# CS106L Lecture 3:
# Initialization & References 

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# Attendance

# Quick reminder

Second assignment goes out on **Friday, January 17th** and is due **Friday, January 24th.**

# Anonymous Feedback Form

https://tinyurl.com/feedbackW25

# On pacing

# A quick recap

1. **`auto`:** a keyword that tells the compiler to deduce the type of an object or variable

# 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

```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;

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

    // vs
    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

# Initialization

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

**How? 🤔:**

**1. Direct initialization**

2. Uniform initialization

3. Structured Binding

# 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

```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?

**NO**

**C++ Doesn't Care**

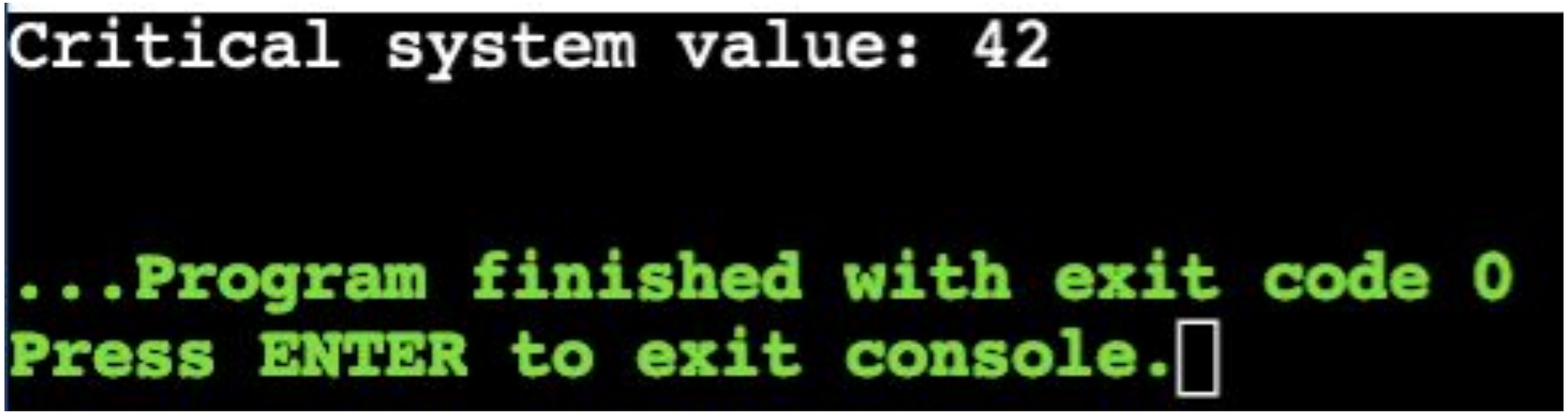
😱

```
numOne is: 12
numTwo is: 12


...Program finished with exit code 0
Press ENTER to exit console.
```

# Problem? 🧐

```cpp
#include <iostream>

int main() {
    // Direct initialization with a floating-point value
    int criticalSystemValue(42.5);

    // Critical system operations...
    // ...

    std::cout << "Critical system value: " << criticalSystemValue << std::endl;

    return 0;
}
```

# Problem? 🧐


Critical system value: 42
...Program finished with exit code 0
Press ENTER to exit console.

# Recall

```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?

**NO**

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```
numOne is: 12
numTwo is: 12


...Program finished with exit code 0
Press ENTER to exit console.
```

# What happened? 🧐

```cpp
#include <iostream>

int main() {
    // Direct initialization with a floating-point value
    int criticalSystemValue(42.5);

    // Critical system operations...
    // ...

    std::cout << "Critical system value: " << criticalSystemValue << std::endl;

    return 0;
}
```

The user intended to save a float, 42.5, into **`criticalSystemValue`**

# What happened? 🧐

```cpp
#include <iostream>

int main() {
    // Direct initialization with a floating-point value
    int criticalSystemValue(42.5);

    // Critical system operations...
    // ...

    std::cout << "Critical system value: " << criticalSystemValue << std::endl;

    return 0;
}
```

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

# What happened? 🧐

```cpp
#include <iostream>

int main() {
    // Direct initialization with a floating-point value
    int criticalSystemValue(42.5);

    // Critical system operations...
    // ...

    std::cout << "Critical system value: " << criticalSystemValue << std::endl;

    return 0;
}
```

So C++ said “Meh, I’ll store 42.5 as an int,” and we possibly now have an error. This is commonly called a **narrowing conversion**

# Initialization

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

**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!!:**

the curly braces!

With uniform

# Uniform initialization (C++11)

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

    std::cout << "numOne is.                    :endl;
    std::cout << "numTwo is:                    :endl;
}
```

**Notice!!:**

the curly braces!

With uniform initialization C++

```
narrowing_conversion.cpp:5:16: error: type 'double' cannot be narrowed to 'int' in
 initializer list [-Wc++11-narrowing]
    int numOne{12.0};
               ^~~~
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1 error generated.
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**Notice!!:**

12 instead of 12.0

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int main() {
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    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 :o)

# 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 :o)

1. 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;
}
```

# Uniform initialization (Map)

```cpp
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#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;
}
```

```
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)

```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;
}
```

```
1 2 3 4 5
```

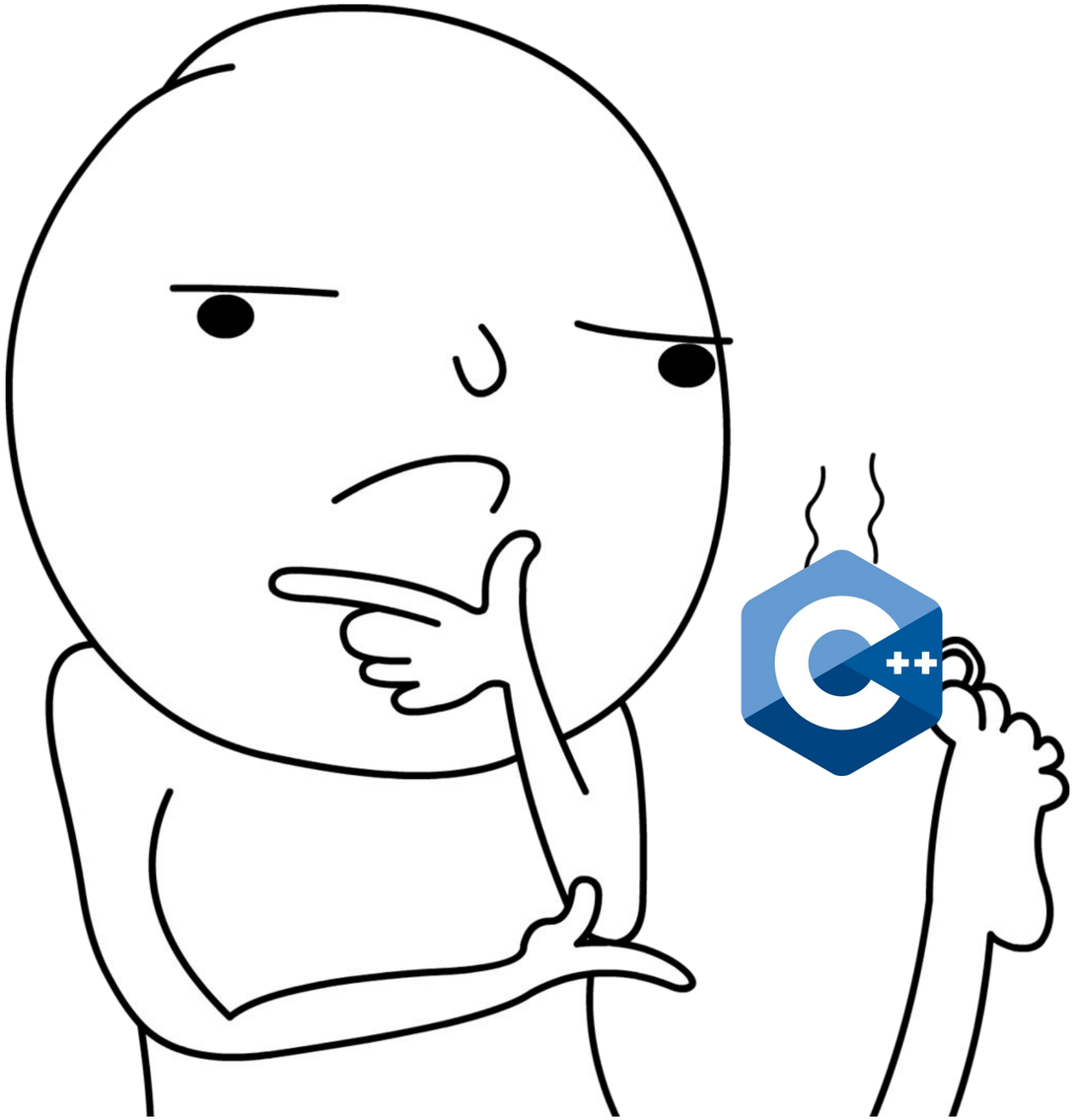
# Recall

## List Initialization

```
StanfordID id;
id.name = "Jacob Roberts-Baca";
id.sunet = "jtrb";
id.idNumber = 6504417;
```


```
// Order depends on field order in struct. '=' is optional
StanfordID jrb = { "Jacob Roberts-Baca", "jtrb", 6504417 };
StanfordID fi { "Fabio Ibanez", "fibanez", 6504418 };
```

# 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
std::tuple<std::string, std::string, std::string> getClassInfo() {
    std::string className = "CS106L";
    std::string buildingName = "Turing Auditorium";
    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;
}
```

# Structured Binding (C++ 17)

```cpp
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;
}
```

Notice - uniform initialization!

# Structured Binding (C++ 17)

```cpp
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;
}
```

# 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 = "Turing Auditorium";
    std::string language = "C++";
    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;
    return 0;
}
```

