

CS106L Lecture 3:

Initialization & References 🦄

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Attendance



Quick reminder

Second assignment goes out on **Friday, April 11th** and is due **Friday, April 18th**.

Anonymous Feedback Form

<https://tinyurl.com/feedbackS25>

On pacing



A quick recap

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

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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

```
#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

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How? 🤔:

1. Direct initialization

2. Uniform initialization

3. Structured Binding

Direct initialization

```
#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

```
#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;

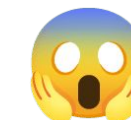
    return 0;
}
```

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? 🤔

```
void checkCool() {  
    if (temperature > 100.0) {  
        std::cout << "Emergency cooling activated!" << std::endl;  
    } else {  
        std::cout << "Temperature normal. No emergency cooling required."  
    }  
}  
  
int main() {  
    Reactor reactor(criticalTemperature);  
    reactor.checkCool();  
  
    return 0;  
}
```



Recall

```
#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.
```

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

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)

```
#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)

```
#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

initialization C++

Uniform initialization (C++11)

```
#include <iostream>
```

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

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

```
narrowing_conversion.cpp:5:16: error: type 'double' cannot be narrowed to 'int' in  
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    int numOne{12.0};
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narrowing_conversion.cpp:5:16: note: insert an explicit cast to silence this issue
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```
    int numOne{12.0};
```

```
        static_cast<int>( )
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1 error generated.
```



Notice!!:

the curly braces!

With uniform

initialization C++

Uniform initialization (C++11)

```
#include <iostream>

int main() {
    // Notice the brackets
    int numOne{12};
    float numTwo{12.0};

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

    return 0;
}
```

Notice!!:

12 instead of 12.0



Uniform initialization (C++11)

```
#include <iostream>

int main() {
    // Notice the brackets
    int numOne{12};
    float numTwo{12.0};

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

    return 0;
}
```

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

Notice!!:

12 instead of 12.0



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)

```
#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)

```
#include <iostream>
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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)

```
#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)

```
#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;
```

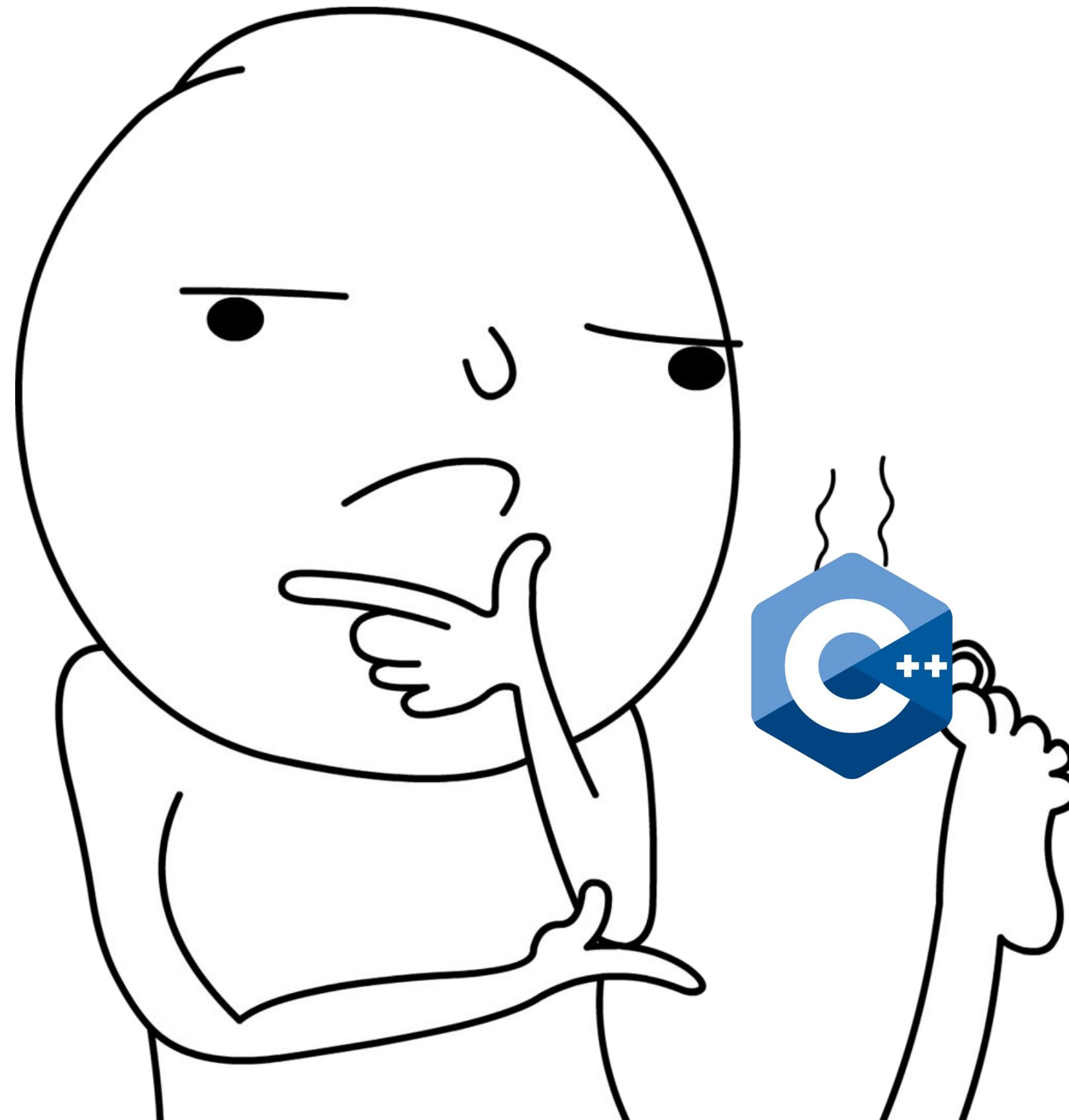


We'll learn more
about this next time!



```
// 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)

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

std::tuple<std::string, std::string, std::string> getClassInfo() {
    std::string className = "CS106L";
    std::string buildingName = "260-113";
    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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    return {className, buildingName, language};
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```

Notice - uniform initialization!

