 'int' in
 initializer list [-Wc++11-narrowing]
    int numOne{12.0};
               ^~~~
narrowing_conversion.cpp:5:16: note: insert an explicit cast to silence this issue
    int numOne{12.0};
               ^~~~
               static_cast<int>( )
1 error generated.
```

Notice!!:

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With uniform

Uniform initialization (C++11)

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#include <iostream>

int main() {
    // Notice the brackets
    int numOne{12.0};
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    std::cout << "numOne is.                    :endl;
    std::cout << "numTwo is:                    :endl;
}
```

Notice!!:

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    return 0;
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Notice!!:

12 instead of 12.0

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int main() {
    // Notice the brackets
    int numOne{12};
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    std::cout << "numOne is: " << numOne << std::endl;
    std::cout << "numTwo is: " << numTwo << std::endl;

    return 0;
}
```

Notice!!:

12 instead of 12.0

```
numOne is: 12
numTwo is: 12
```

Uniform initialization (C++11)

Uniform initialization is awesome because:

1. It's **safe!** It doesn't allow for narrowing conversions—which can lead to unexpected behaviour (or critical system failures 😳)

Uniform initialization (C++11)

Uniform initialization is awesome because:

1. It's **safe!** It doesn't allow for narrowing conversions—which can lead to unexpected behaviour (or critical system failures 😳)

2. It's **ubiquitous!** It works for all types like `vectors`, `maps`, and custom classes, among other things!

Uniform initialization (Map)

```cpp
#include <iostream>
#include <map>

int main() {
    // Uniform initialization of a map
    std::map<std::string, int> ages{
        {"Alice", 25},
        {"Bob", 30},
        {"Charlie", 35}
    };

    // Accessing map elements
    std::cout << "Alice's age: " << ages["Alice"] << std::endl;
    std::cout << "Bob's age: " << ages.at("Bob") << std::endl;

    return 0;
}
```

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    std::cout << "Bob's age: " << ages.at("Bob") << std::endl;

    return 0;
}
```

```
Alice's age: 25
Bob's age: 30
```

Uniform initialization (Vector)

```cpp
#include <iostream>
#include <vector>

int main() {
    // Uniform initialization of a vector
    std::vector<int> numbers{1, 2, 3, 4, 5};

    // Accessing vector elements
    for (int num : numbers) {
        std::cout << num << " ";
    }
    std::cout << std::endl;

    return 0;
}
```

Uniform initialization (Vector)

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#include <iostream>
#include <vector>

int main() {
    // Uniform initialization of a vector
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    // Accessing vector elements
    for (int num : numbers) {
        std::cout << num << " ";
    }
    std::cout << std::endl;

    return 0;
}
```

```
1 2 3 4 5
```

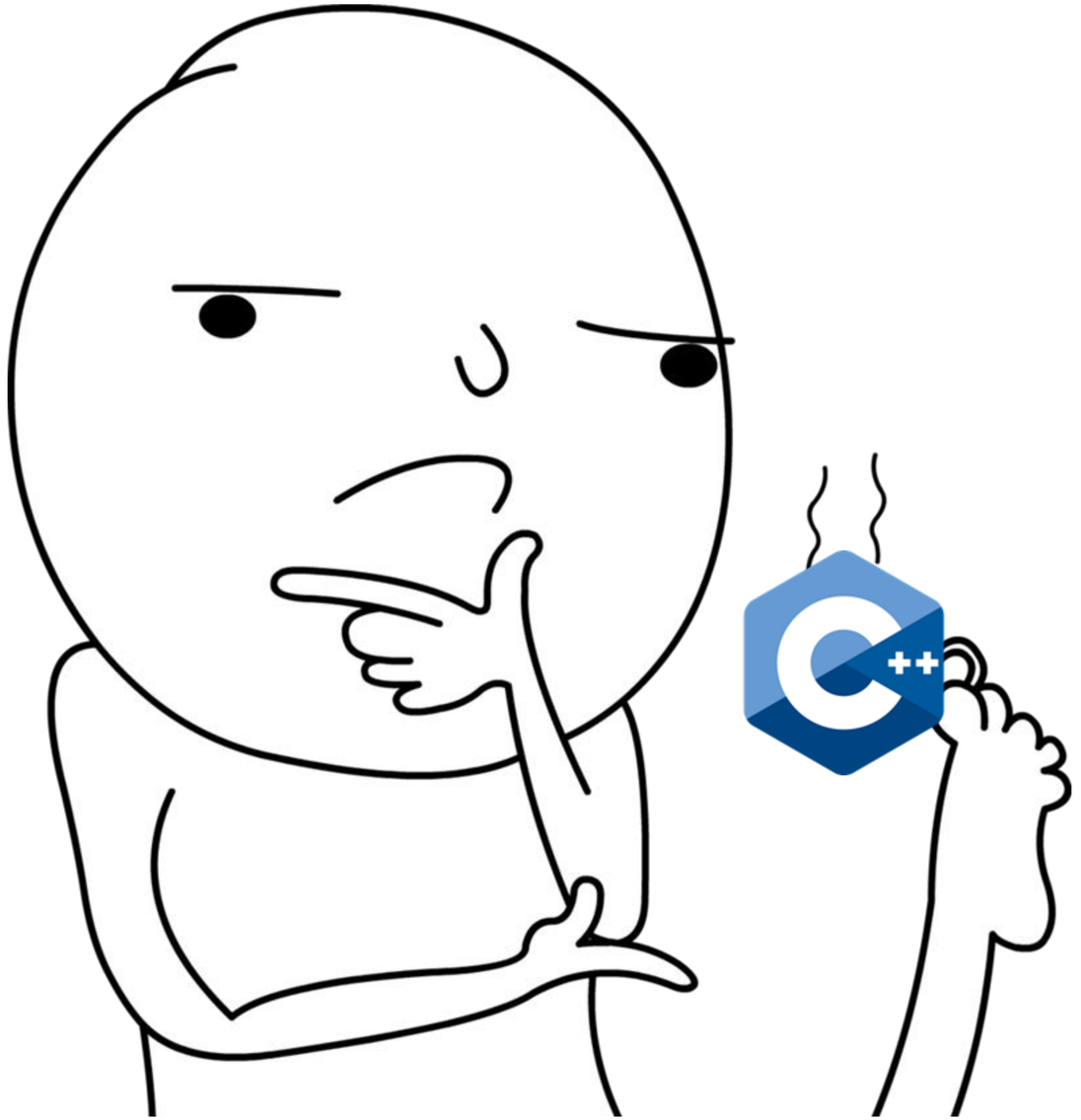
Recall

Using list initialization

```
StanfordID issueNewID() {
    StanfordID id;
    id.name = "THE Stanford Tree";
    id.sunet = "theTREE";
    id.idNumber = 0000002;
    return id;
}
```

```
StanfordID issueNewID() {
    StanfordID id = { "THE Stanford Tree", "theTREE", 0000002 };
    return id;
}
```

What questions do we have?



Initialization

What?: “Provides initial values at the time of construction” - *cppreference.com*

How? 🤔:

1. Direct initialization
2. Uniform initialization
3. **Structured Binding**

Structured Binding (C++ 17)

- A useful way to initialize some variables from data structures with fixed sizes at compile time

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- A useful way to initialize some variables from data structures with fixed sizes at compile time
- Ability to access multiple values returned by a function

Structured Binding (C++ 17)

```cpp
#include <iostream>
#include <tuple>
#include <string>

std::tuple<std::string, std::string, std::string> getClassInfo() {
    std::string className = "CS106L";
    std::string buildingName = ”Thornton 110";
    std::string language = "C++";
    return {className, buildingName, language};
}

int main() {
    auto [className, buildingName, language] = getClassInfo();
    std::cout << "Come to " << buildingName << " and join us for " << className
              << " to learn " << language << "!" << std::endl;