# Structured Binding (C++ 17)

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#include <iostream>
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std::tuple<std::string, std::string, std::string> getClassInfo() {
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int main() {
    auto classInfo = getClassInfo();
    std::string className = std::get<0>(classInfo);
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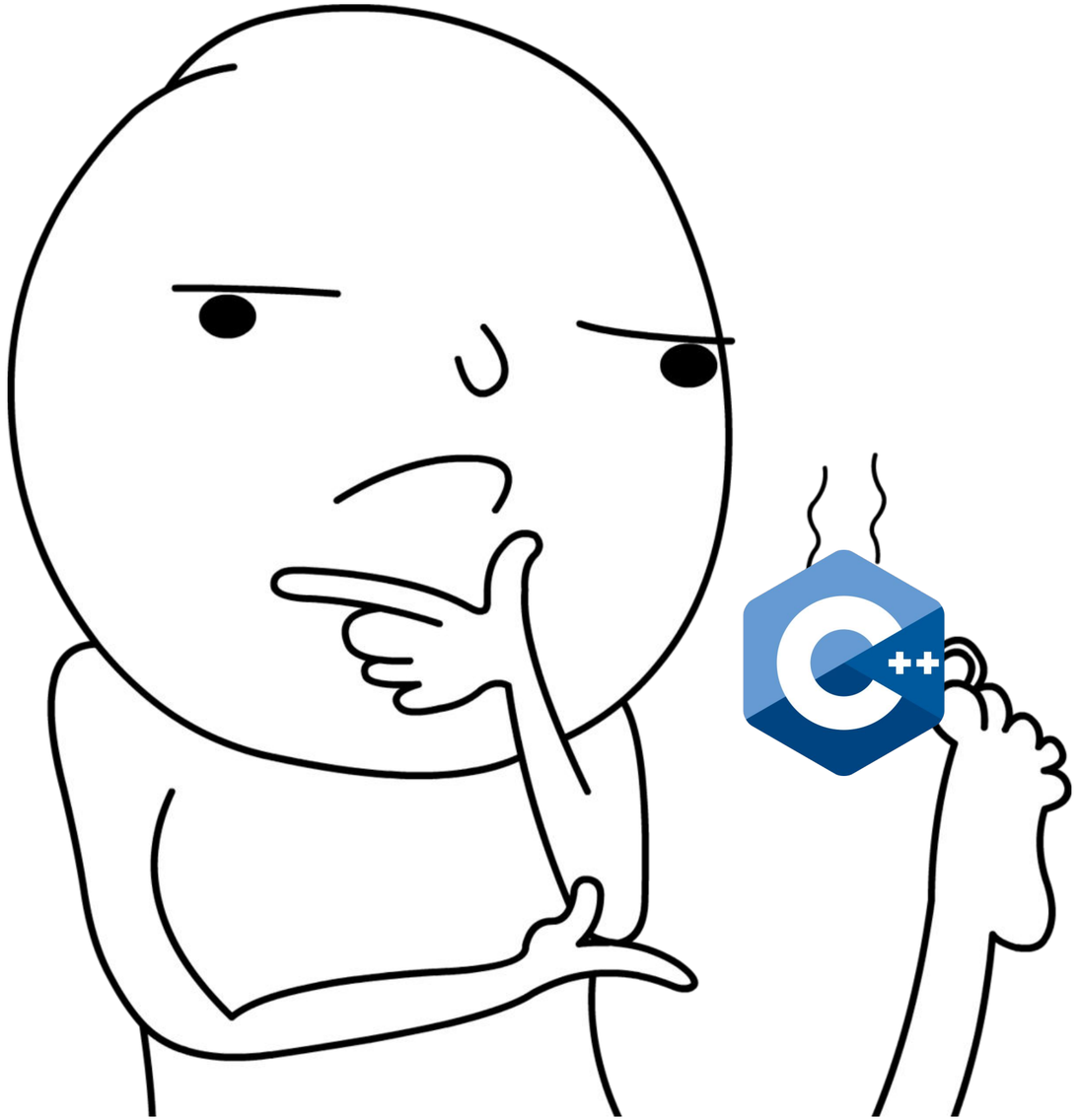
int main() {
    auto [className, buildingName, language] = getClassInfo();
    std::cout << "Come to " << buildingName << " and join us for " << className
              << " to learn " << language << "!" << std::endl;

    return 0;
}
```

# 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*

# References

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

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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

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

ref = 10;  // Assigning a new value through the
reference
std::cout << num << std::endl;  // Output: 10
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`ref` is a variable of type `int&`, that is an *alias* to num

# The & and the how

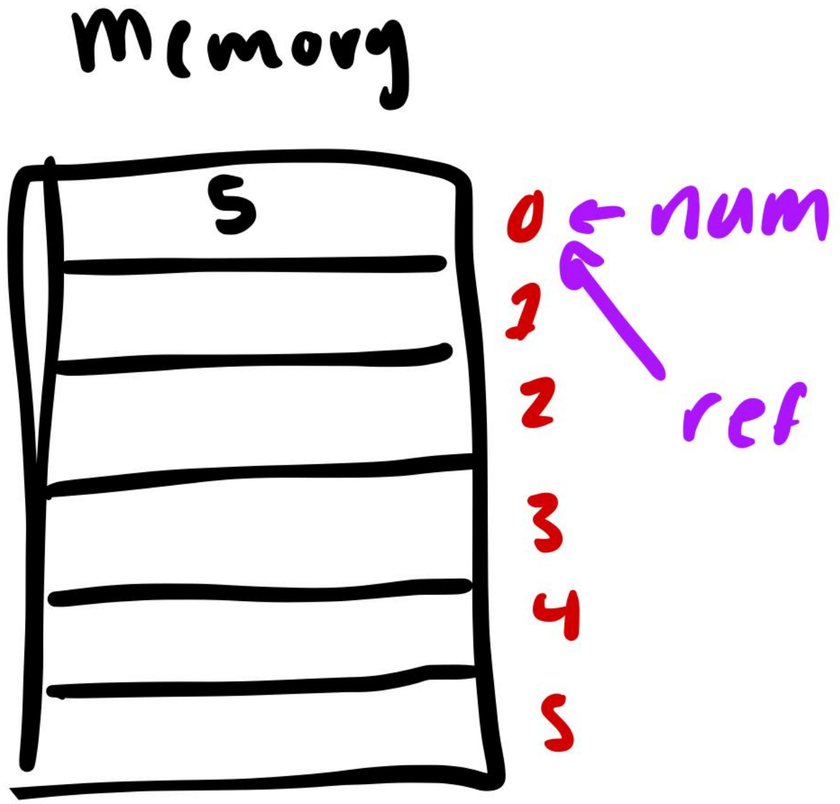
```cpp
int num = 5;
int& ref = num;

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 🖼️

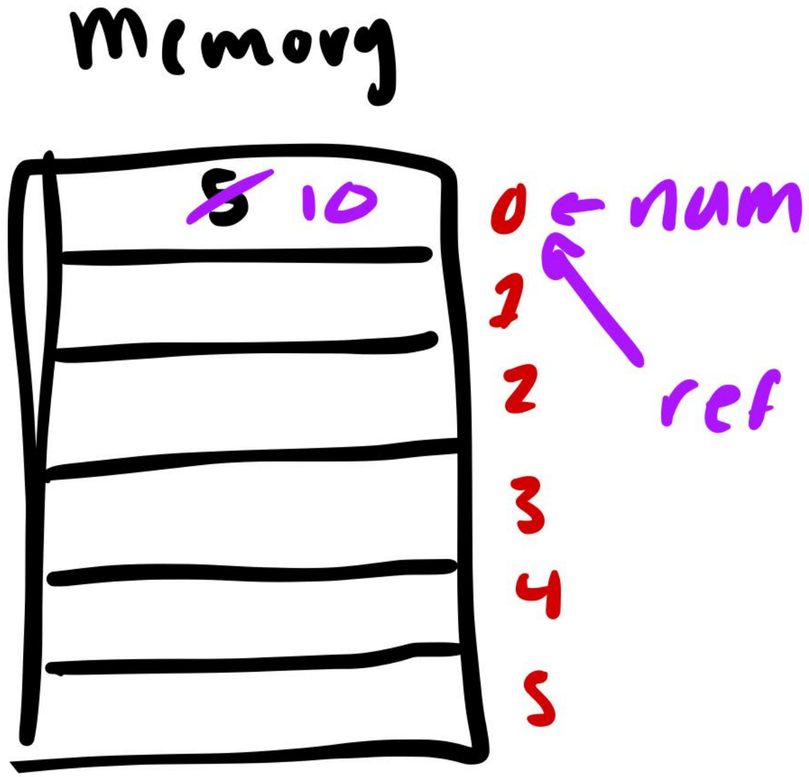

`num` is a variable of type `int`, that is assigned to have the value `5`

# Visually 🖼️




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

# Visually 🖼️

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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 = 2;
    squareN(num);
    std::cout << num << std::endl;

    return 0;
}
```

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

int main() {
    int num = 2;
    squareN(num);
    std::cout << num << std::endl;

    return 0;
}
```

# 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:

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

```
#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 = 2;
    squareN(num);
    std::cout << num << std::endl;

    return 0;
}
```