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int main() {
    auto [className, buildingName, language] = getClassInfo();
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    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;
}
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}
```



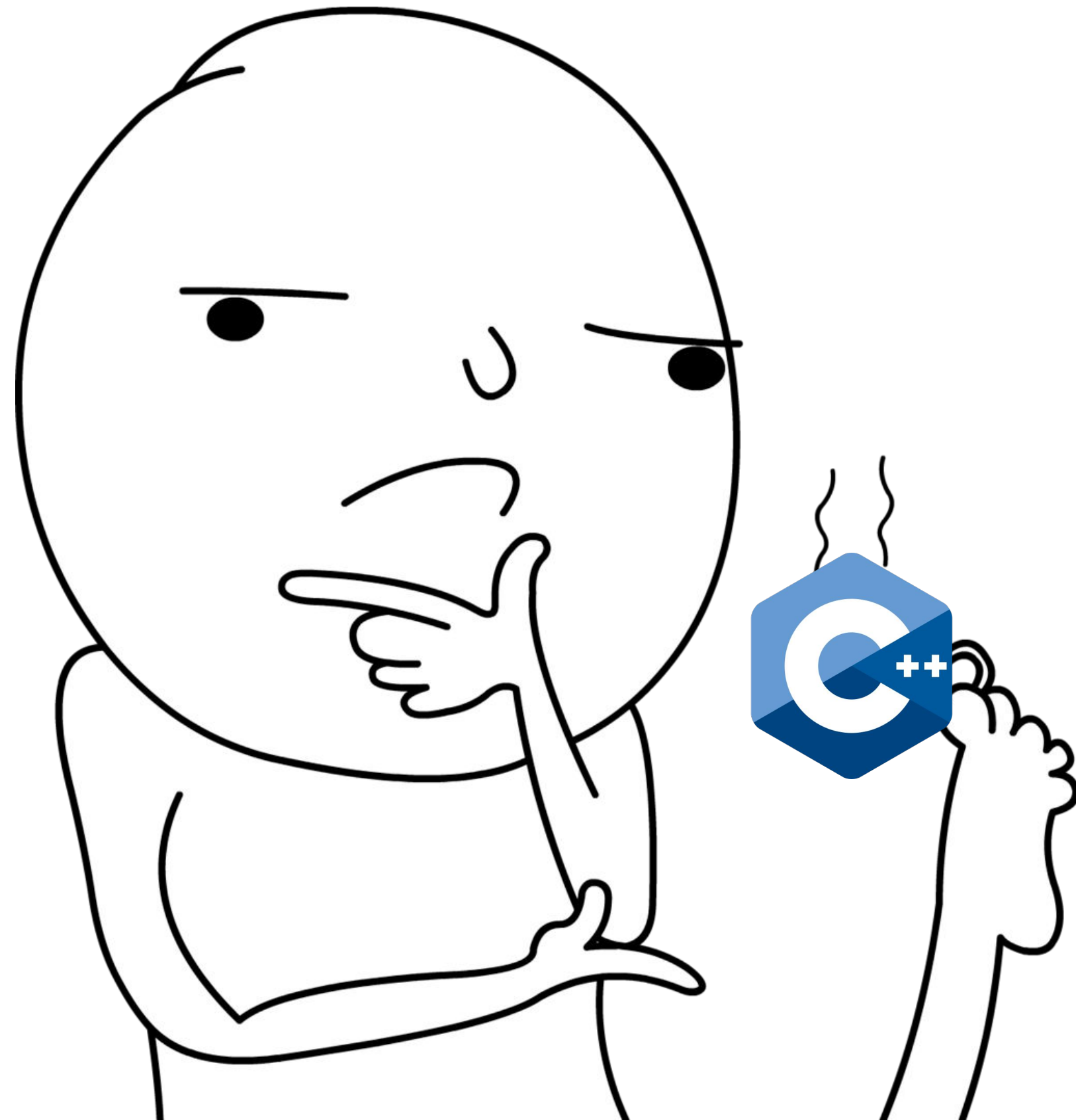
```
int main() {
    auto [className, buildingName, language] = getClassInfo();
    std::cout << "Come to " << buildingName << " and join us for " << className
              << " to learn " << language << "!" << std::endl;

    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

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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  
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std::cout << num << std::endl;    // Output: 10
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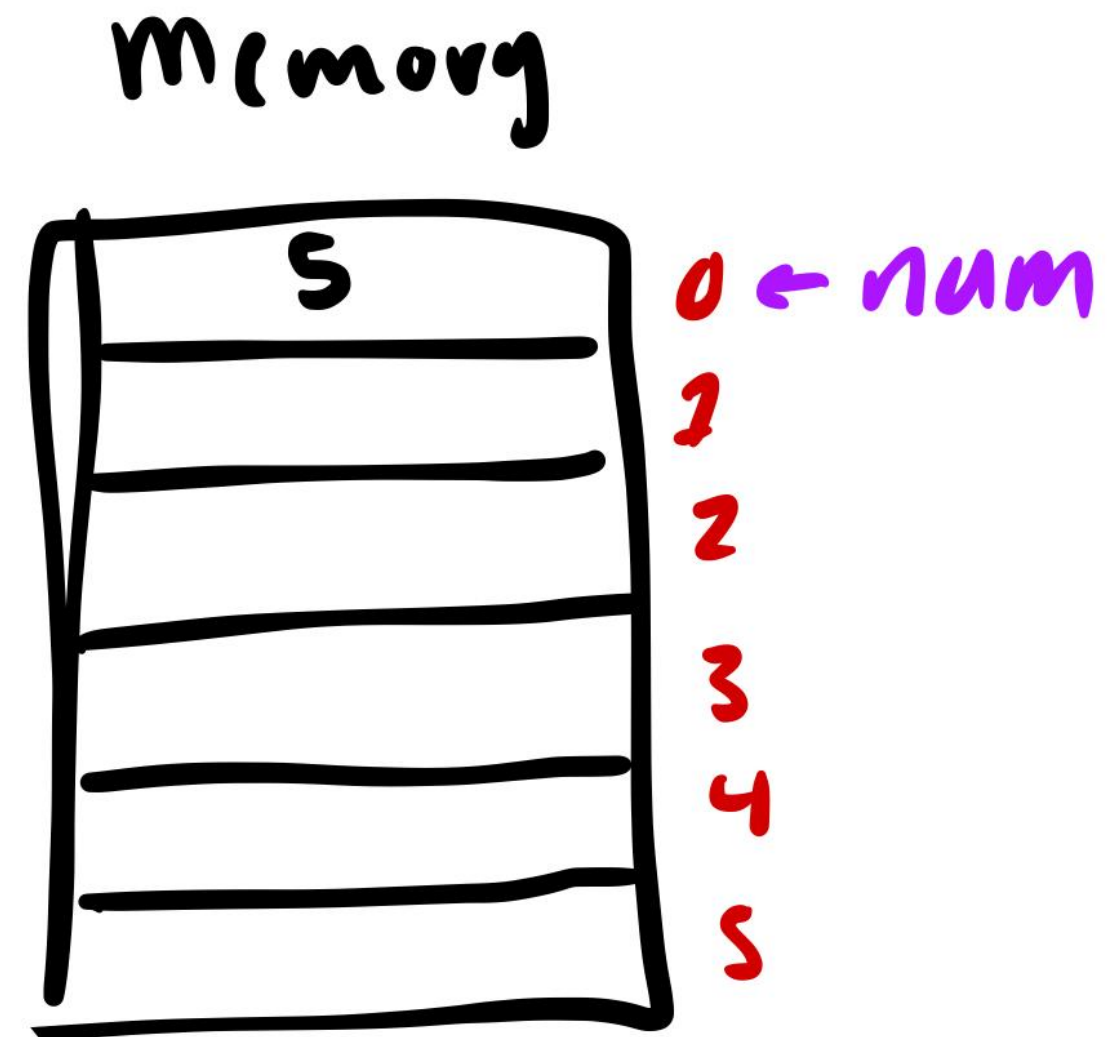
ref is a variable of type `int&`, that is an alias to `num`