    return 0;
}
```

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Notice - uniform initialization!

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    return {className, buildingName, language};
}

int main() {
    auto classInfo = getClassInfo();
    std::string className = std::get<0>(classInfo);
    std::string buildingName = std::get<1>(classInfo);
    std::string language = std::get<2>(classInfo);

    std::cout << "Come to " << buildingName << " and join us for " << className
              << " to learn " << language << "!" << std::endl;
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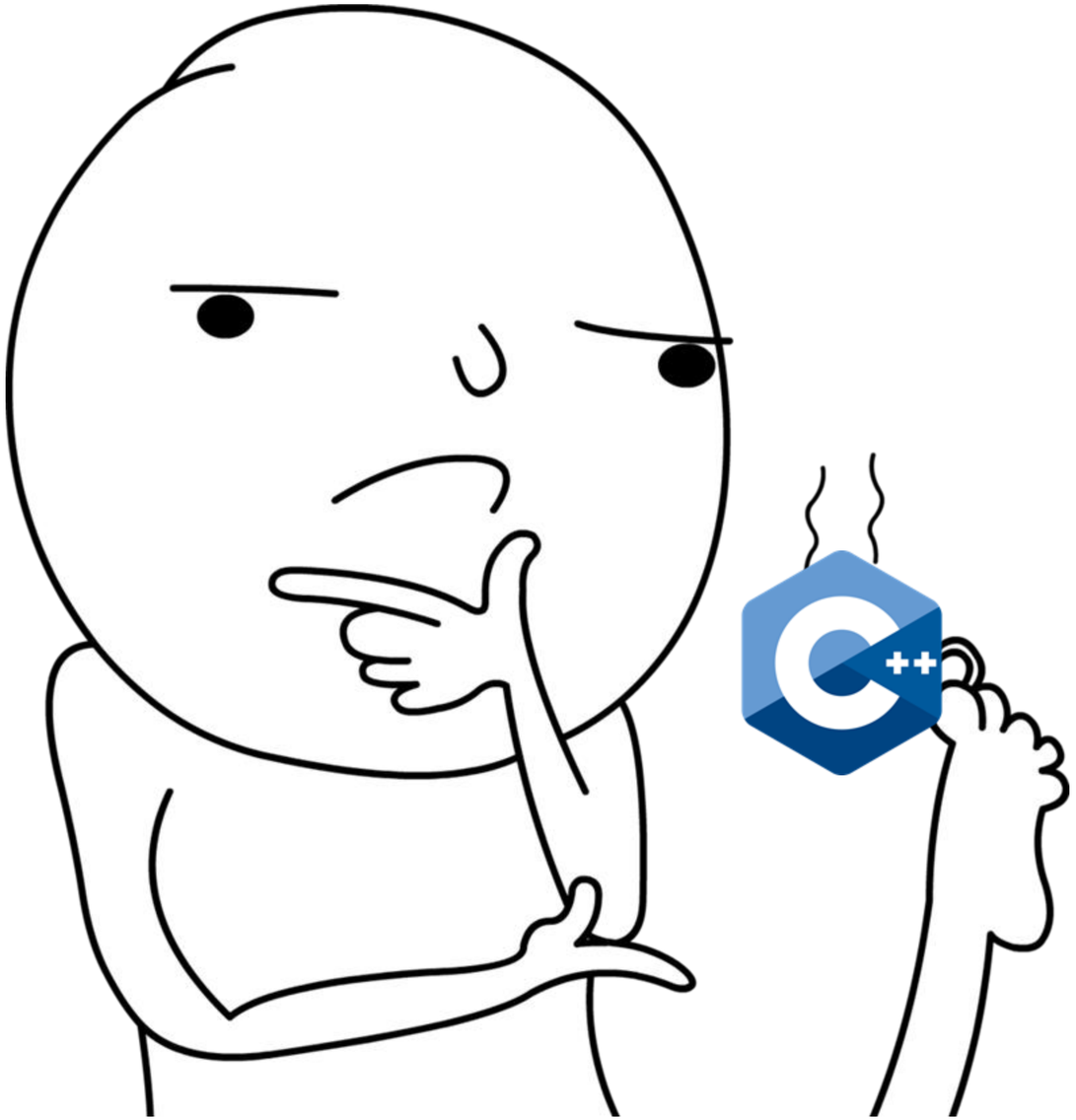
}
```

Structured Binding (C++ 17)

- A useful way to initialize some variables from data structures with fixed sizes at compile time
- Ability to access multiple values returned by a function
- Can use on objects where the size is **known at compile-time**

What questions do we have?



Plan

1. Initialization
2. **References**
3. L-values vs R-values
4. Const
5. Compiling C++ programs

References

What?: “Declares a name variable as a reference”

tldr: a reference is an alias to an already-existing thing - *cppreference.com*

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How? 🤔**:**

Use an ampersand (&)

The & and the how

```
int num = 5;
int& ref = num;

ref = 10;  // Assigning a new value through the
reference
std::cout << num << std::endl;  // Output: 10
```

num is a variable of type int, that is assigned to have the value 5

The & and the how

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int num = 5;
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`ref` is a variable of type `int&`, that is an *alias* to num

The & and the how

```cpp
int num = 5;
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ref = 10;  // Assigning a new value through the reference
std::cout << num << std::endl;  // Output: 10
```

So when we assign 10 to ref, we also change the value of num, since `ref` is an *alias* for num

Visually 🖼️

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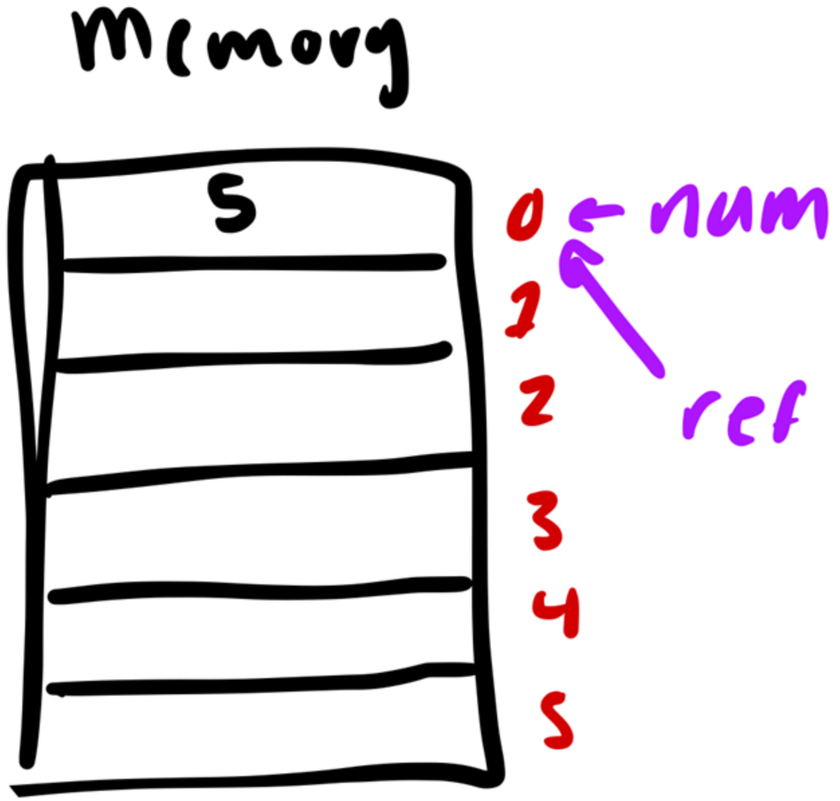

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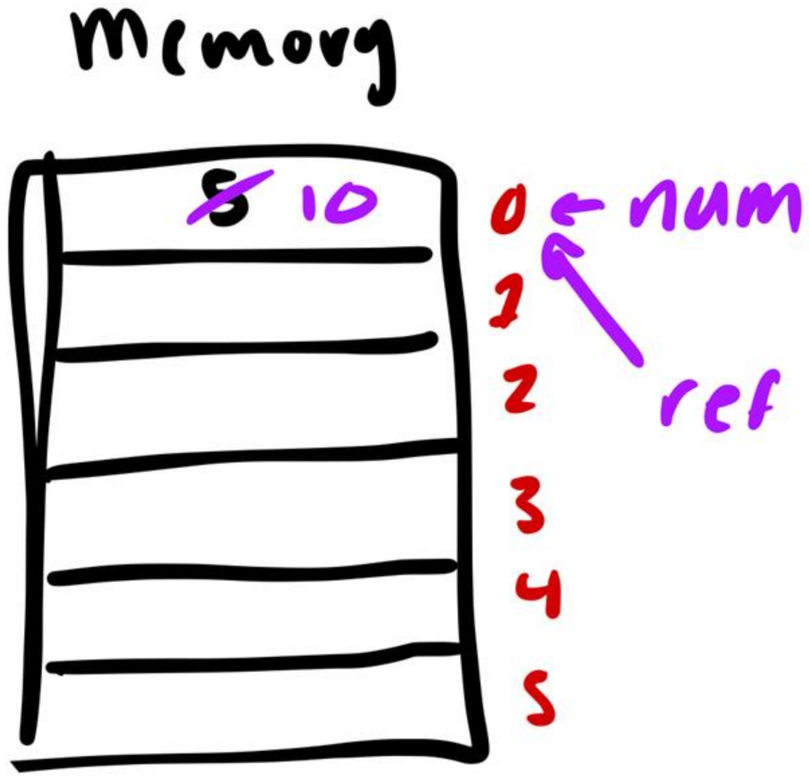

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Pass by reference

In 106B we learn about “pass by reference”. We can apply the same ideas from referenced variables to functions! Take a look:

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```cpp
#include <iostream>
#include <math.h>

// note the ampersand!
void squareN(int& n) {
    // calculates n to the power of 2
    n = std::pow(n, 2);
}

int main() {
    int num = 5;
    squareN(num);
    std::cout << num << std::endl;

    return 0;
}
```

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    int num = 5;
    squareN(num);
    std::cout << num << std::endl;

    return 0;
}
```

Pass by reference

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Notice!!: `n` is being passed into **`squareN`** by reference, denoted by the ampersand!

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#include <iostream>
#include <math.h>

// note the ampersand!
void squareN(int& n) {
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    n = std::pow(n, 2);
}

int main() {
    int num = 5;
    squareN(num);
    std::cout << num << std::endl;

    return 0;
}
```

Pass by reference

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So what❓: This means that **n** is actually going to be modified inside of **squareN**.