# 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:

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

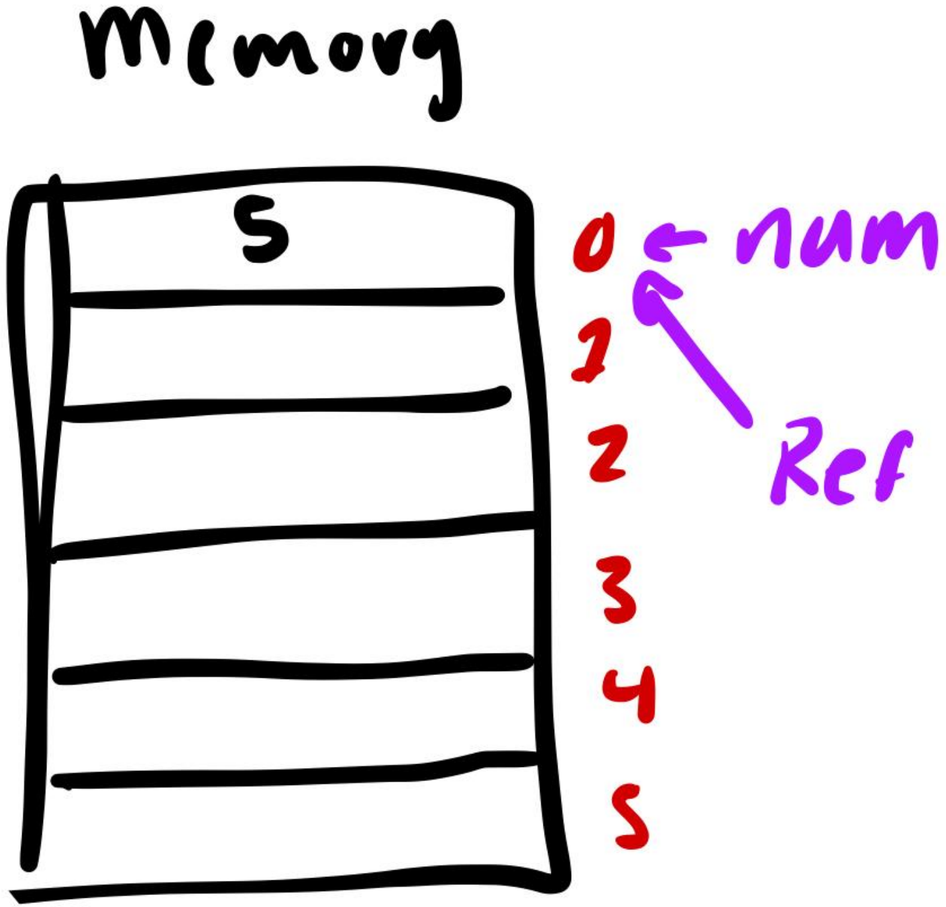
```cpp
#include <iostream>
#include <math.h>

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

int main() {
    int num = 2;
    squareN(num);
    std::cout << num << std::endl;

    return 0;
}
```