The & and the how

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

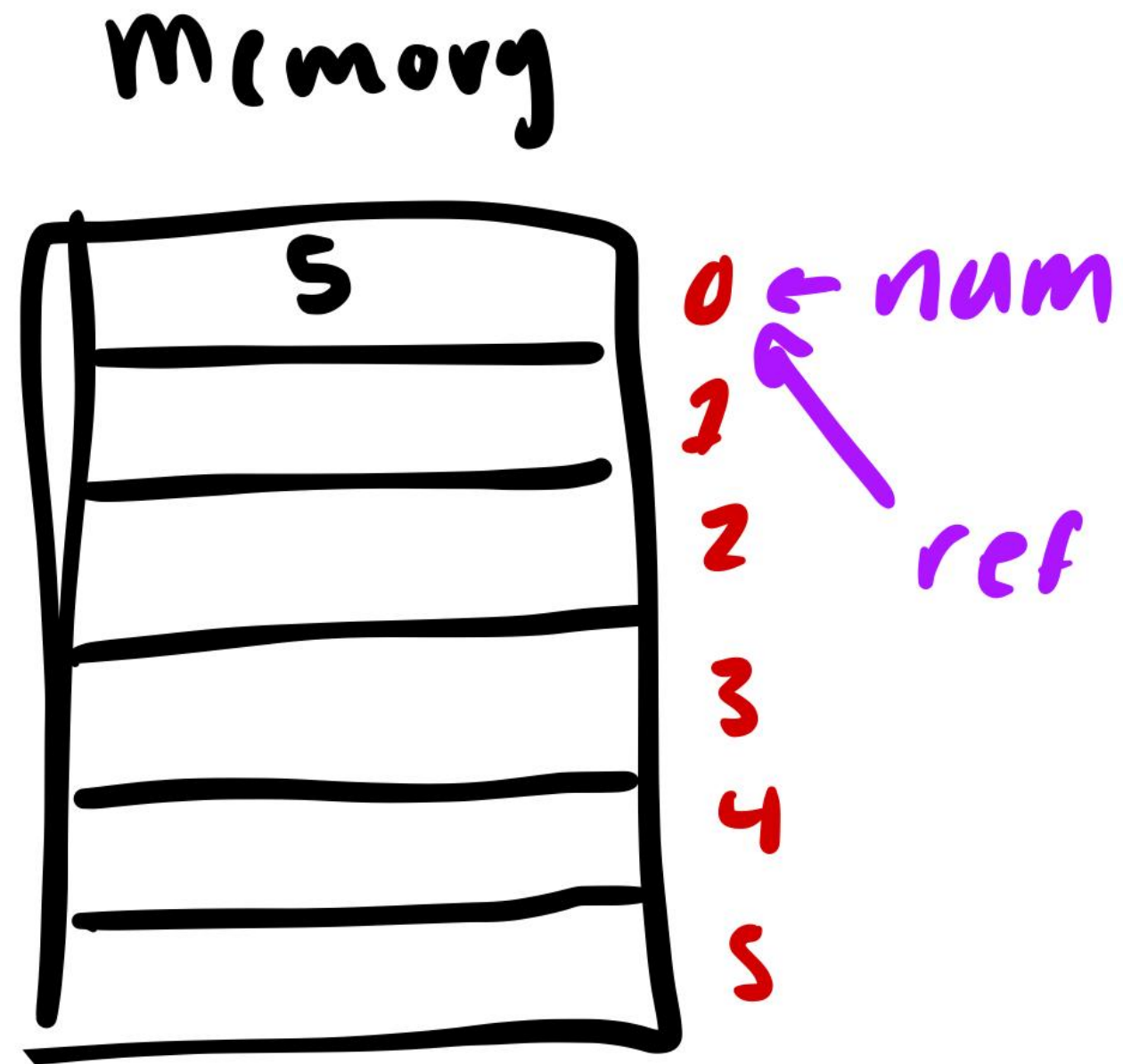
So when we assign 10 to ref, we also change the value of num, since ref is an alias for num

Visually



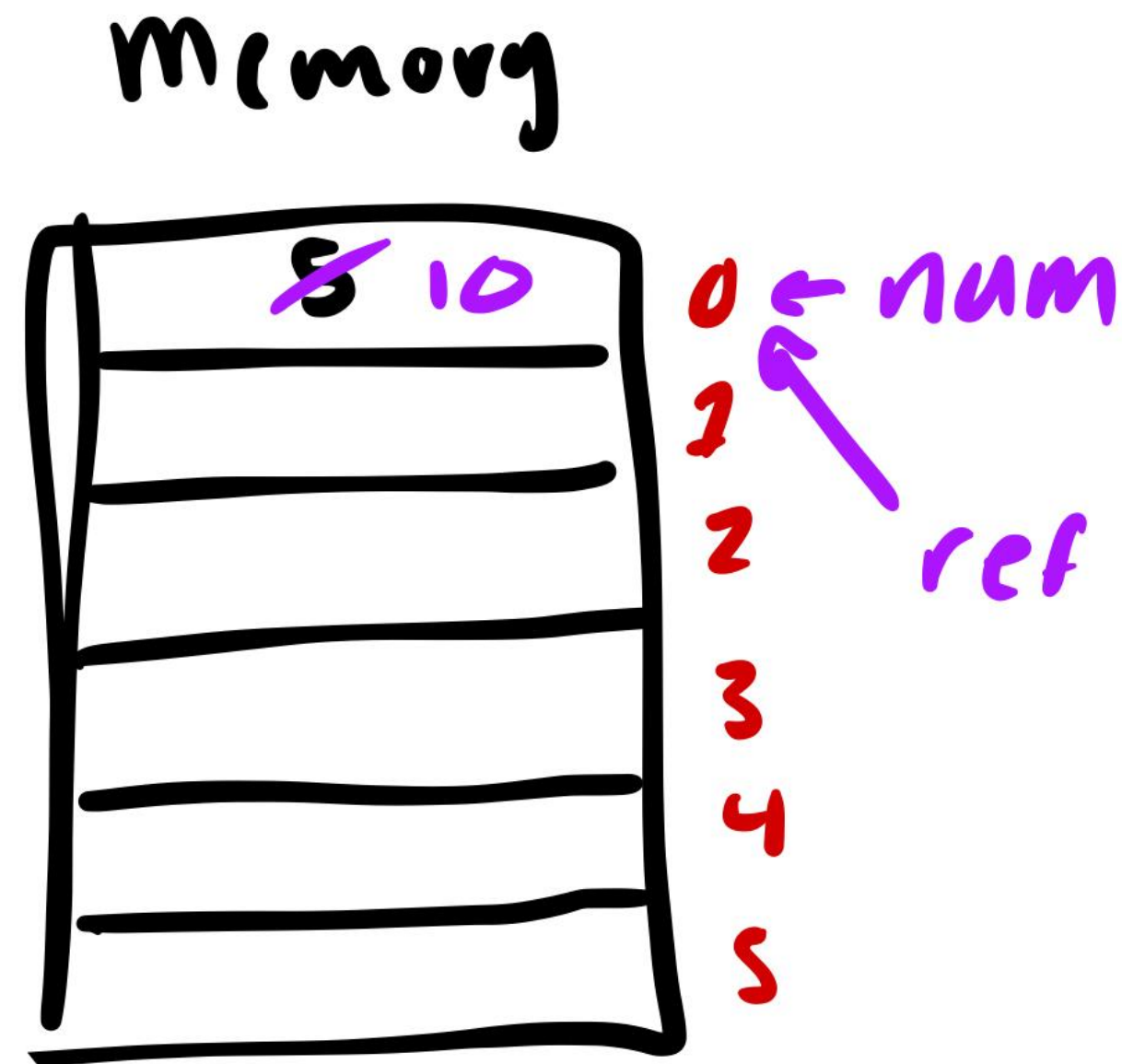
num is a variable of type `int`, that is assigned to have the value 5

Visually



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

Visually



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

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:

Pass by reference

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```
#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;
}
```

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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#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;
}
```

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 = 5;
    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**.