```cpp
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#include <math.h>

// note the ampersand!
void squareN(int& n) {
    // calculates n to the power of 2
    n = std::pow(n, 2);
}

int main() {
    int num = 5;
    squareN(num);
    std::cout << num << std::endl;

    return 0;
}
```
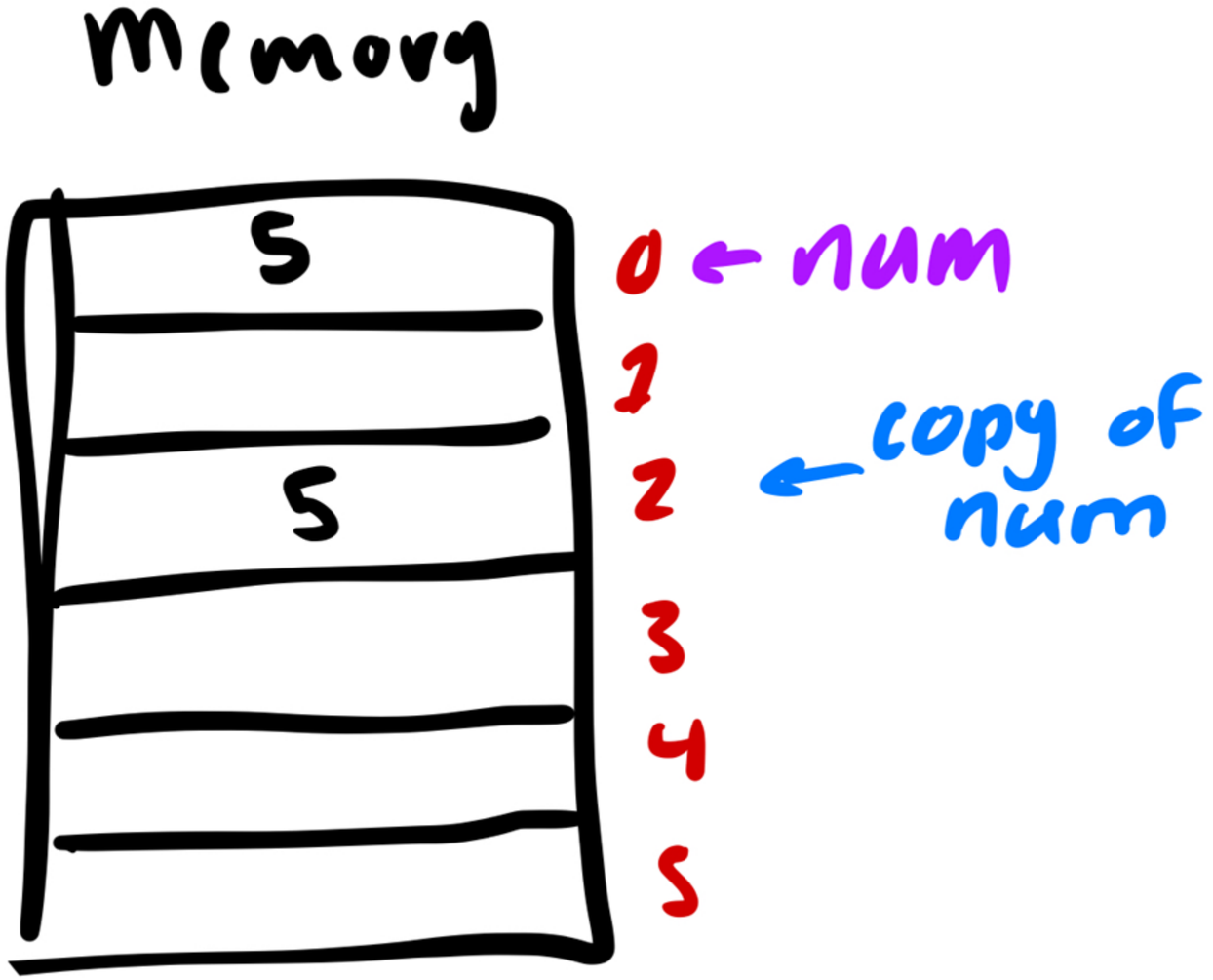
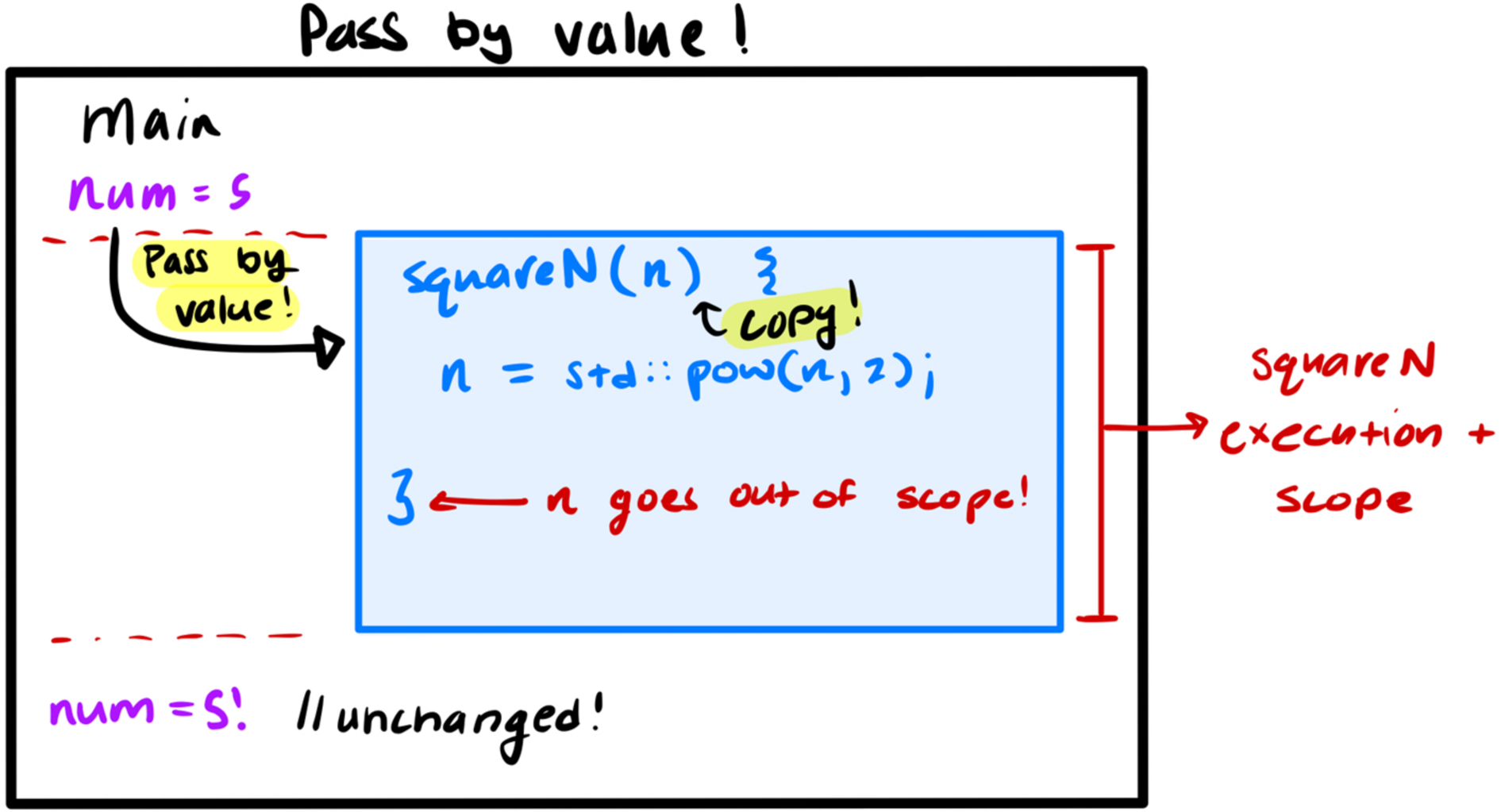

Recall: Pass by Value

Passing in a variable by ***value*** into a function just means "**Hey make a copy, don't take in the actual variable!**"

What does that look like?