# Recall




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

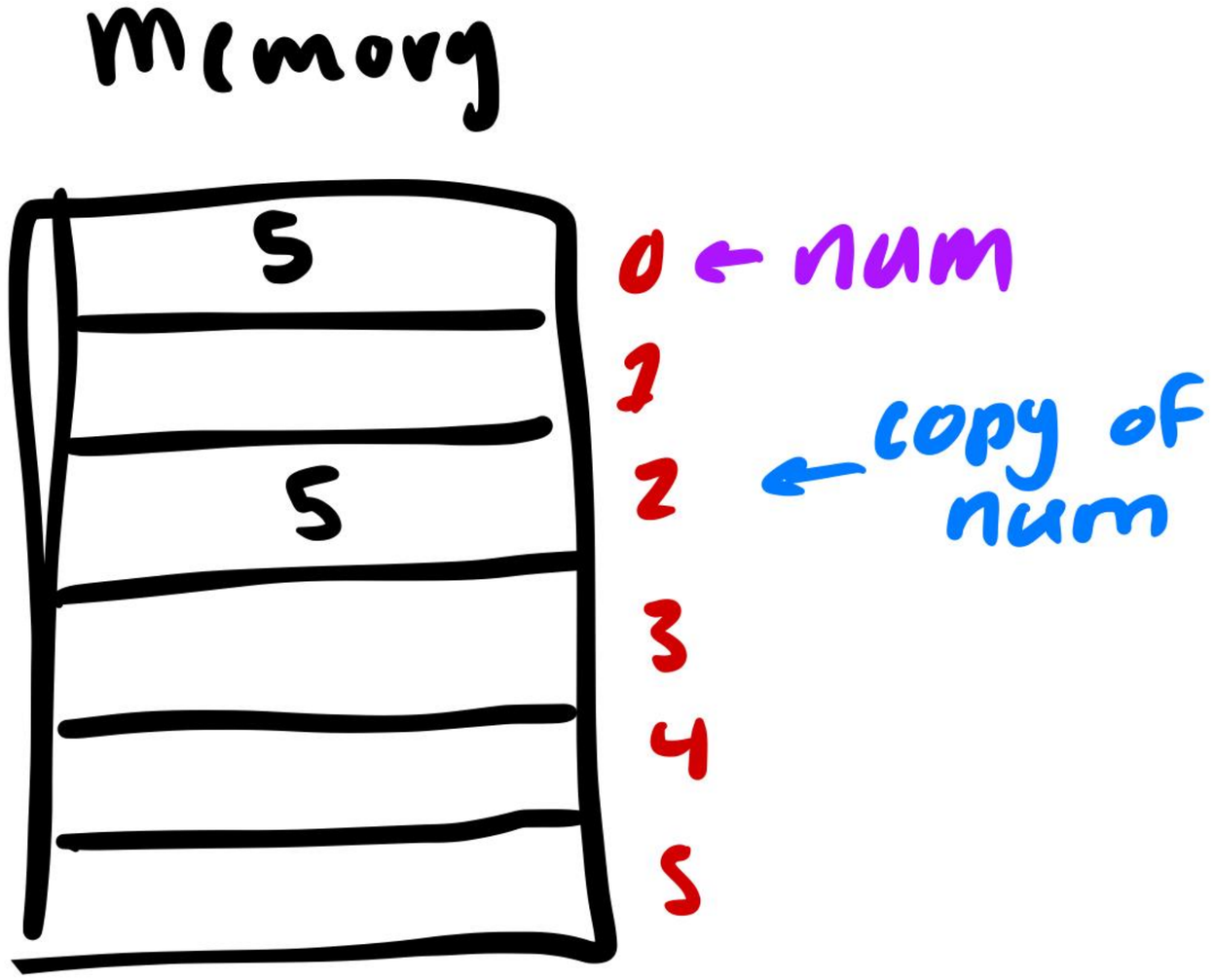
# Recall

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

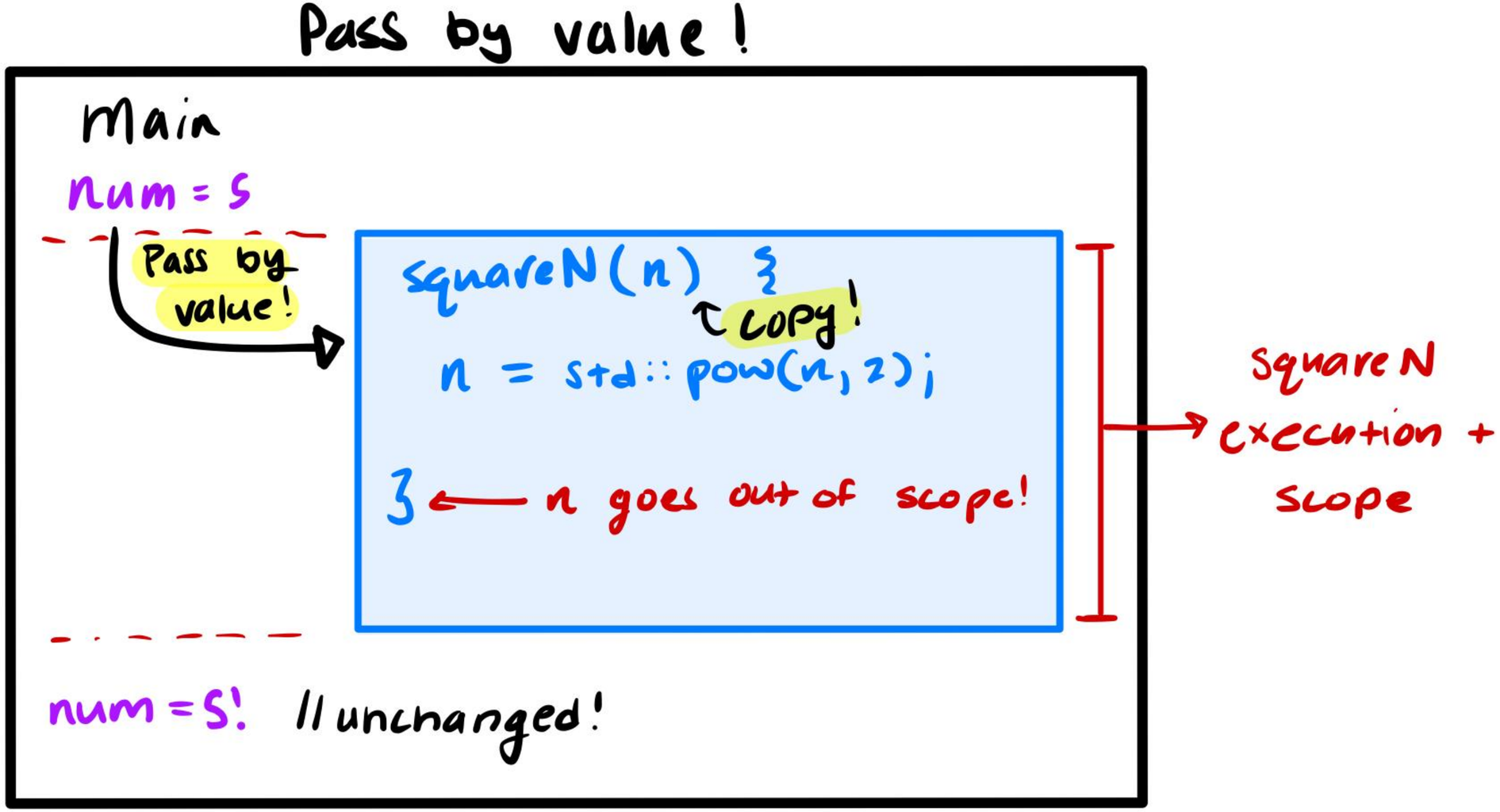
# Passing by value

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

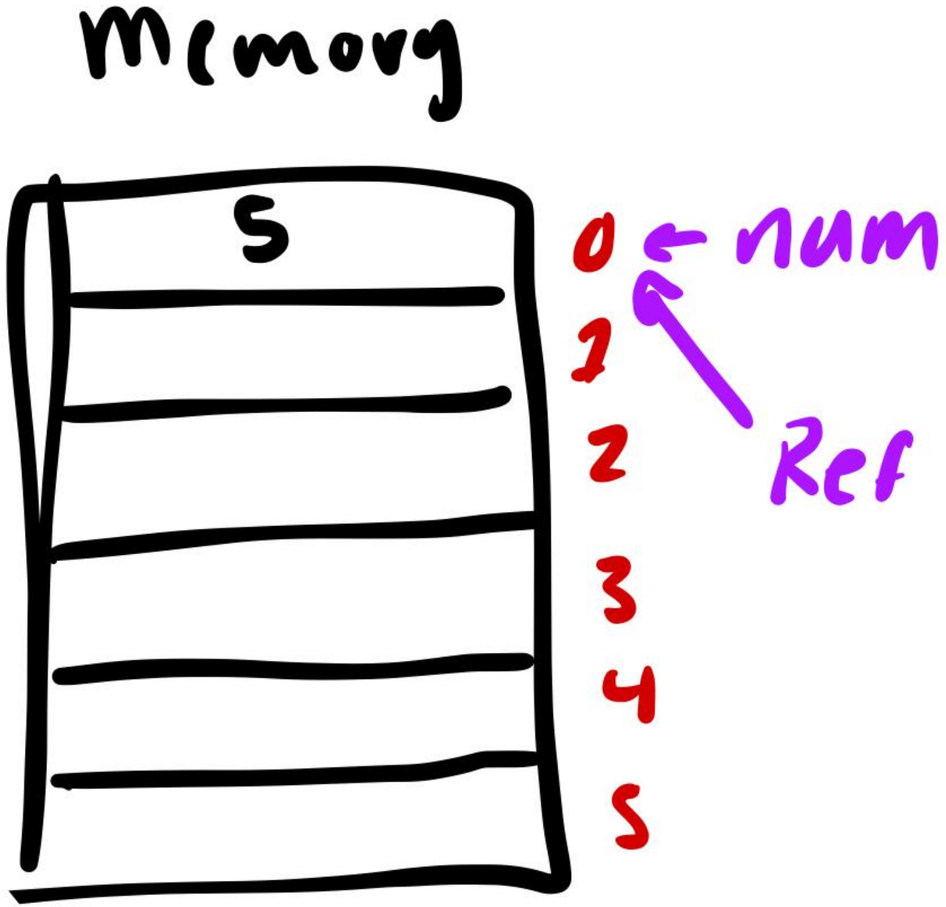
# What does that look like?



# Passing by value (makes a copy)

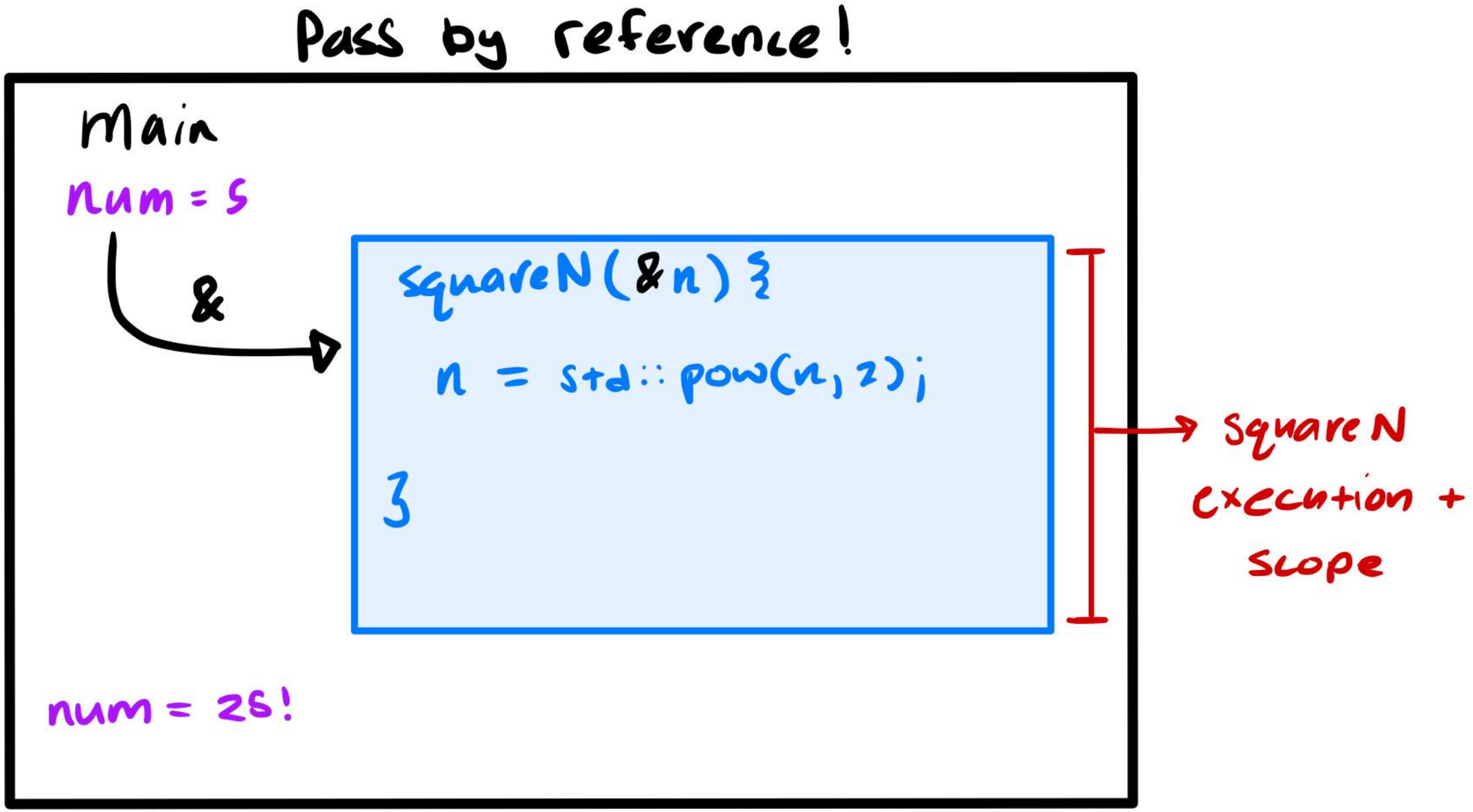


# Recall

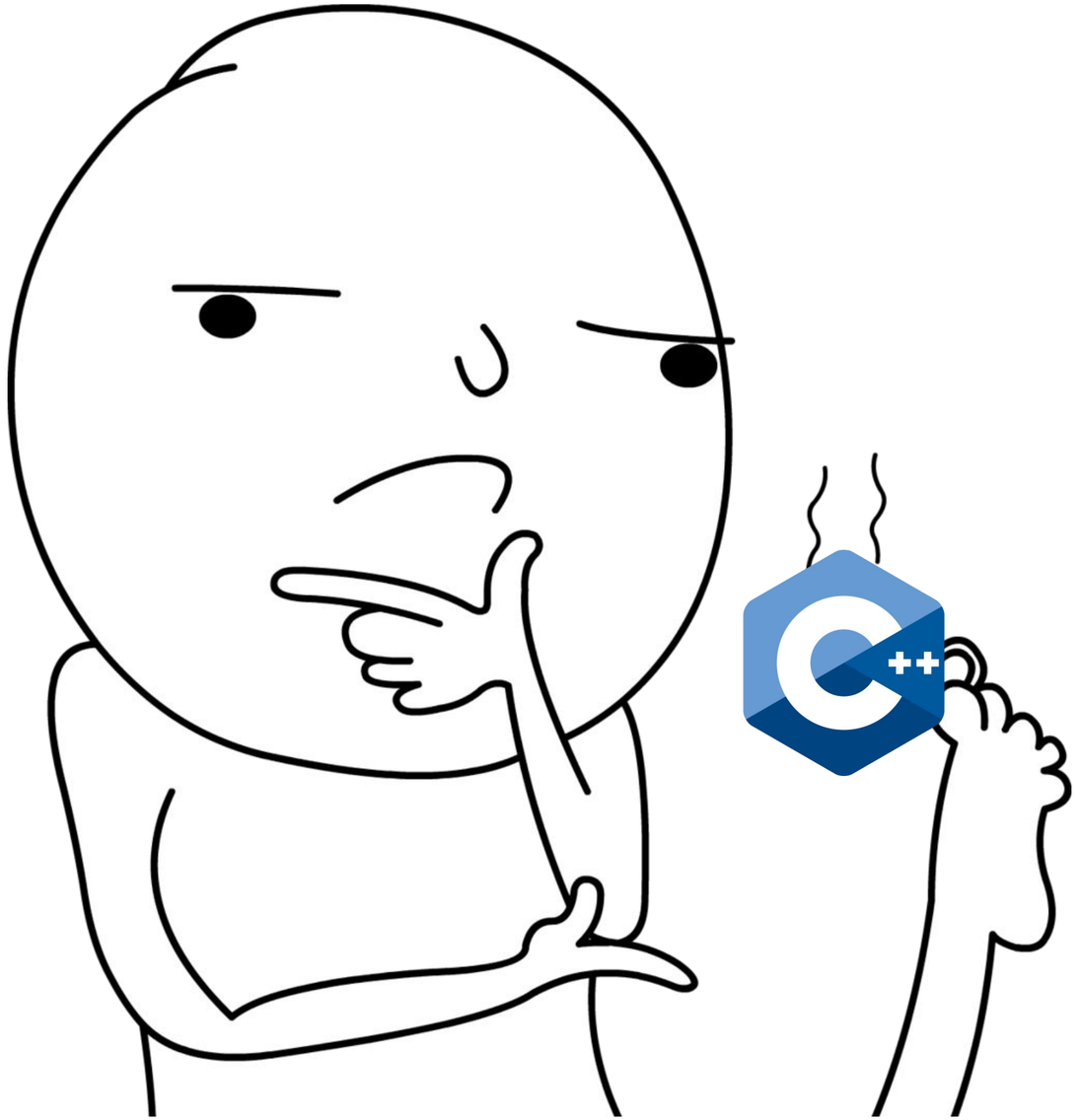



**A reference** *refers* to the same memory as its associated variable!

# Passing by reference



# What questions do we have?



# 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

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

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



🤔 But nums is passed in by reference...