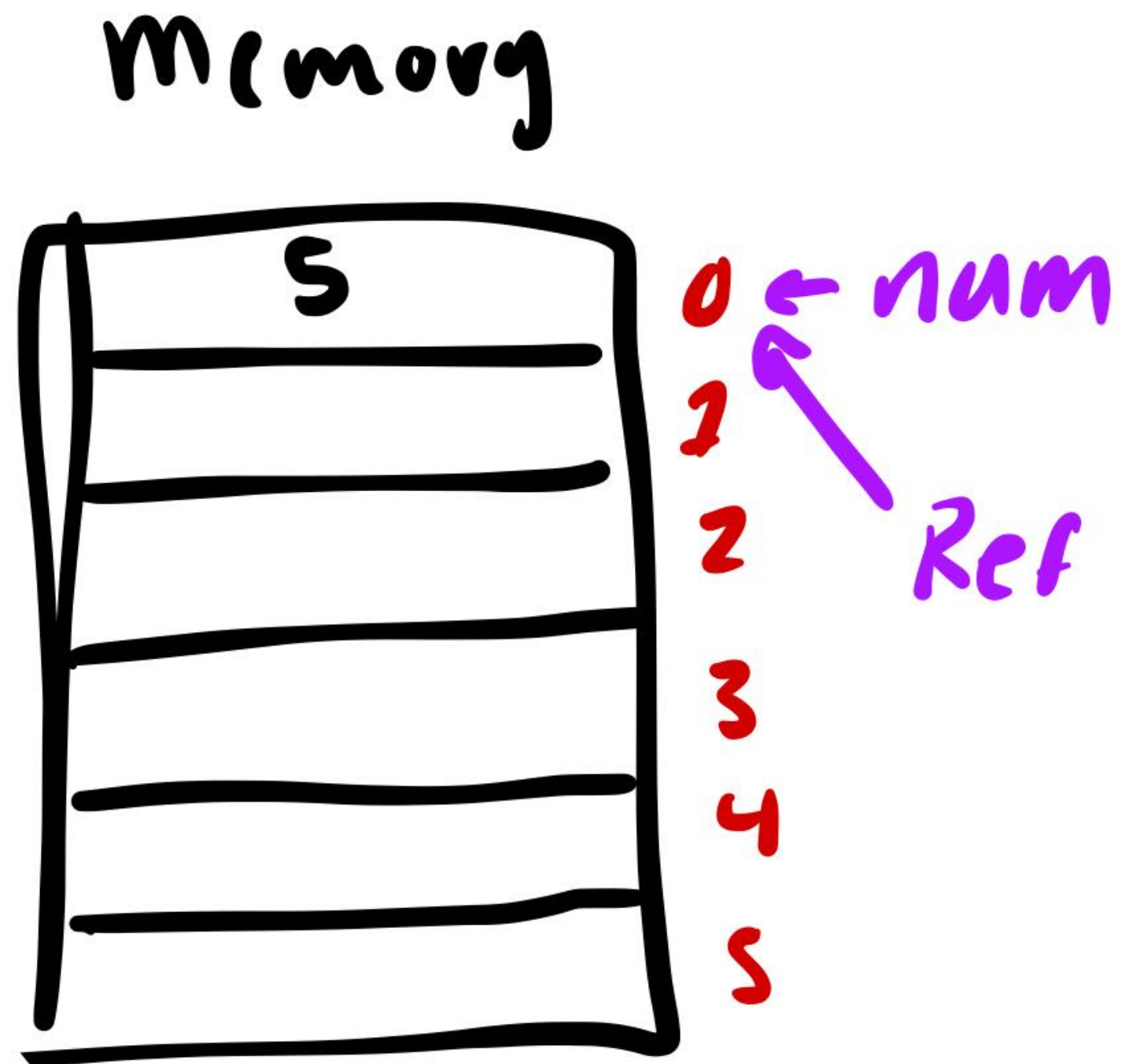
```
#include <iostream>
#include <math.h>

// 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;
}
```