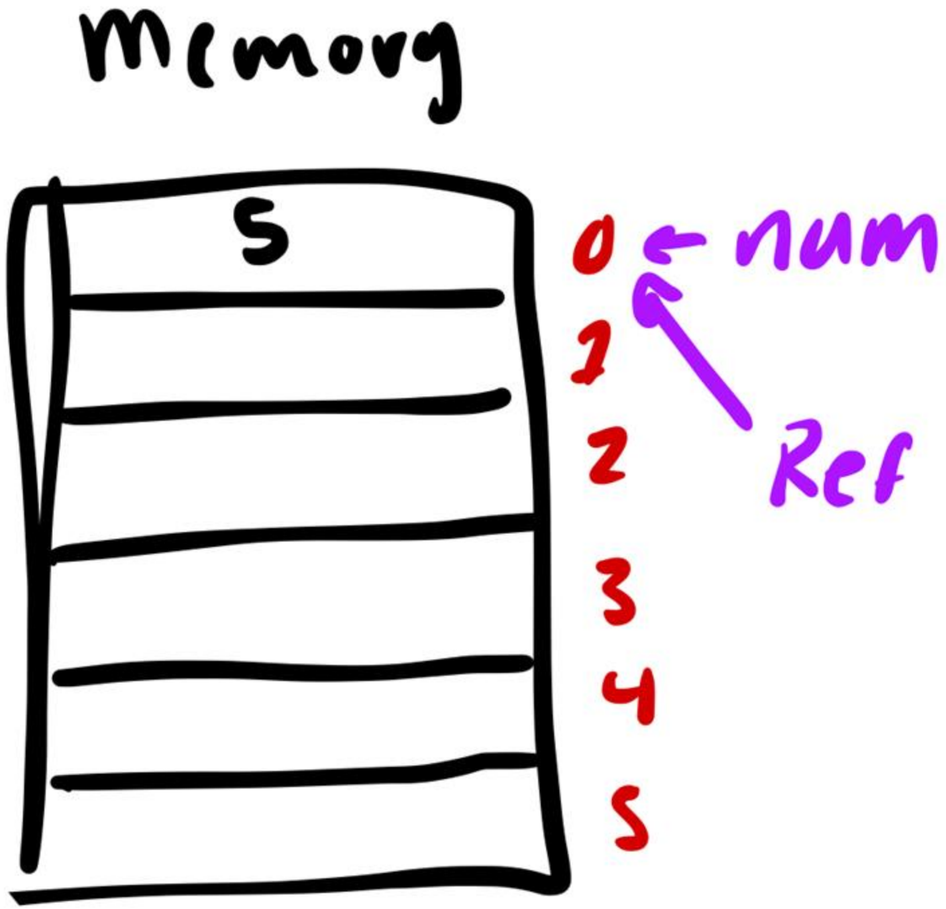
Recall: Pass by Value (makes a copy)



Recall: Pass by Reference

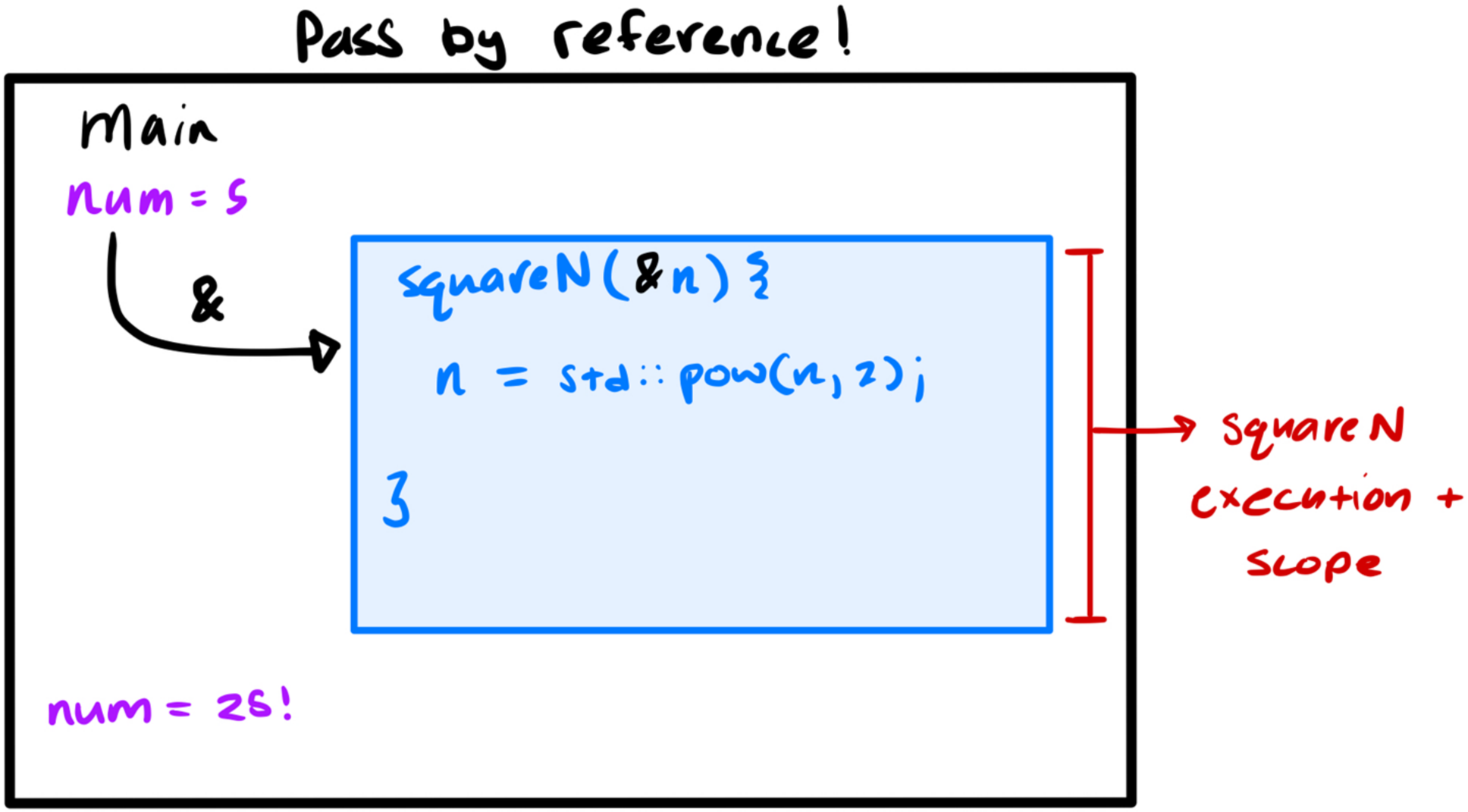
Passing in a variable by ***reference*** into a function just means "**Hey take in the actual piece of memory, don't make a copy!**"

Recall: Pass by Reference



A reference *refers* to the same memory as its associated variable!

Recall: Pass by Reference



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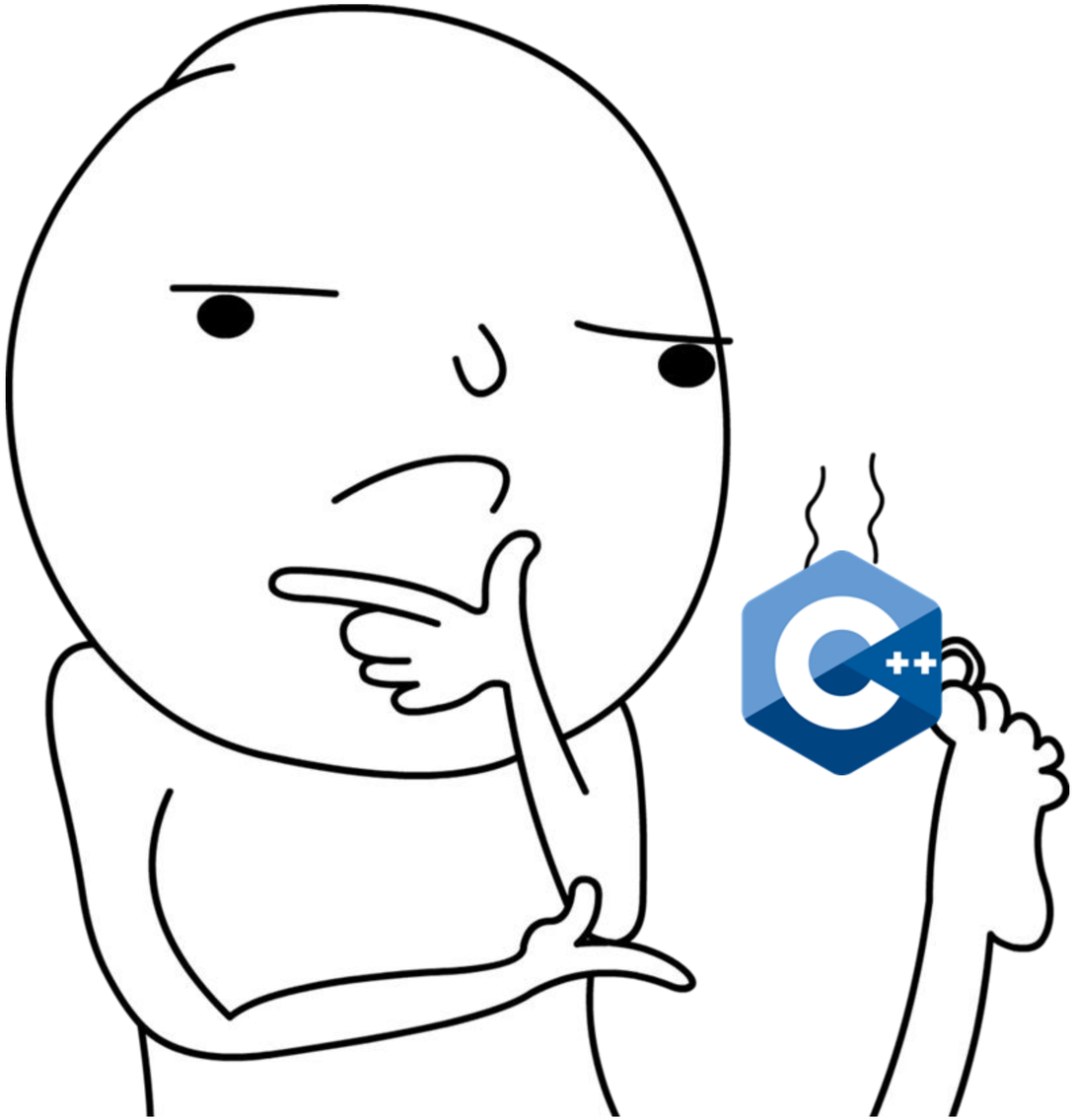

OK! Let’s take a look at an edge case!