# A classic reference-copy bug

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}
```

**Note the structured binding!**

🤔 But nums is passed in by reference...

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

# A classic reference-copy bug

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

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>

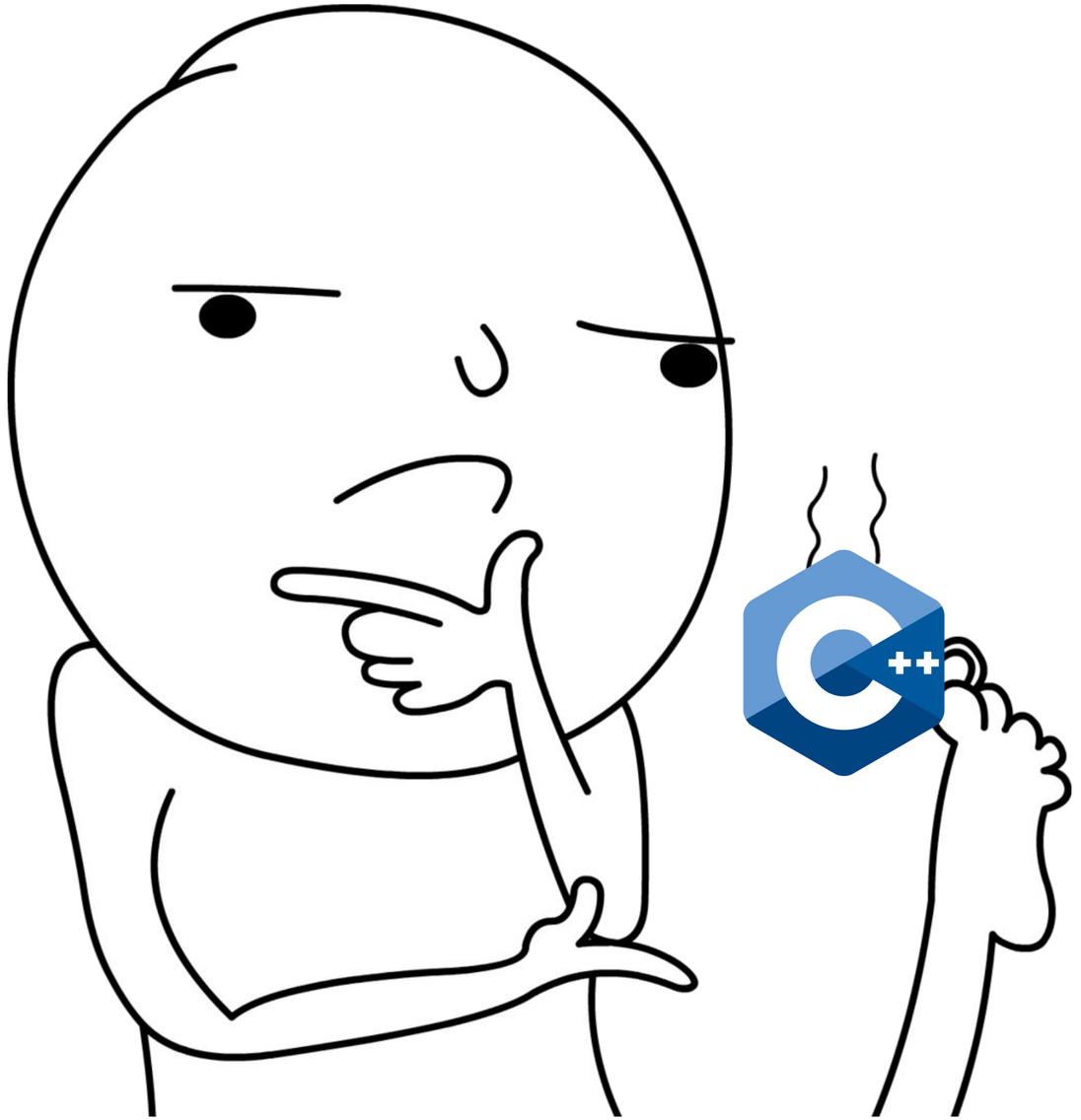
void shift(std::vector<std::pair<int, int>> &nums) {
    for (auto& [num1, num2] : nums) {
        num1++;
        num2++;
    }
}
```

# A note, this also works!

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

void shift(std::vector<std::pair<int, int>> &nums) {
    for (size_t int i = 0; i < num.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 |
|---|---|---|
| **Where with respect to equal sign?** | left or right | right |
| **Example** | `int x = 10;`<br>`int y = x;` | `int x = 10;`<br>`int y = x;` |

# l-value and r-value PAIN

```cpp
#include <stdio.h>
#include <cmath>
#include <iostream>

int squareN(int& num) {
    return std::pow(num, 2);
}

int main()
{
    int lValue = 2;
    auto four = squareN(lValue);
    auto fourAgain = squareN(2);
    std::cout << four << std::endl;
    return 0;
}
```

# l-value and r-value PAIN

```cpp
#include <stdio.h>
#include <cmath>
#include <iostream>

int squareN(int& num) {
    return std::pow(num, 2);
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int main()
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    int lValue = 2;
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```

is int& num an l-value?

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#include <iostream>

int squareN(int& num) {
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}

int main()
{
    int lValue = 2;
    auto four = squareN(lValue);
    auto fourAgain = squareN(2);
    std::cout << four << std::endl;
    return 0;
}
```

## is `int&` num 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!

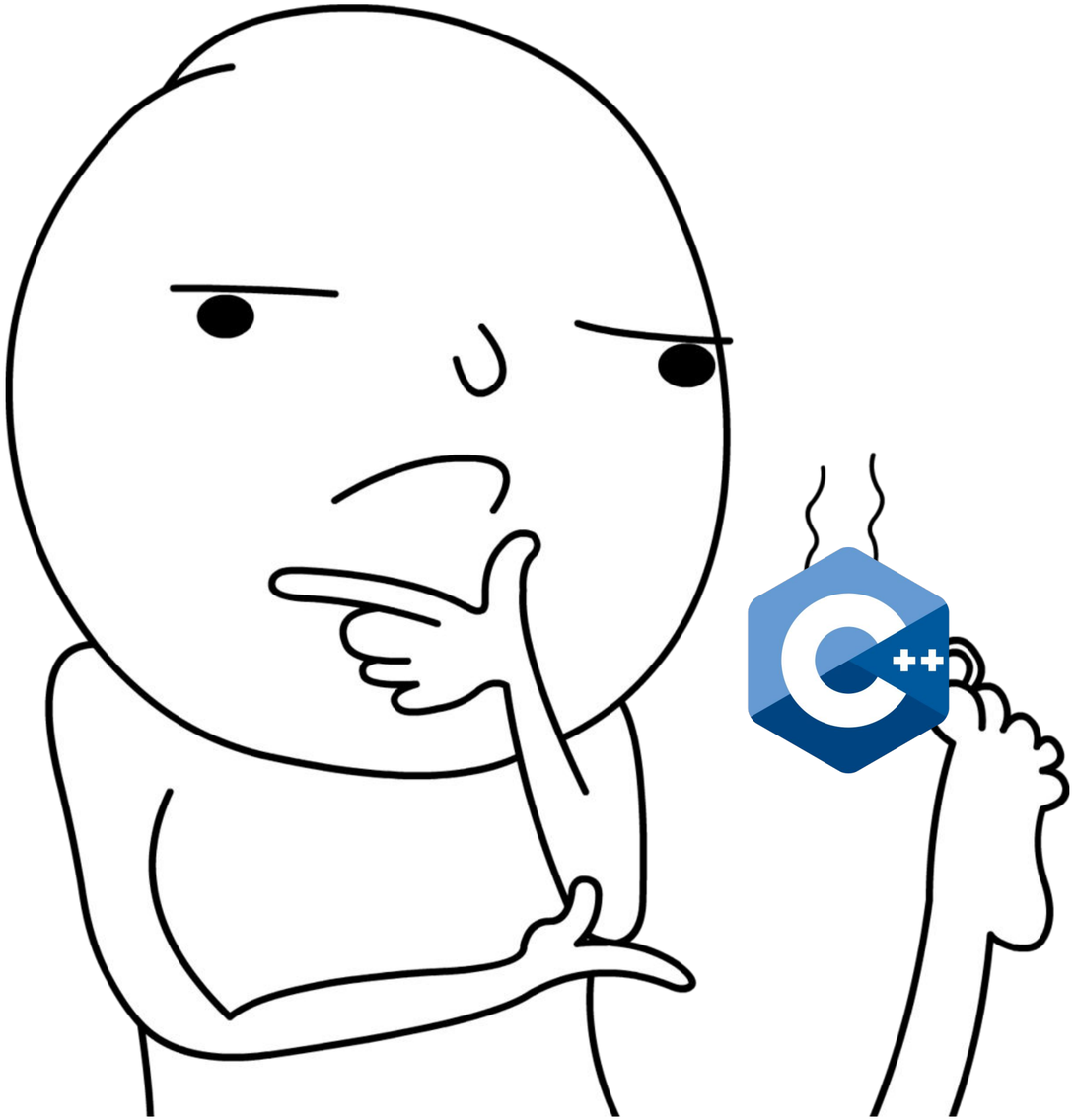
# l-value and r-value PAIN

```cpp
#include <stdio.h>
#include <cmath>
#include <iostream>

int squareN(int& num) {
    return std::pow(num, 2);
}

int main()
{
    int lv
    auto f
    auto f
    std::cout << four << std::endl;
    return 0;
}
```