Recall



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

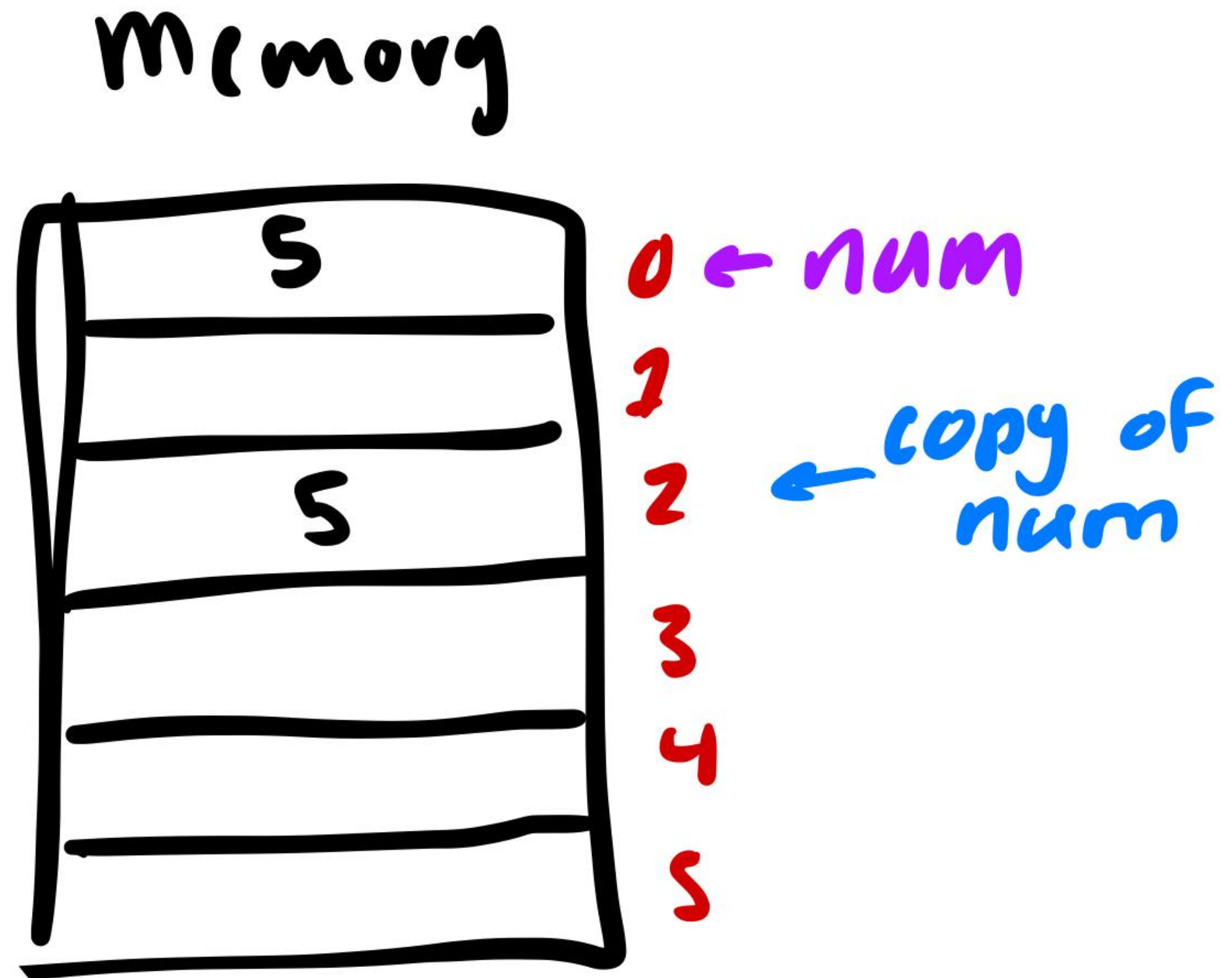
Recall

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

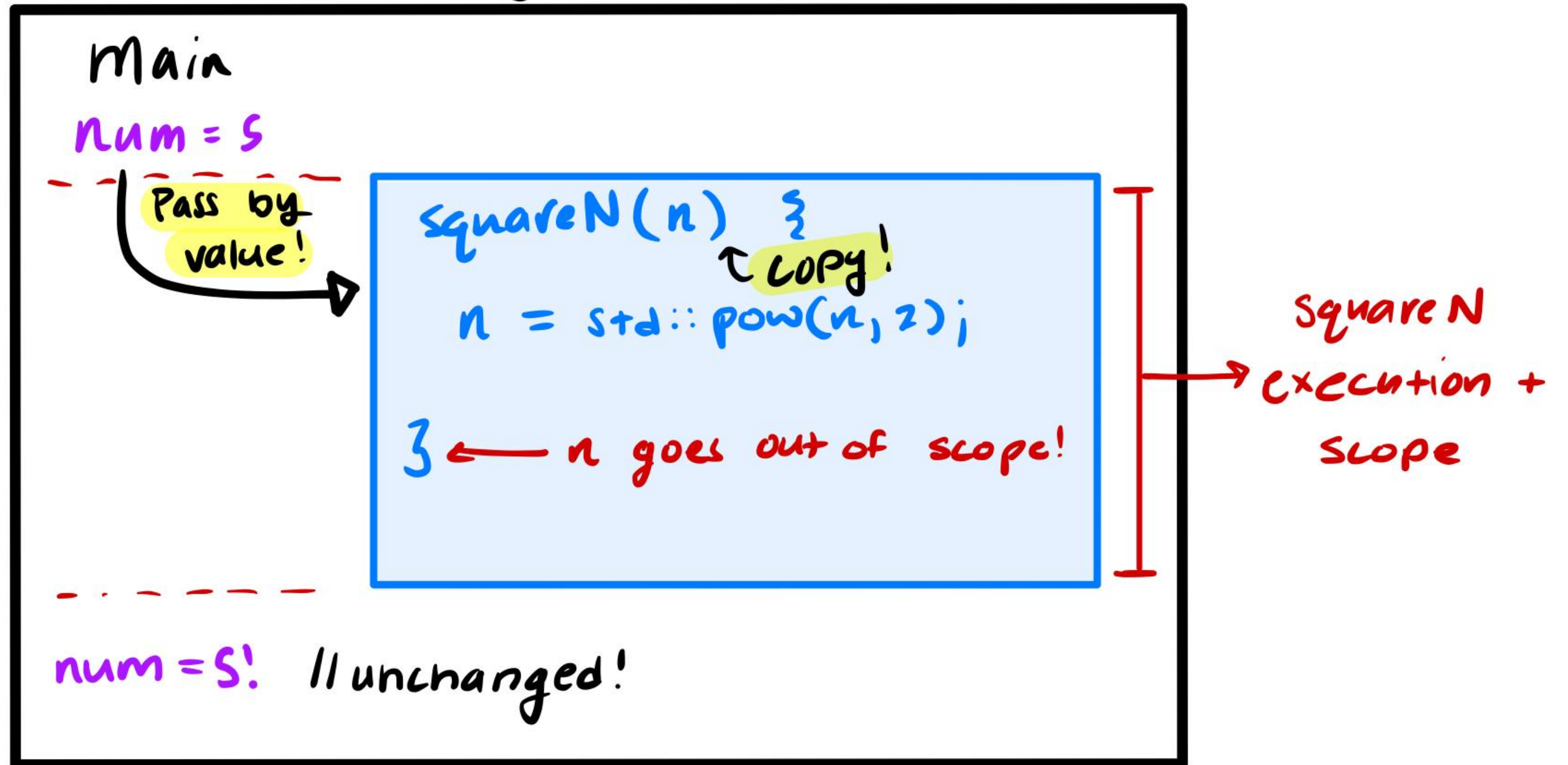
Passing in a variable by *value* into a function just means “**Hey make a copy, don’t take in the actual variable!**”

What does that look like?

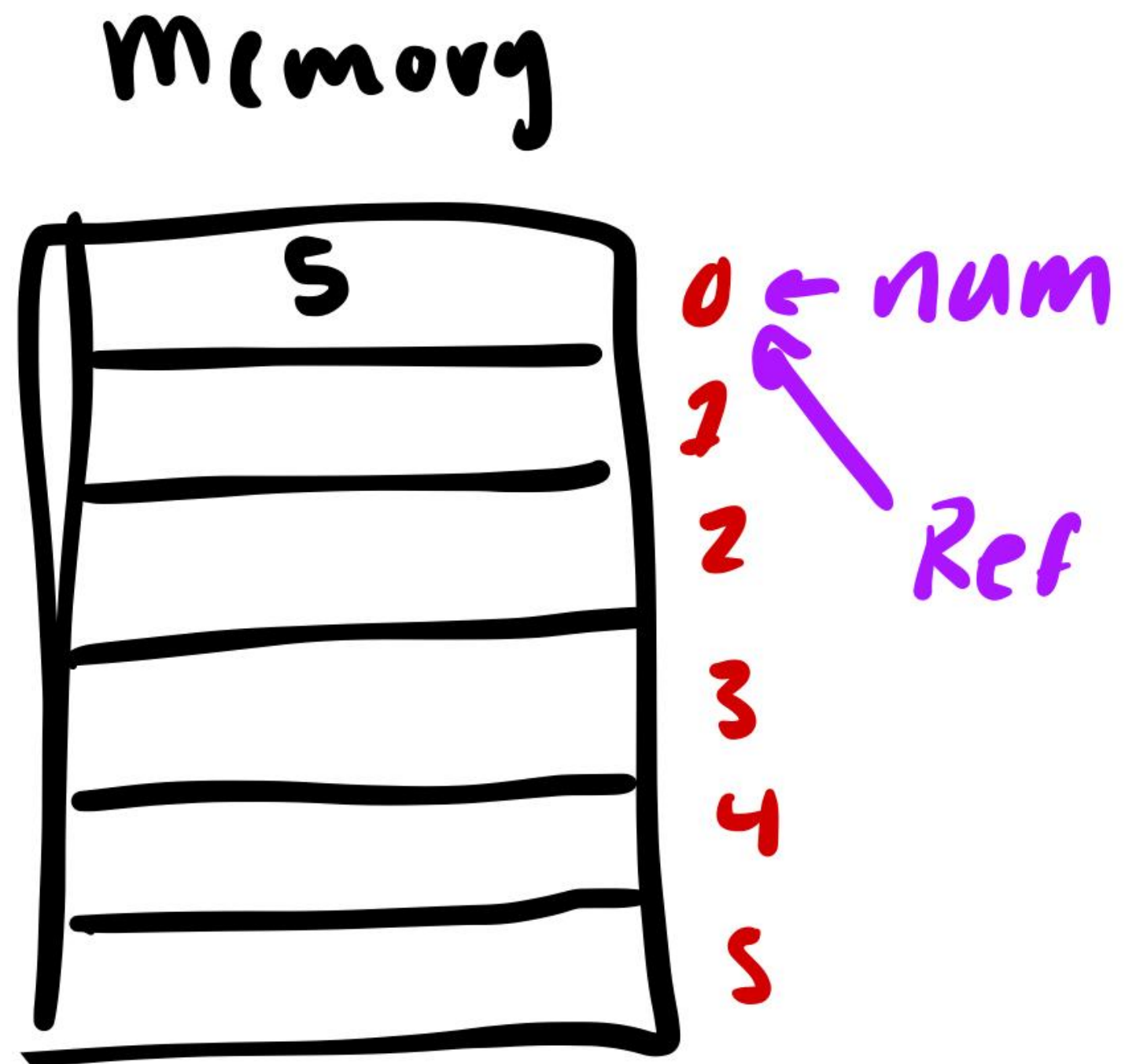


Passing by value (makes a copy)

Pass by value !