```
#include <iostream>
#include <math.h>
#include <vector>

void shift(std::vector<std::pair<int, int>> &nums) {
    for (auto [num1, num2] : nums) {
        num1++;
        num2++;
    }
}
```

A classic reference-copy bug

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🤔 But nums is passed in by reference...

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}
```

Note the structured binding!

🤔 But nums is passed in by reference...

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#include <math.h>
#include <vector>

void shift(std::vector<std::pair<int, int>> &nums) {
    for (auto [num1, num2] : nums) {
        num1++;
        num2++;
    }
}
```

We're **not** modifying nums in this function!

A classic reference-copy bug

```
#include <iostream>
#include <math.h>
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void shift(std::vector<std::pair<int, int>> &nums) {
    for (auto [num1, num2] : nums) {
        num1++;
        num2++;
    }
}
```

We are modifying the `std::pair`'s inside of nums

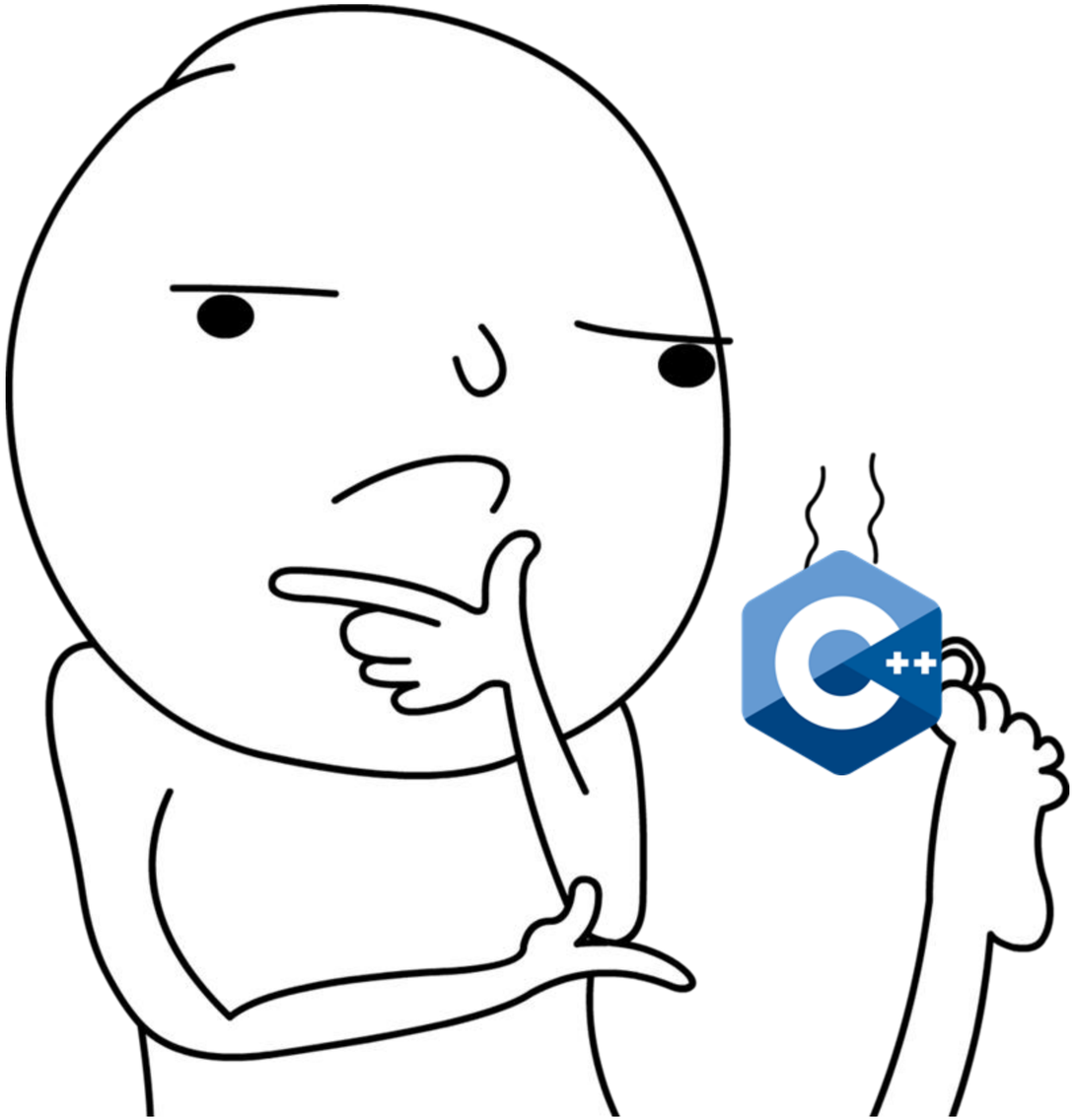
A classic reference-copy bug: fixed!

```
#include <iostream>
#include <math.h>
#include <vector>

void shift(std::vector<std::pair<int, int>> &nums) {
    for (auto& [num1, num2] : nums) {
        num1++;
        num2++;
    }
}
```

A note, this also works!

```
#include <iostream>
#include <math.h>
#include <vector>

void shift(std::vector<std::pair<int, int>> &nums) {
    for (size_t i = 0; i < nums.size(); i++) {
        nums[i].first++;
        nums[i].second++;
    }
}
```

What questions do we have?



Plan

1. Initialization
2. References
3. **L-values vs R-values**
4. Const
5. Compiling C++ programs

l-values and r-values

	l-value	r-value
Full Name	Locator Value	Read Value
Where with respect to equal sign?	left or right	right
Memory	Has a memory address	Temporary value (No memory address)
Example	`int x = 10;` `int y = x;`	`int x = 10;` `int y = x;`

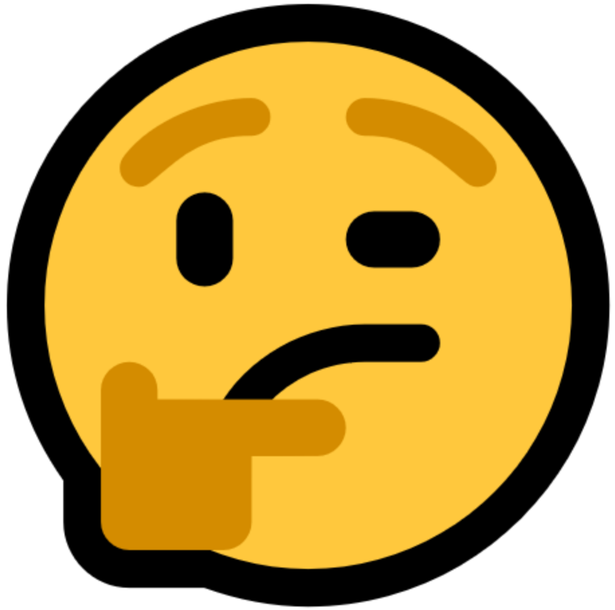
l-value and r-value PAIN

```cpp
#include <iostream>
#include <math.h>

// note the ampersand!
void squareN(int& n) {
    // calculates n to the power of 2
    n = std::pow(n, 2);
}

int main() {
    int num = 5;
    squareN(num);
    std::cout << num << std::endl;

    return 0;
}
```



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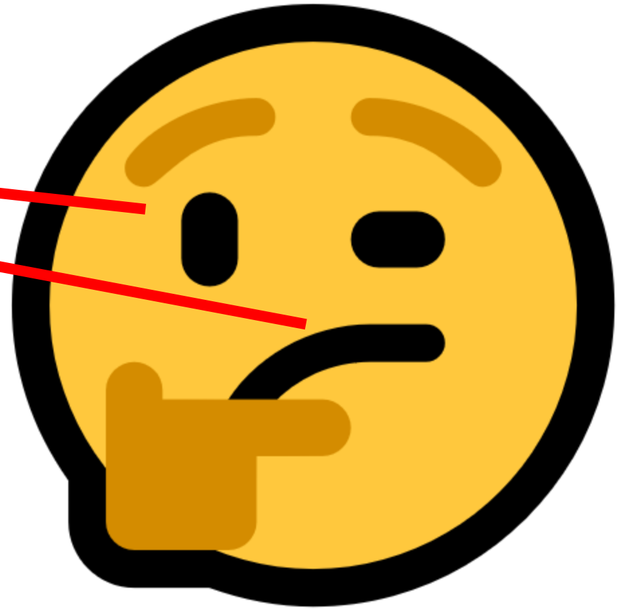
is **int&** n an l-value?



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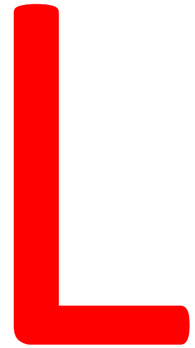

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}

int main() {
    int num = 5;
    squareN(num);
    std::cout << num << std::endl;

    return 0;
}
```

is `int&` n an l-value?

It turns out that num is an l-value! But Why?

1. Remember what we said about r-values are temporary. Notice that num is being passed in by reference!

2. We ***cannot*** pass in an r-value by reference because they're temporary!

l-value and r-value PAIN

```
#include <iostream>
#include <math.h>

// note the ampersand!
void squareN(int& n) {
    // ca
    n = s
}

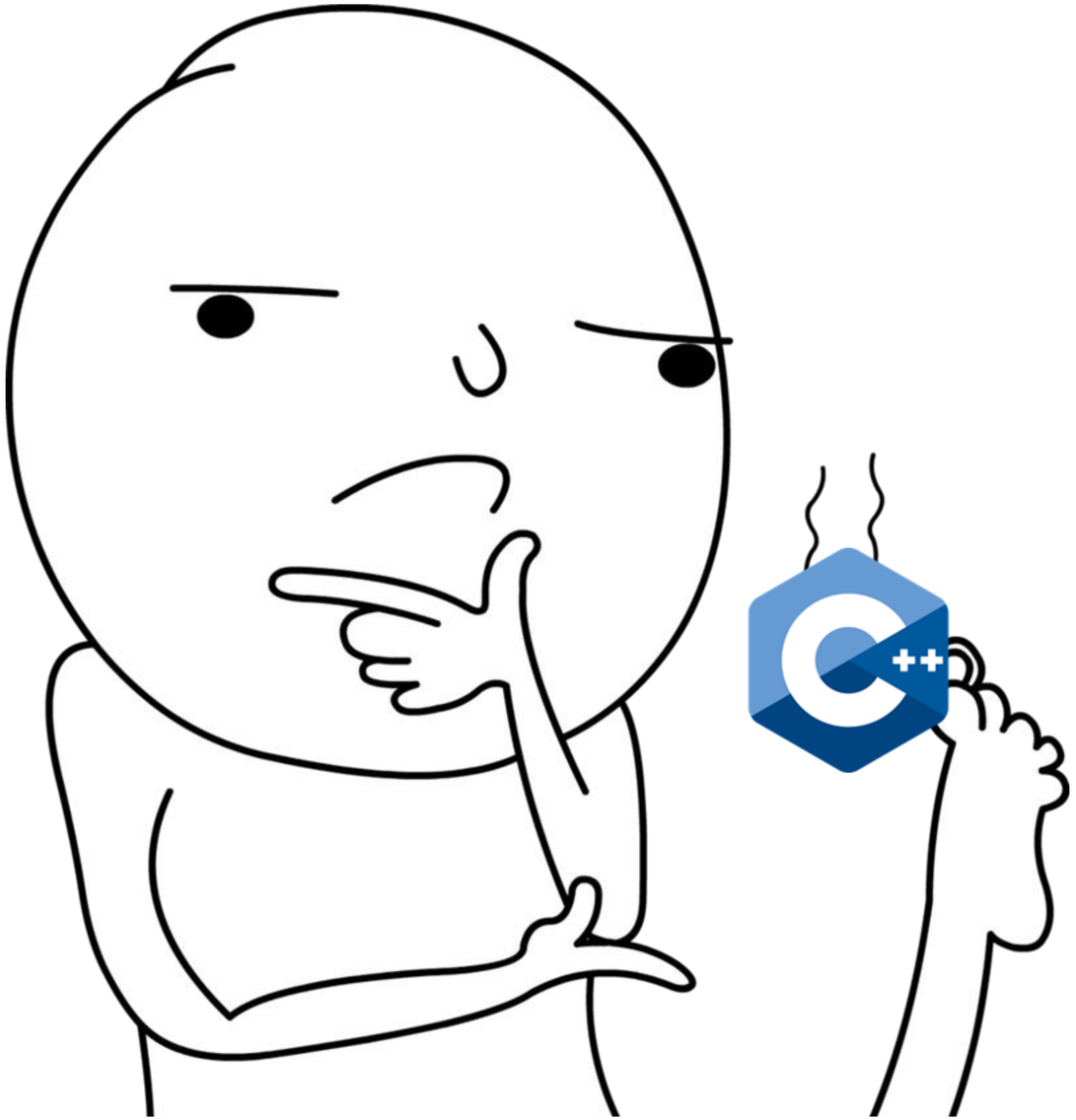
int main() {
    int num = 5;
    squareN(5);
    std::cout << num << std::endl;

    return 0;
}
```

```
references.cpp:7:6:       candidate function not viable: expects an lvalue for 1st argument
    7 | void squareN(int& n)
      |      ^       ~~~~~~
1 error generated.
```