Well what happens?

```
lvalue_pain.cpp:5:5: note: candidate function not viable: expects an lvalue for 1st
argument
int squareN(int& num) {
    ^
1 error generated.
```

# What questions do we have?



# Plan

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

# `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;
}
```

# const

```cpp
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#include <vector>

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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);
    ref_vec.push_back(3);
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    vec.push_back(3); /// this is ok!
    const_vec.push_back(3); /// no, this is const!
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}
```

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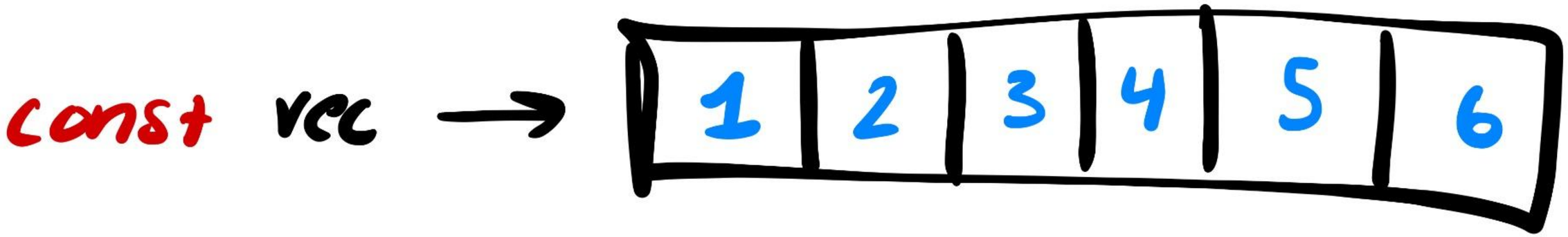
    vec.push_back(3); /// this is ok!
    const_vec.push_back(3); /// no, this is const!
    ref_vec.push_back(3); /// this is ok, just a reference!
    const_ref.push_back(3); /// this is const, compiler error!

    return 0;
}
```

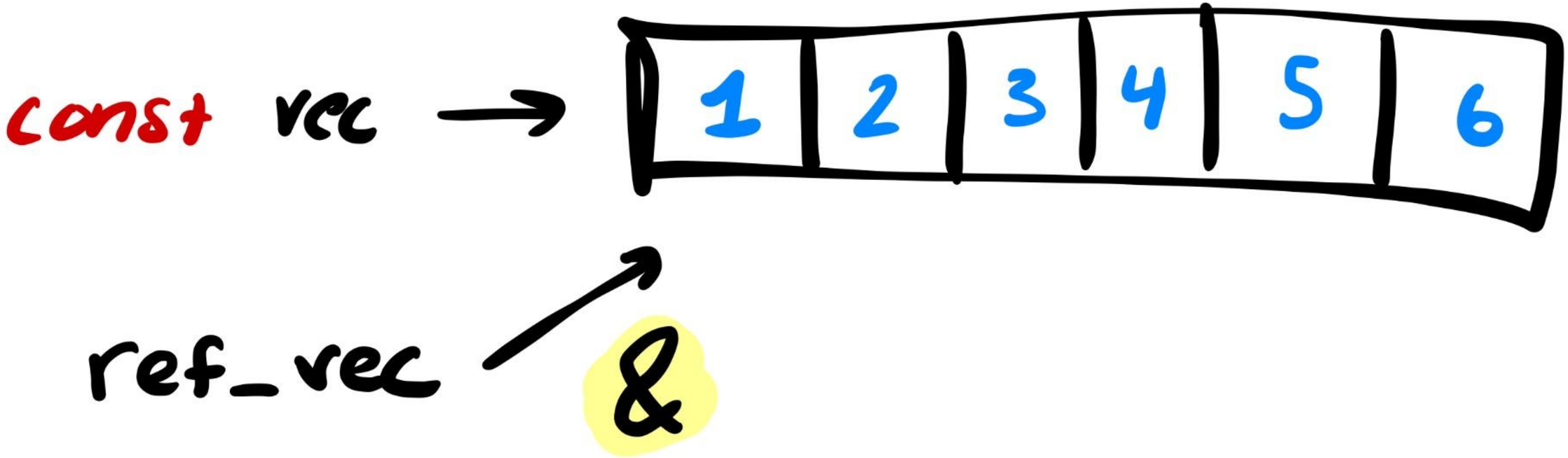
# You can’t declare a non-const reference to a const variable

```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;
}
```

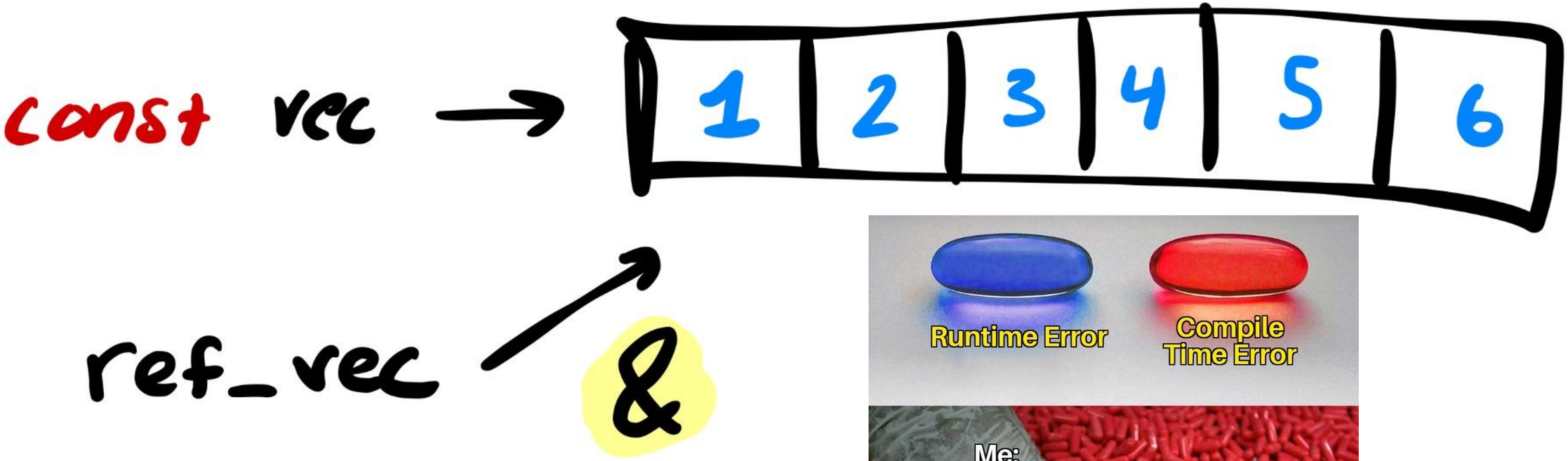
# You can’t declare a non-const reference to a const variable



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



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





[meme sauce]

# 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 };
    const std::vector<int>& bad_ref{ const_vec }; /// Good!

    return 0;
}
```

# Plan

1. Initialization
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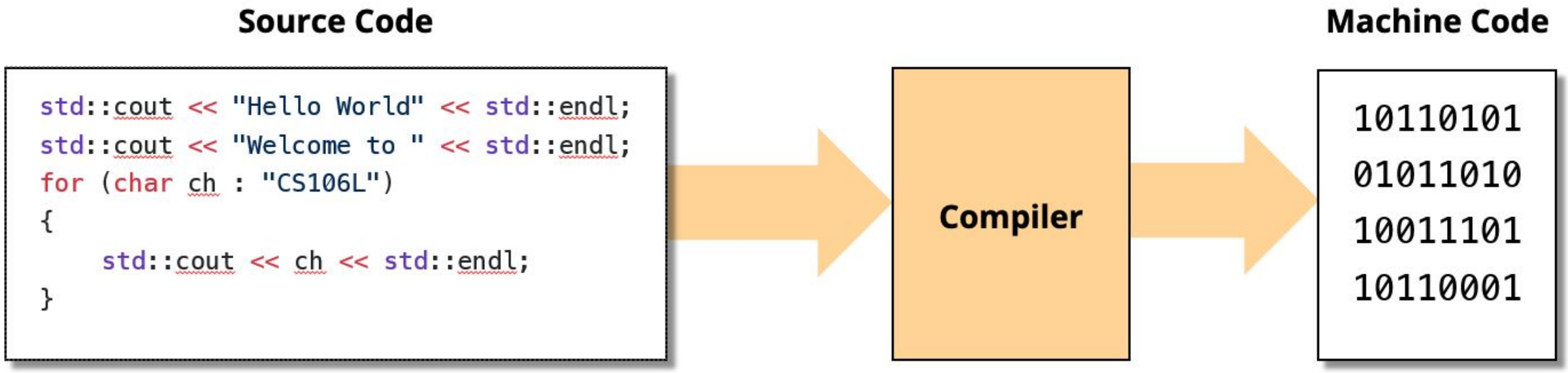
5. **Compiling C++ programs**

# Compiling C++ Programs

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

We'll be making use of VSCode which makes C++ compilation quite easy.

# Compiling C++ Programs



# What you need to know

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```
g++ -std=c++20 main.cpp -o main
```

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g++ -std=c++20 main.cpp -o main
```

This is the compiler command

# 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++20 main.cpp -o main
```