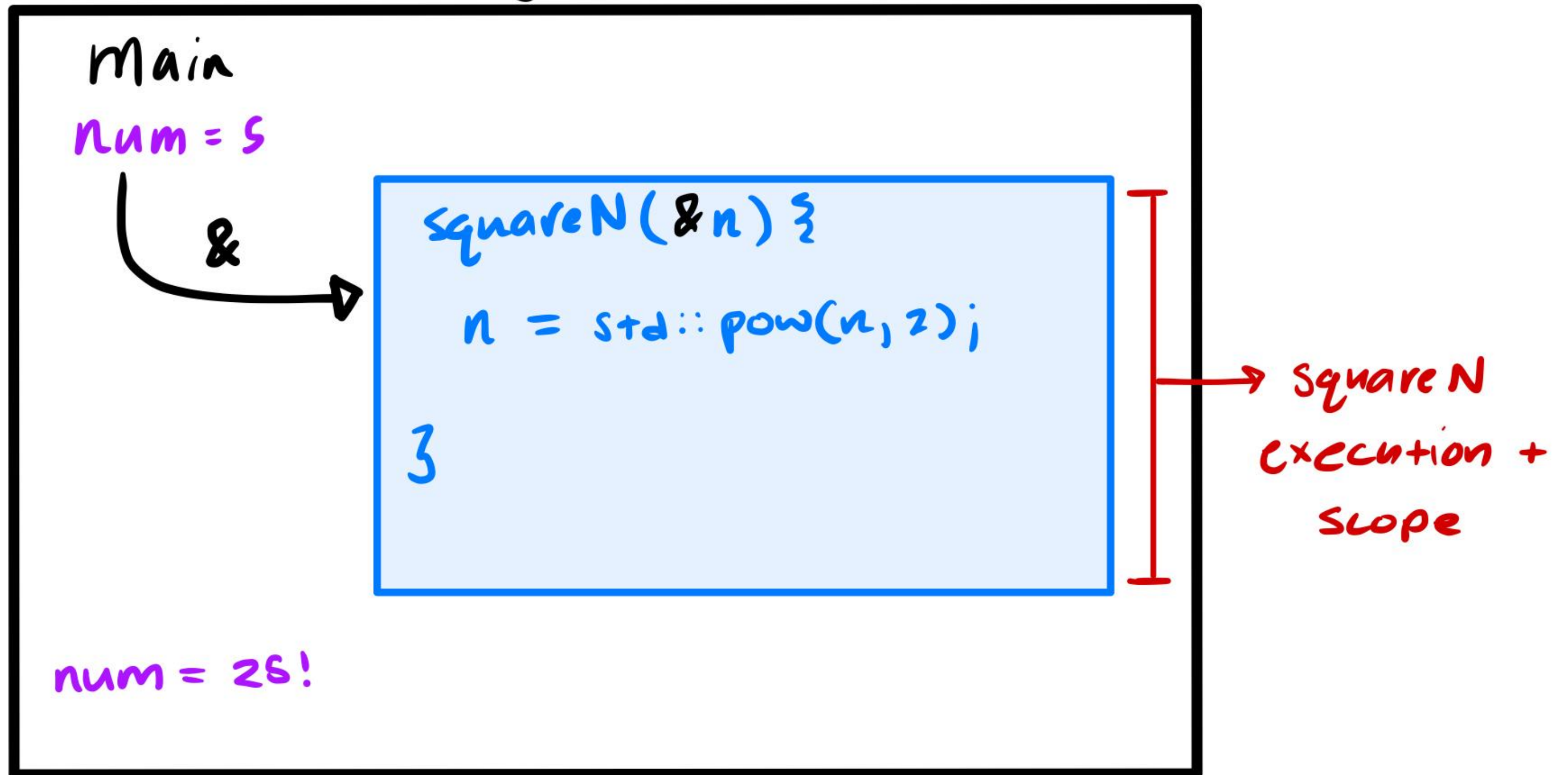
Recall



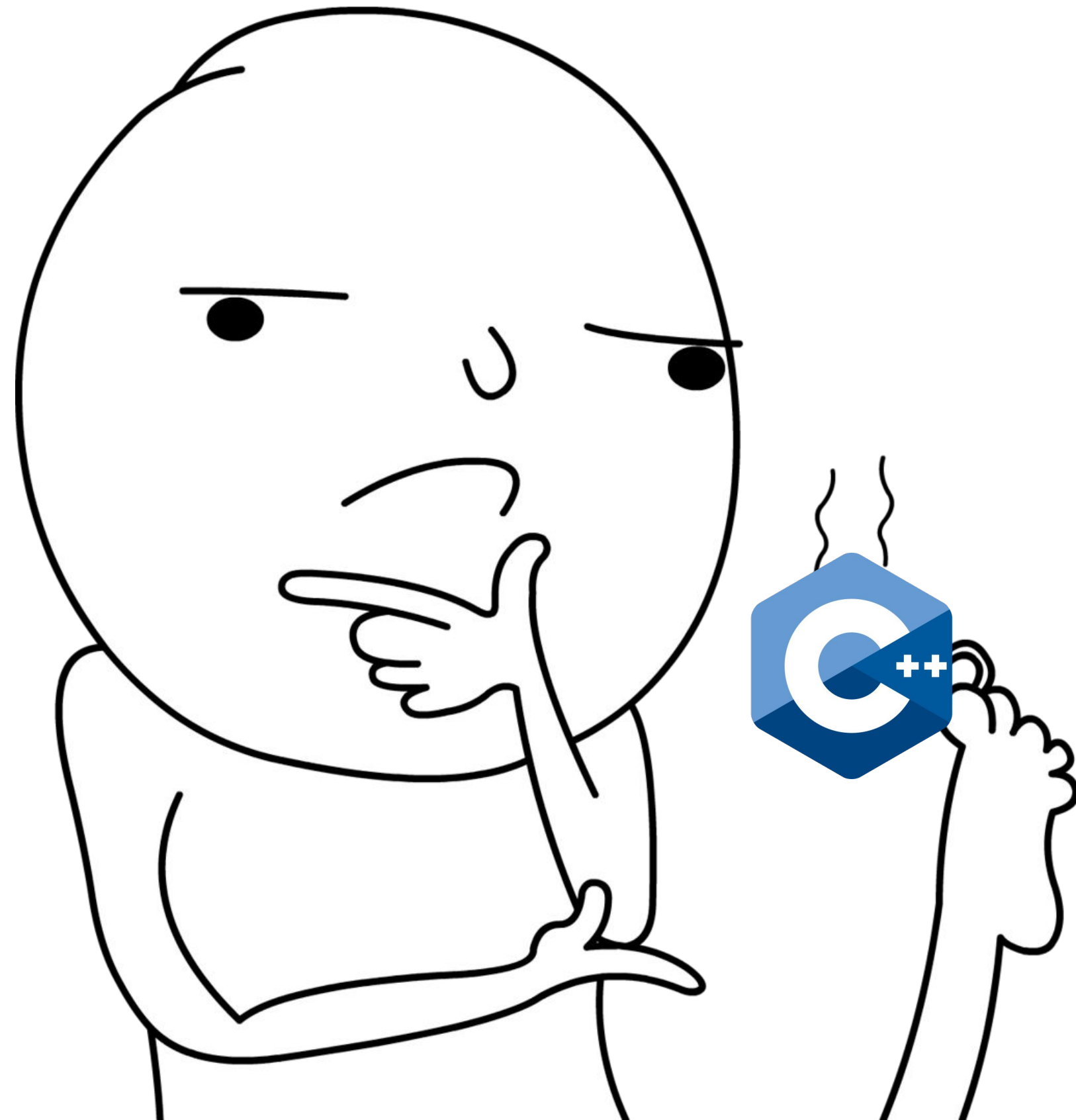
A **reference** *refers* to the same memory as its associated variable!

Passing by reference

Pass 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>
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void shift(std::vector<std::pair<int, int>> &nums) {
    for (auto [num1, num2] : nums) {
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But nums is
passed in by
reference...