Well what happens?

What questions do we have?



Plan

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4. **Const**
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`const`

What?:

A qualifier for objects that declares they cannot be modified – *cppreference.com*

pop quiz (not really)

const

```cpp
#include <iostream>
#include <vector>

int main()
{
    std::vector<int> vec{ 1, 2, 3 };  /// a normal vector
    const std::vector<int> const_vec{ 1, 2, 3 };  /// a const vector
    std::vector<int>& ref_vec{ vec };  /// a reference to 'vec'
    const std::vector<int>& const_ref{ vec };  /// a const reference

    vec.push_back(3);
    const_vec.push_back(3);
    ref_vec.push_back(3);
    const_ref.push_back(3);

    return 0;
}
```

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    std::vector<int>& ref_vec{ vec };  /// a reference to 'vec'
    const std::vector<int>& const_ref{ vec };  /// a const reference

    vec.push_back(3); /// this is ok!
    const_vec.push_back(3);
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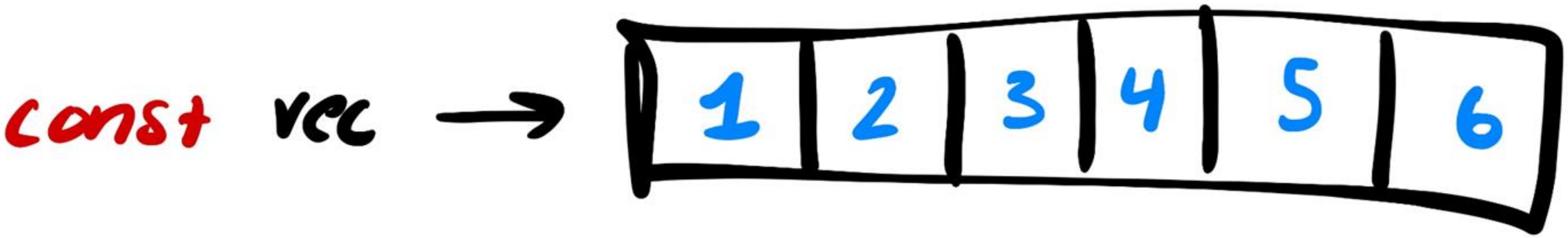
    vec.push_back(3); /// this is ok!
    const_vec.push_back(3); /// no, this is const!
    ref_vec.push_back(3); /// this is ok, just a reference!
    const_ref.push_back(3); /// this is const, compiler error!

    return 0;
}
```

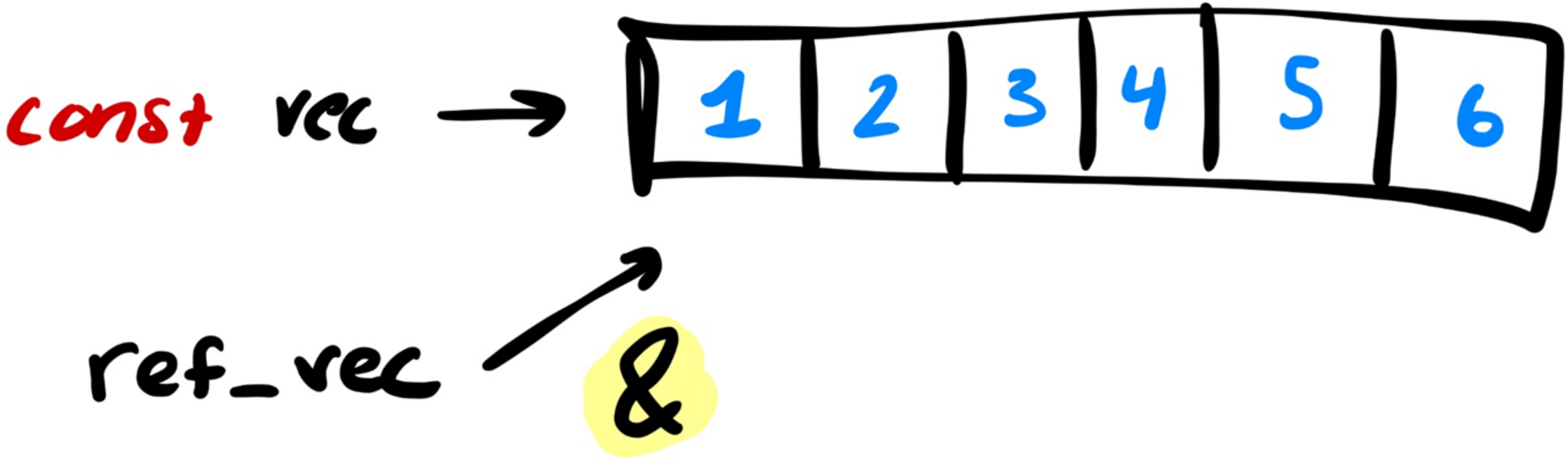
You can’t declare a non-const reference to a const variable

```cpp
#include <iostream>
#include <vector>

int main()
{
    /// a const vector
    const std::vector<int> const_vec{ 1, 2, 3 };
    std::vector<int>& bad_ref{ const_vec };  /// BAD

    return 0;
}
```

You can’t declare a non-const reference to a const variable



You can’t declare a non-const reference to a const variable



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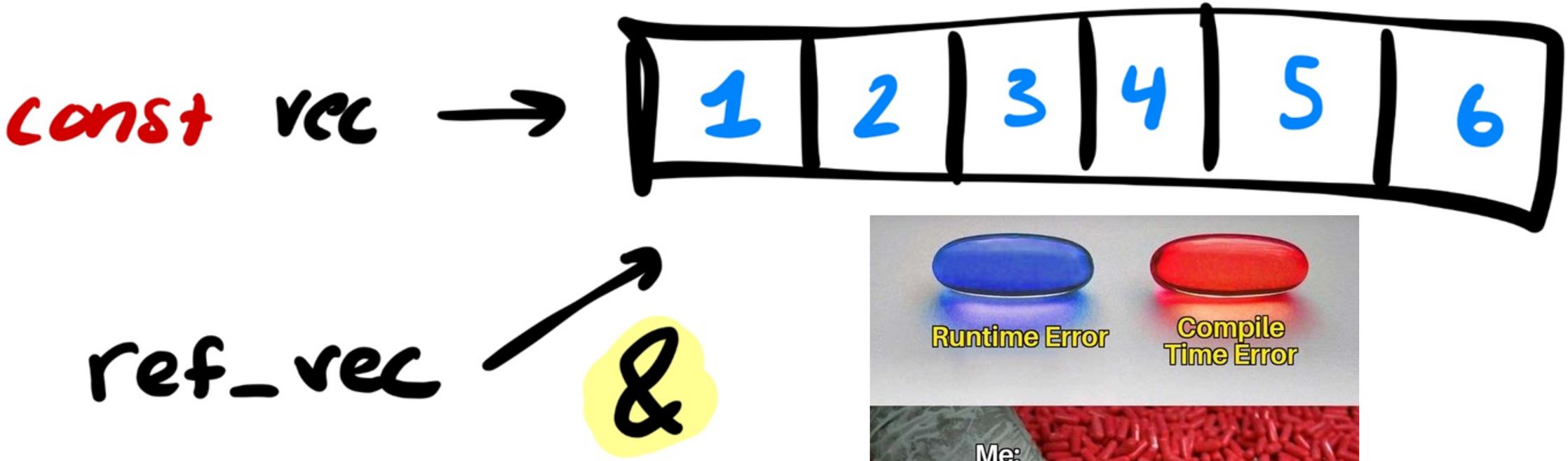

You can declare a const reference to a const variable!