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

# What you need to know

- C++ is a compiled language
- There are computer programs called compilers
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- ***Here is how to compile a program using g++***

```
g++ -std=c++20 main.cpp -o main
```

This is the source file

# 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++***

```
g++ -std=c++20 main.cpp -o main
```

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

# What you need to know

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

```
g++ -std=c++20 main.cpp -o main
```

In this case it's `main`

# 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++***

```
g++ -std=c++20 main.cpp
```

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

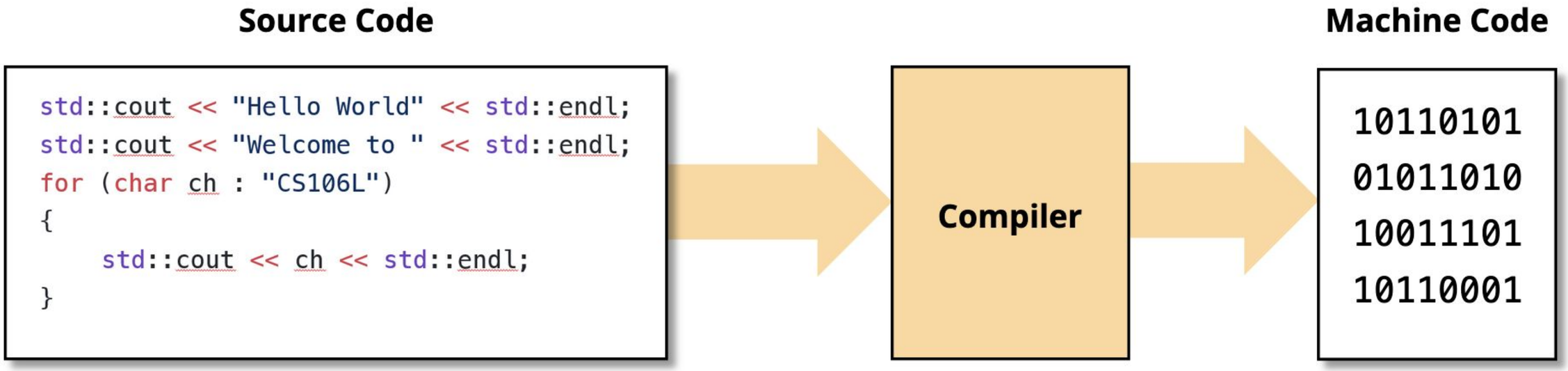
# What you need to know

- 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++***

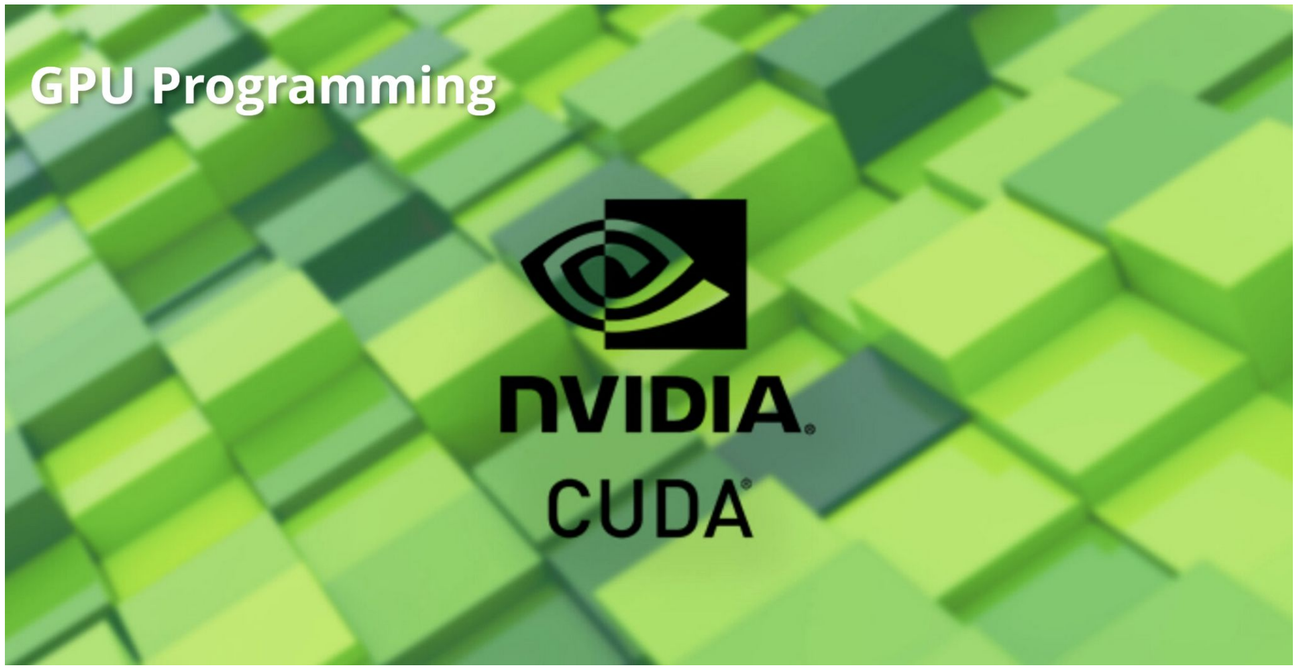
```
g++ -std=c++20 main.cpp
```

# What you need to know

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

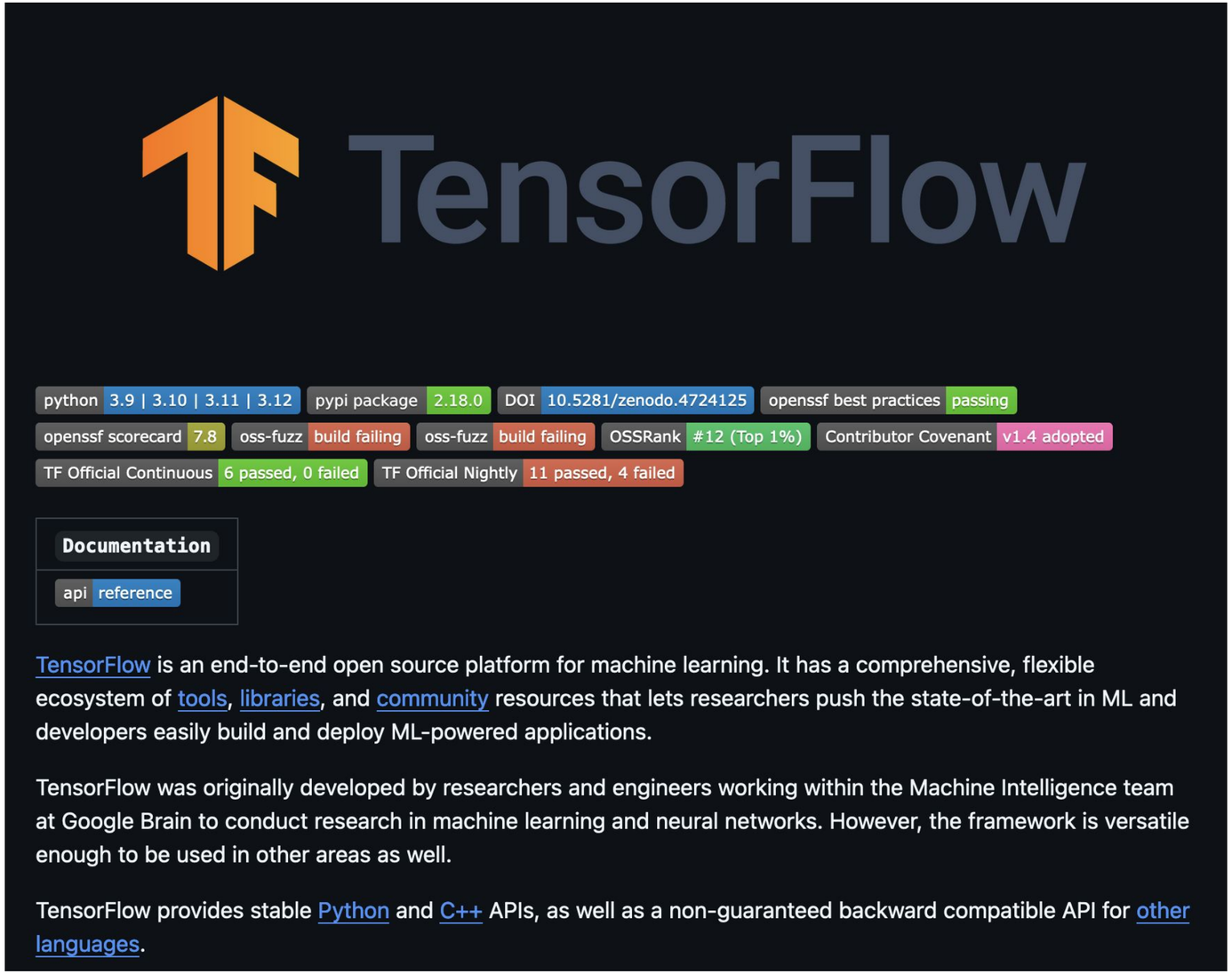



```
$ g++ main.cpp -o main    # g++ is the compiler, outputs binary to main
$ ./main                  # This actually runs our program
```