A classic reference-copy bug

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#include <iostream>
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void shift(std::vector<std::pair<int, int>> &nums) {
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        num2++;
    }
}
```

**Note the structured
binding!**

🤔 But nums is
passed in by
reference...

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```
#include <iostream>
#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>
#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>

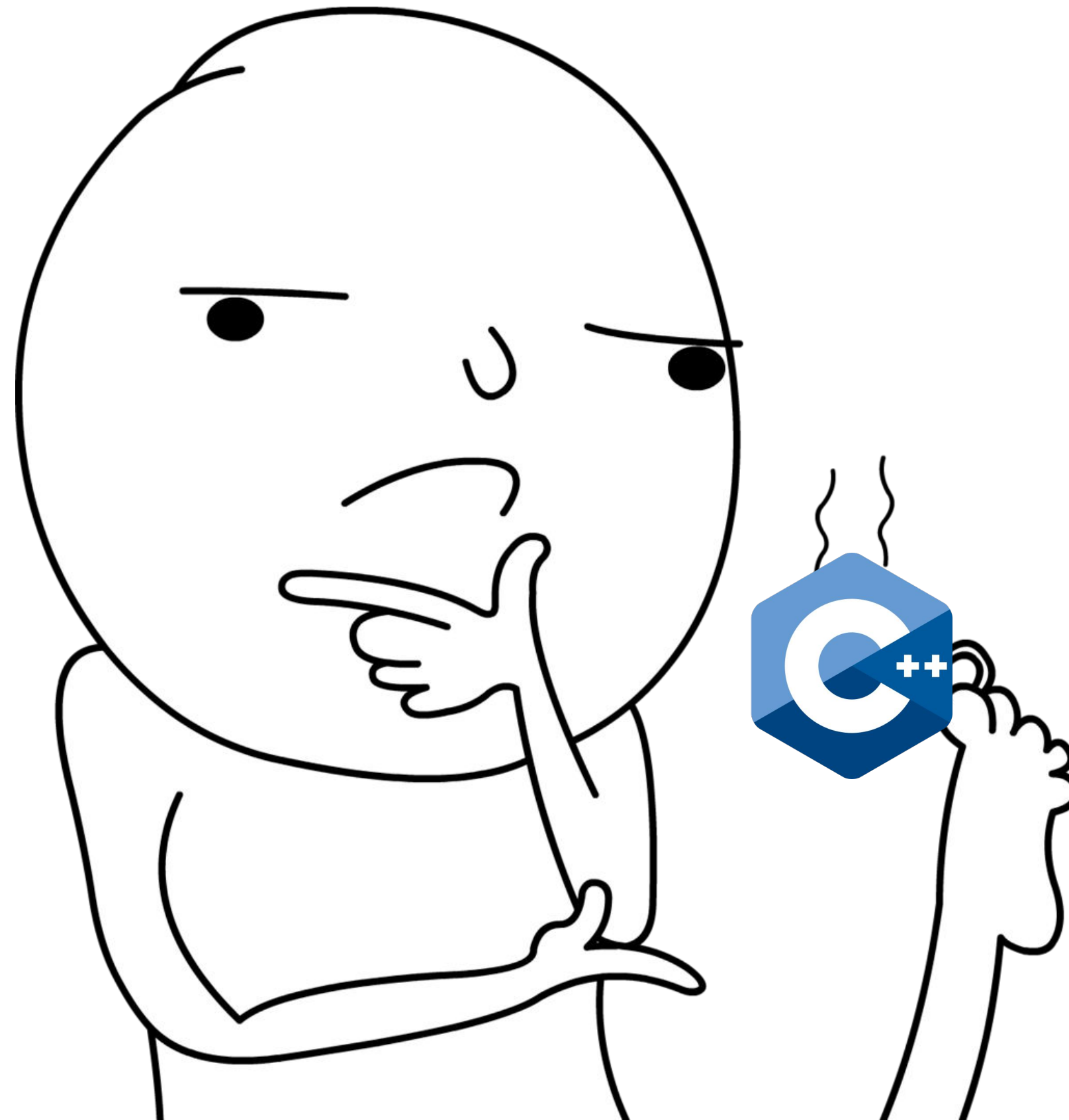
void shift(std::vector<std::pair<int, int>> &nums) {
    for (auto& [num1, num2] : nums) {
        num1++;
        num2++;
    }
}
```

A note, this also works!

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

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

What questions do we have?



Plan

1. Initialization
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- 3. L-values vs R-values**
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l-values and r-values

	l-value	r-value
Where with respect to equal sign?	left or right	right
Example	<code>int x = 10; int y = x;</code>	<code>int x = 10; int y = x;</code>

l-value and r-value PAIN

```
#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;
}
```



I-value and r-value PAIN

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

```
// note the ampersand!
void squareN(int& n) {
    // calculates n to the power of 2
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```
int main() {
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    std::cout << num << std::endl;

    return 0;
}
```

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



l-value and r-value PAIN

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    // calculates n to the power of 2
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}

int main() {
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is **int&** n an l-value?

L

l-value and r-value PAIN

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#include <math.h>

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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;
}
```

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!

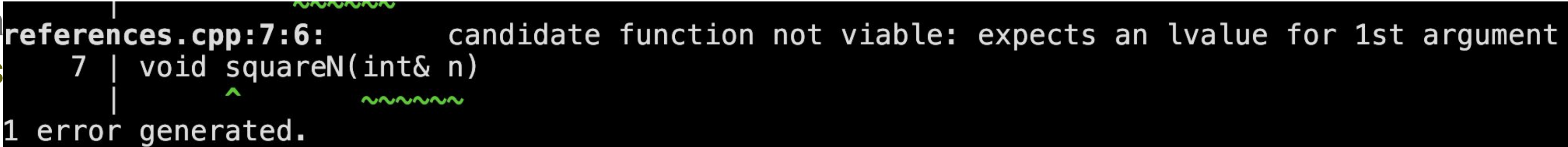
l-value and r-value PAIN

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

```
// note the ampersand!
```

```
void squareN(int& n) {
```

```
    // calculate square of n
    n = n * n;
}
```

A screenshot of a compiler error message from g++. The message is displayed in a black box with white text. It shows the file 'references.cpp' at line 7, column 6, with the error: 'candidate function not viable: expects an lvalue for 1st argument'. Below this, it says '1 error generated.' There are green wavy lines under the function signature 'void squareN(int& n)' and a green caret under the '&' character.

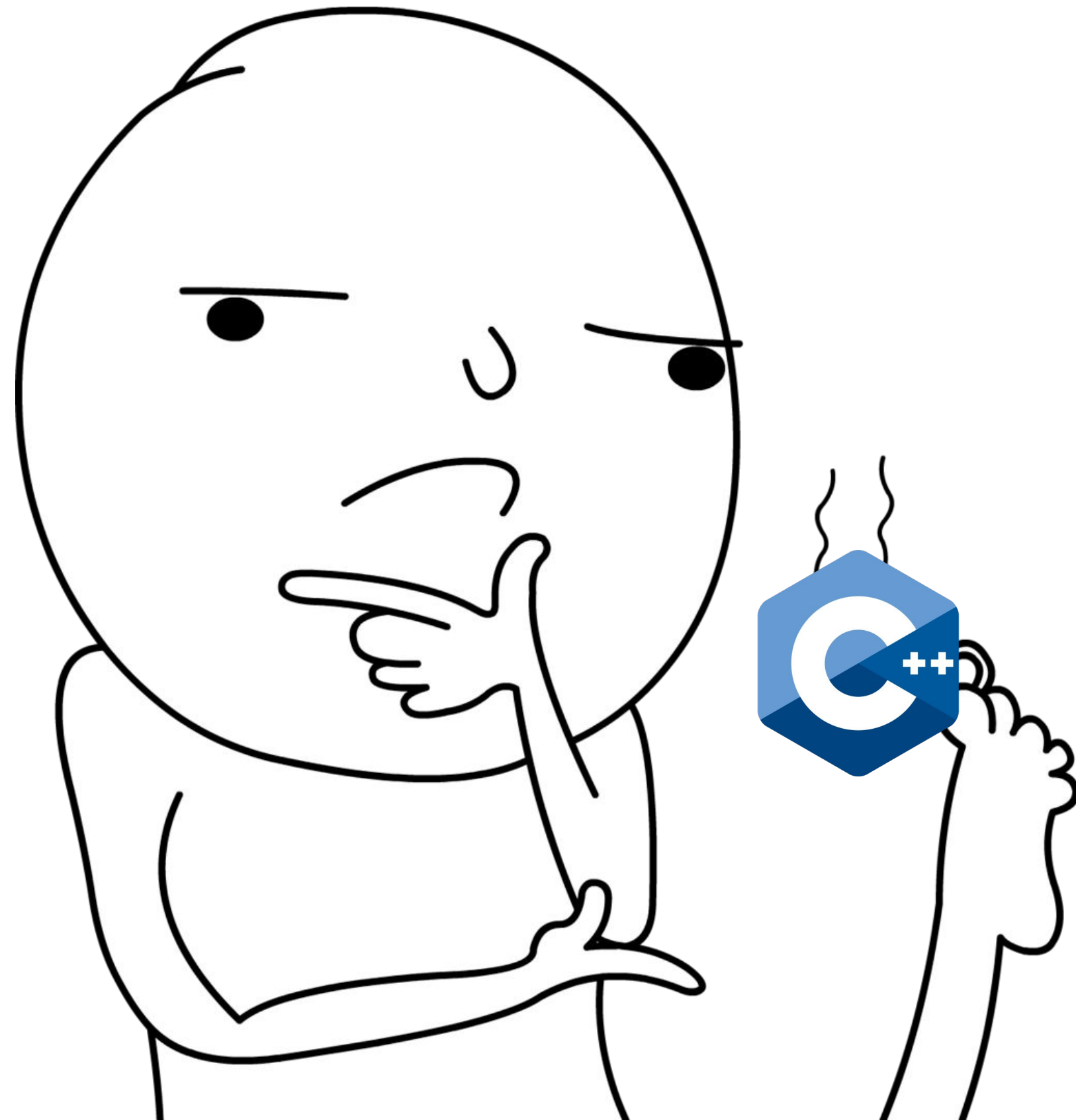
references.cpp:7:6: candidate function not viable: expects an lvalue for 1st argument
7 | void squareN(int& n)
1 error generated.

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

    return 0;
}
```

Well what happens?