```cpp
#include <iostream>
#include <vector>

int main()
{
    /// a const vector
    const std::vector<int> const_vec{ 1, 2, 3 };
    const std::vector<int>& good_ref{ const_vec }; /// Yay!

    return 0;
}
```

Plan

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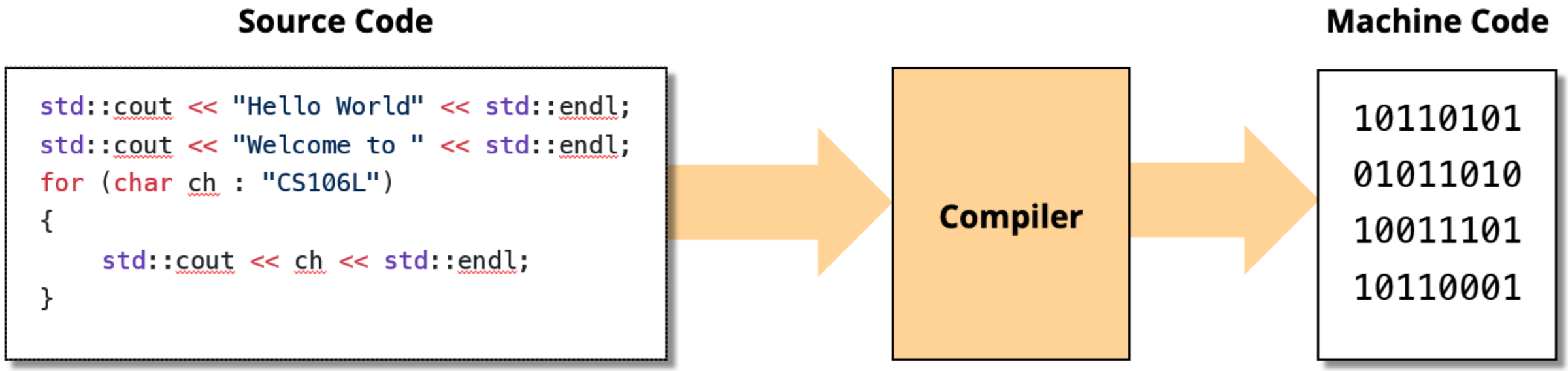
5. **Compiling C++ programs**

Compiling C++ Programs

Everything you need to know about compiling a program for your first assignment.

We'll be making use of VSCode, and through the terminal compilation will be quite easy!

Compiling C++ Programs



What you need to know

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```
g++ -std=c++23 main.cpp -o main
```

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This is the compiler command

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```

This specifies the c++ version you want to compile in

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This is the source file

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```

This means that you're going to give a specific name to your executable

What you need to know

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```
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```

In this case it's `main`

What you need to know

- C++ is a compiled language
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- ***Here is how to compile a program using g++***

```
g++ -std=c++23 main.cpp
```

This is also valid, your executable will be something like `a.out`

What you need to know

- C++ is a compiled language
- There are computer programs called compilers
- A few popular compilers include clang and g++
- ***Here is how to compile a program using g++***

```
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```
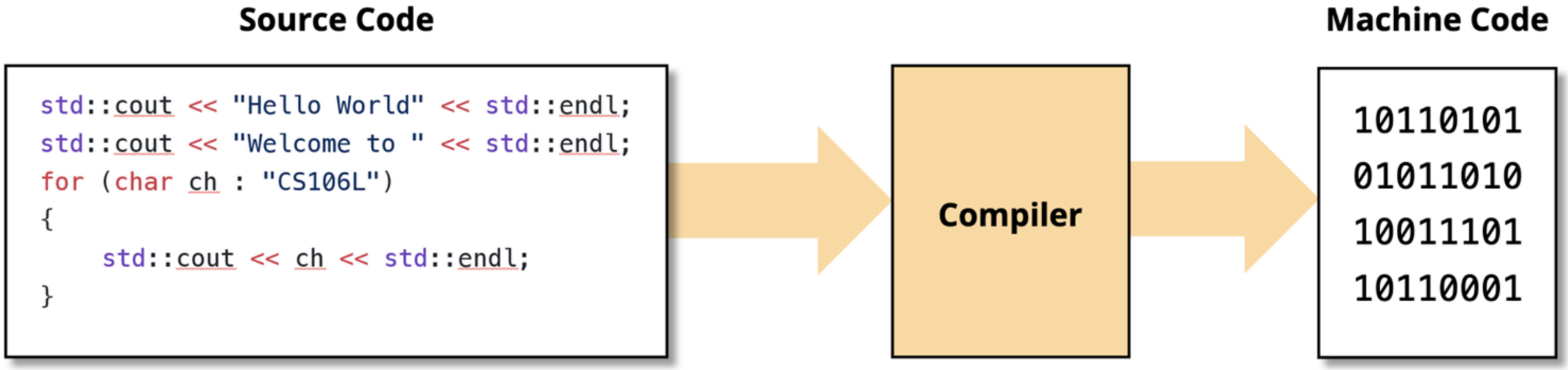
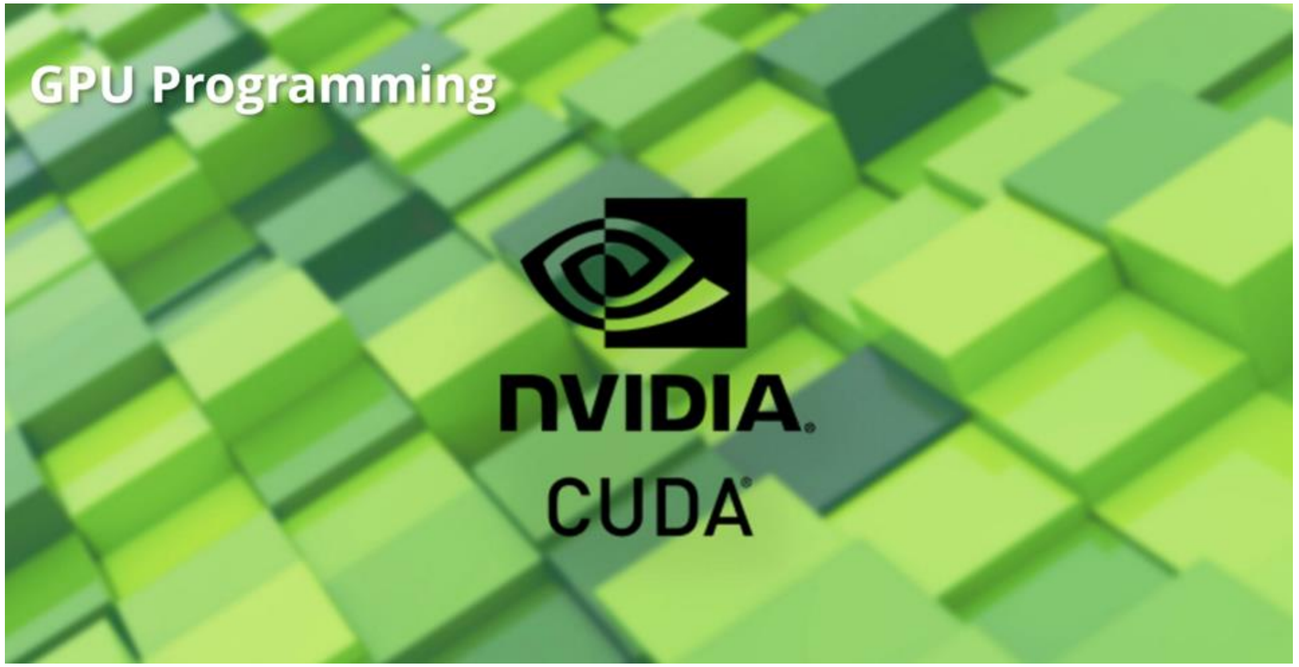

What you need to know

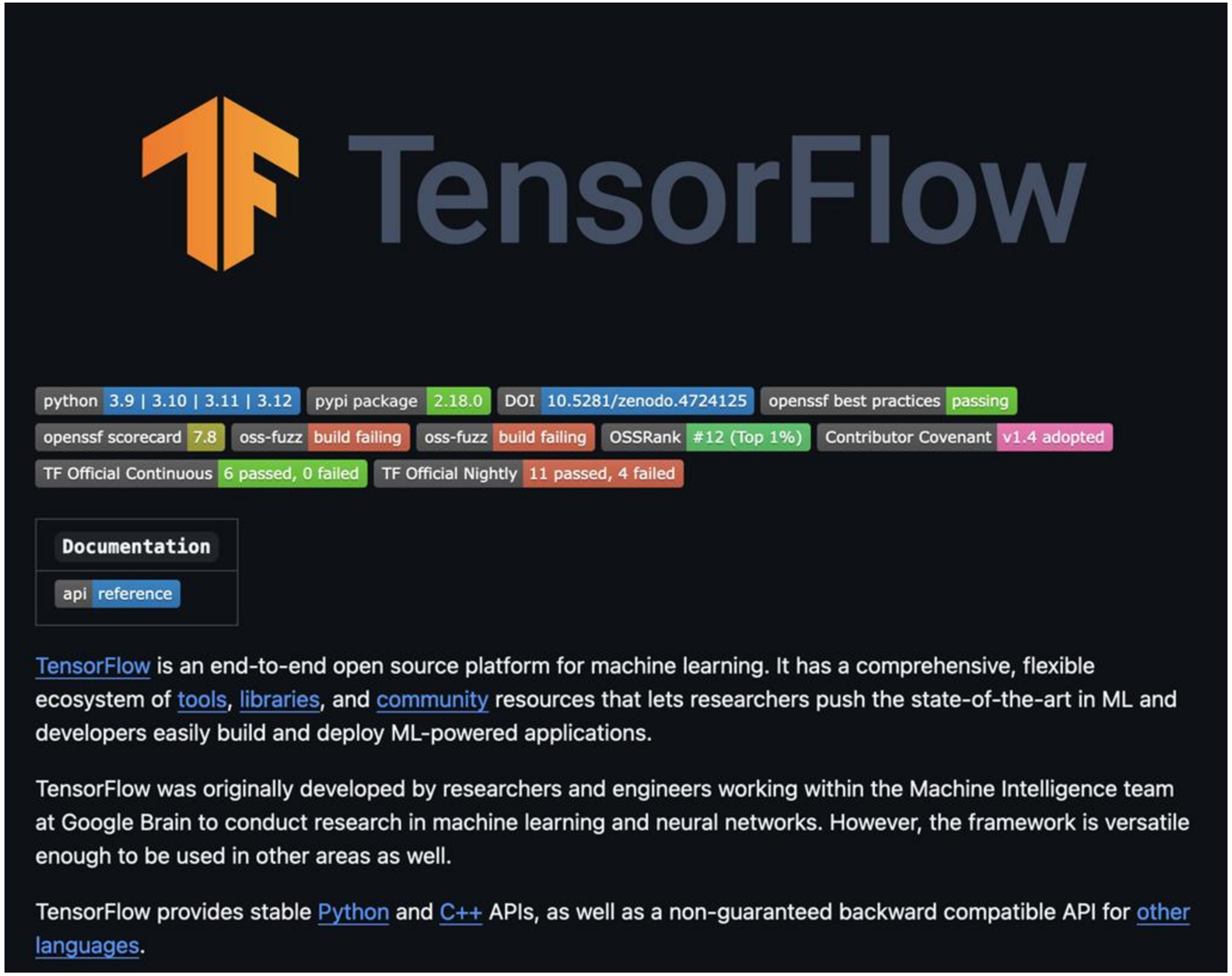
When we write C++ code, it needs to be translated into a form our computer understands it



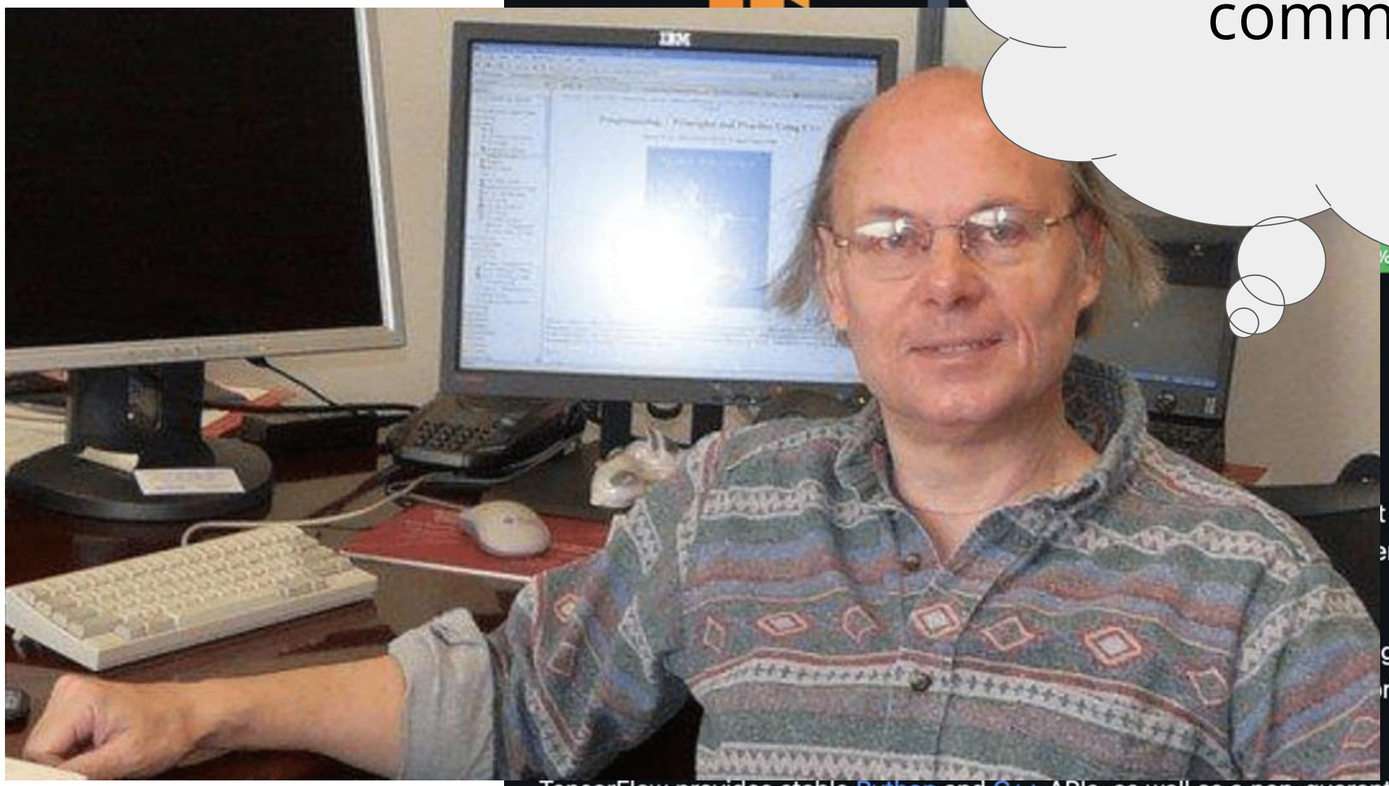