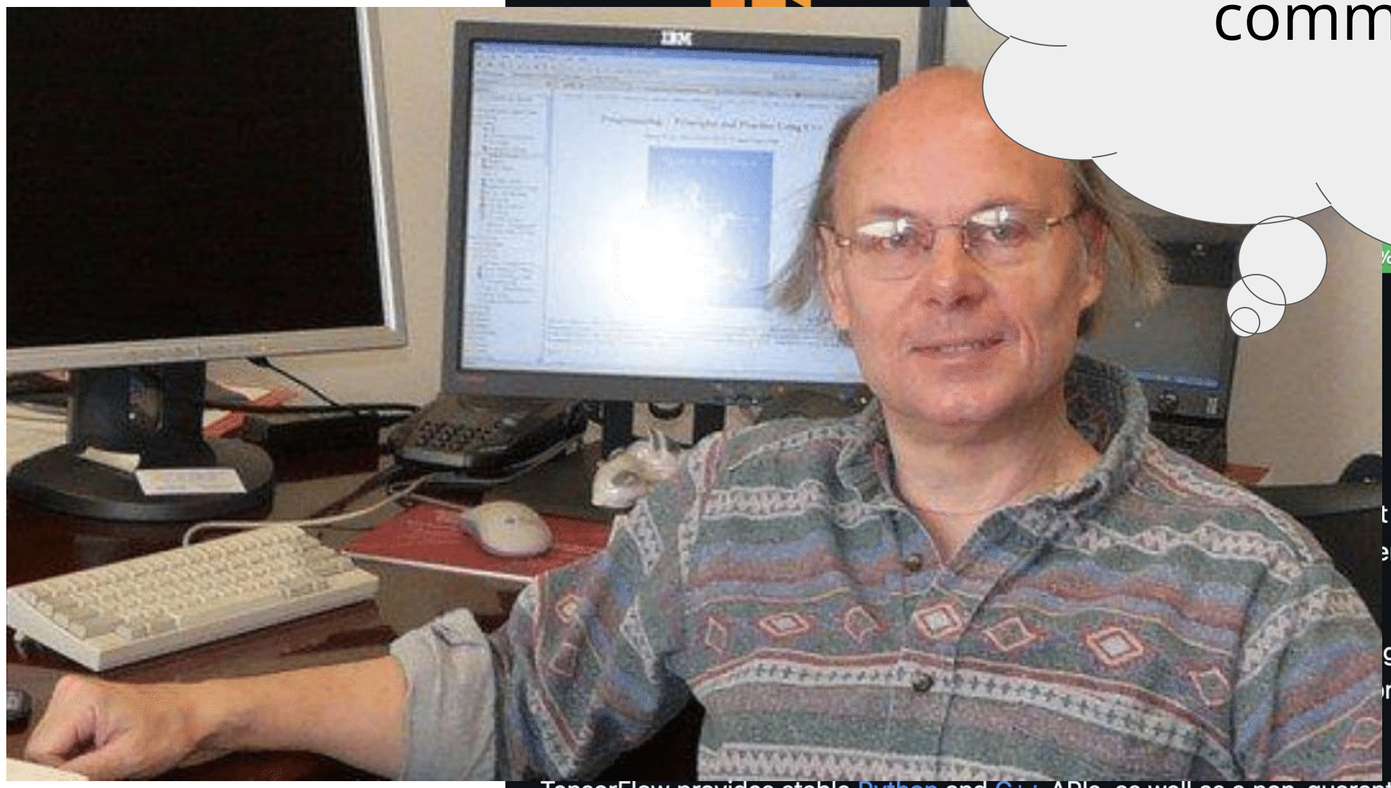





Even the masterpiece among us




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
orks. 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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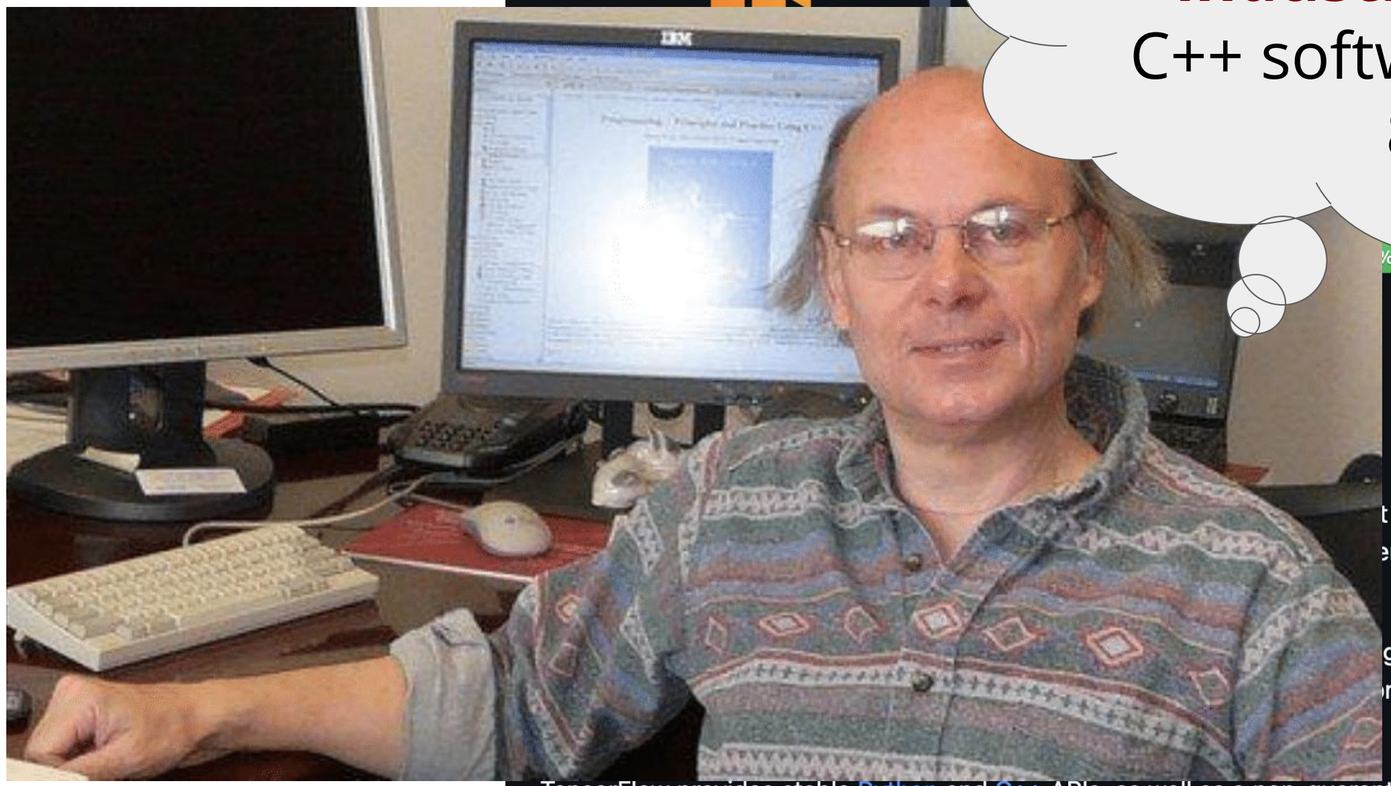

More on compiling and building **industry-grade** C++ software week 8!

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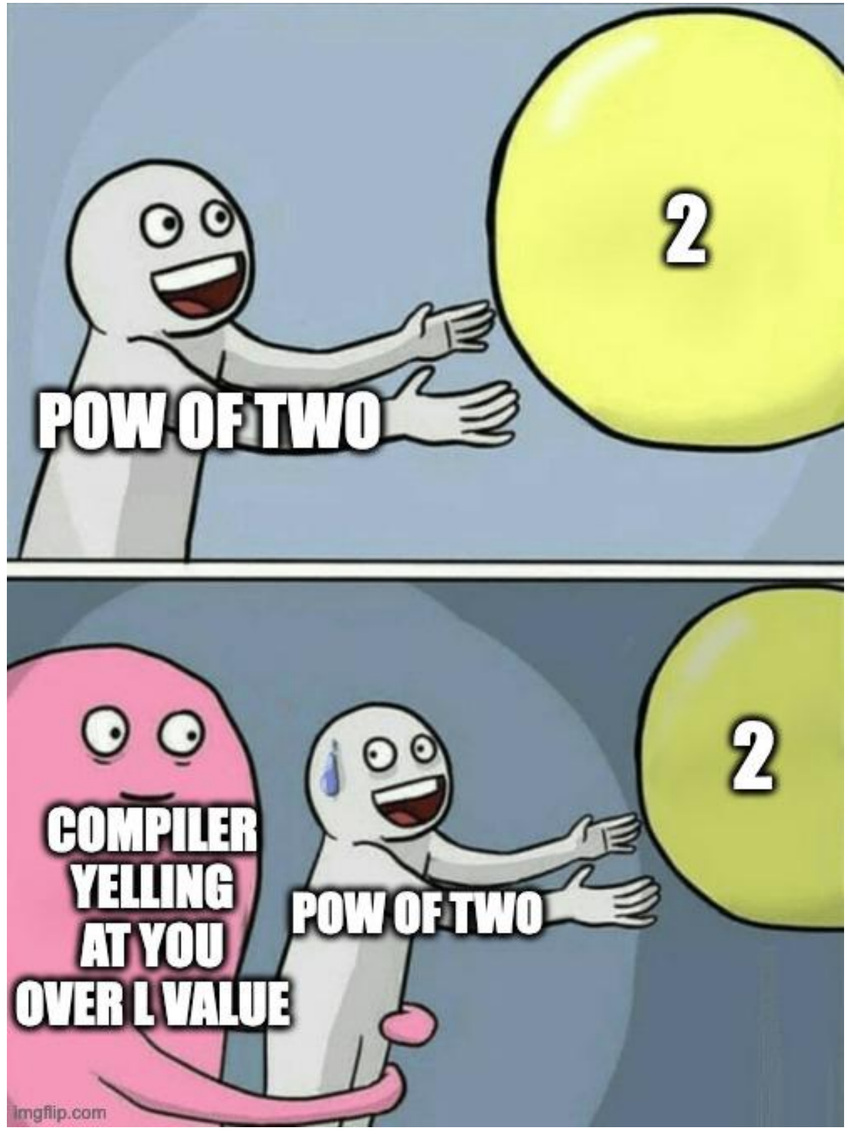
# A recap of today!




**In conclusion**

- 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