```
$ g++ main.cpp -o main    # g++ is the compiler, outputs binary to main
$ ./main                  # This actually runs our program
```



Even the masterpiece among us



The TensorFlow Core is written largely in C++ and it is composed of 2,000+ **source files**



Lol, that’s a cute command 😭

passing

Contributor Covenant v1.4 adopted

t has a comprehensive, flexible
ers push the state-of-the-art in ML and

g within the Machine Intelligence team
rks. However, the framework is versatile

TensorFlow provides stable Python and C++ APIs, as well as a non-guaranteed backward compatible API for other languages.

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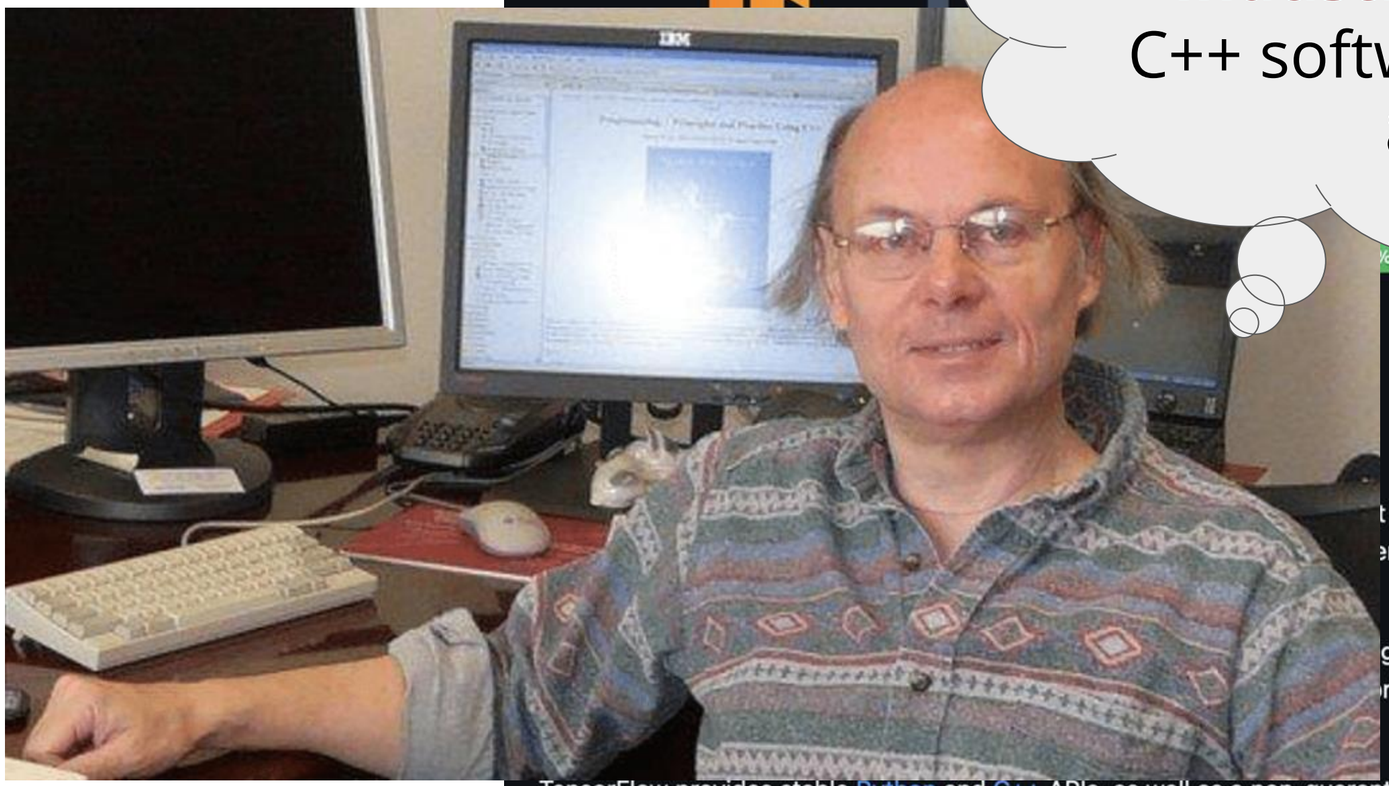

More on compiling and building **industry-grade** C++ software week 8!


```
$ g++ main.cpp -o main    # g++ is the compiler, outputs binary to main
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```

A recap of today!

- Use uniform initialization — it works for all types and objects!
- References are a way to alias variables!
- You can only reference an l-value!
- **`const`** is a way to ensure that you can’t modify a variable