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

```
#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

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#include <iostream>
#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);
    const_ref.push_back(3);

    return 0;
}
```

const

```
#include <iostream>
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int main()
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    const std::vector<int>& const_ref{ vec };    /// a const reference

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

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const

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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!
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const

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#include <iostream>
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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);    /// 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;
}
```

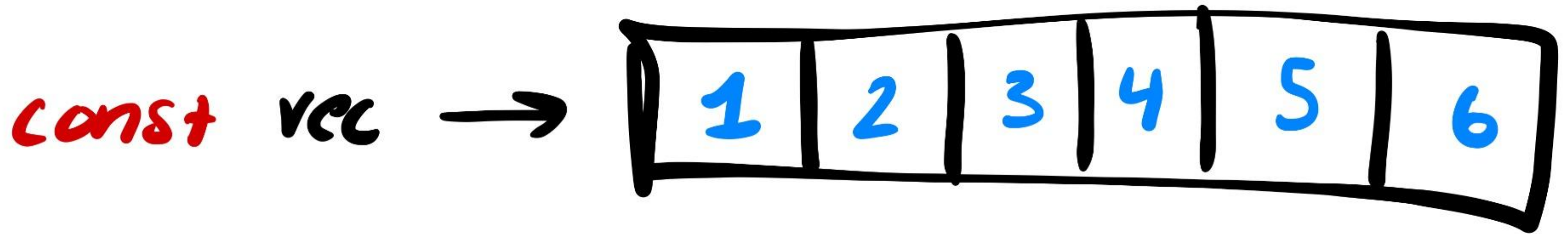
You can't declare a non-const reference to a const variable

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

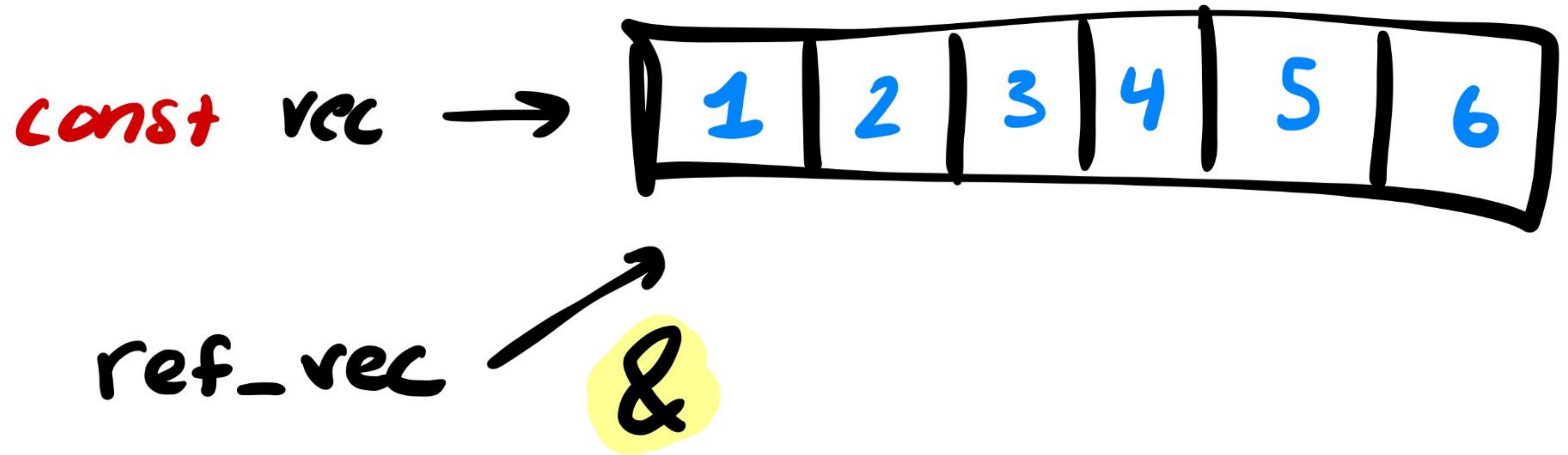
int main()
{
    /// a const vector
    const std::vector<int> const_vec{ 1, 2, 3 };
    std::vector<int>& bad_ref{ const_vec };    /// BAD

    return 0;
}
```

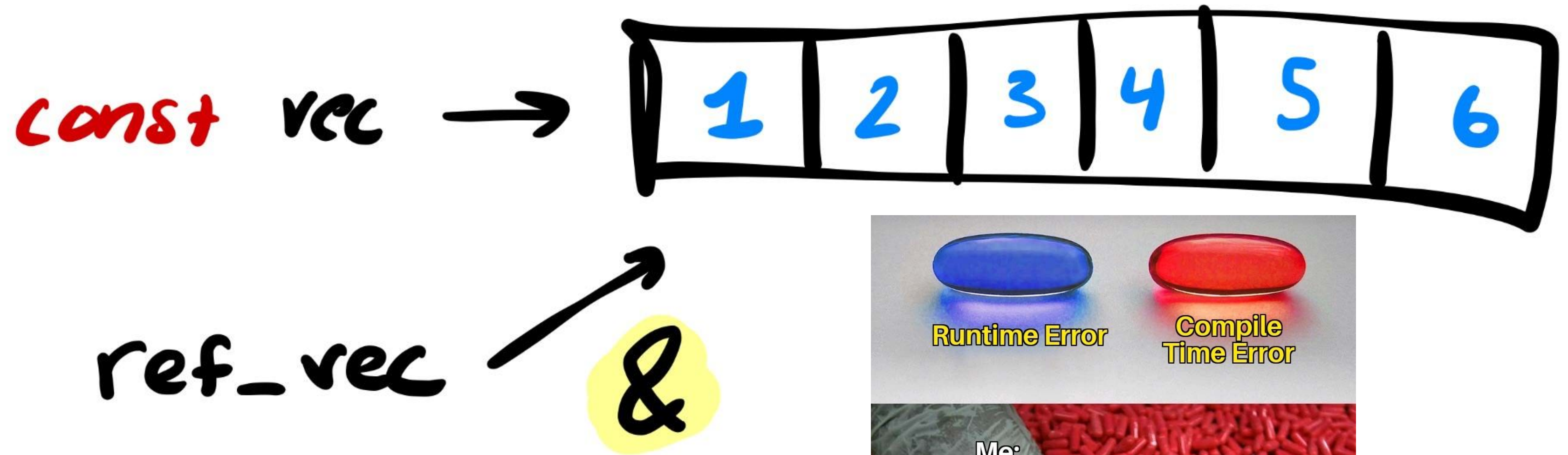
You can't declare a non-const reference to a const variable



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



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



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

```
#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
2. References
3. L-values vs R-values
4. Const
- 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

Source Code

```
std::cout << "Hello World" << std::endl;  
std::cout << "Welcome to " << std::endl;  
for (char ch : "CS106L")  
{  
    std::cout << ch << std::endl;  
}
```

Compiler

Machine Code

```
10110101  
01011010  
10011101  
10110001
```

What you need to know

- C++ is a compiled language

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- There are computer programs called compilers

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- A few popular compilers include clang and g++

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

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```

This is the compiler
command

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++23 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
- A few popular compilers include clang and g++
- **Here is how to compile a program using g++**

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

This is the source file

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++23 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
- 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++23 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++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++**

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

What you need to know

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

Source Code

```
std::cout << "Hello World" << std::endl;  
std::cout << "Welcome to " << std::endl;  
for (char ch : "CS106L")  
{  
    std::cout << ch << std::endl;  
}
```

Compiler

Machine Code

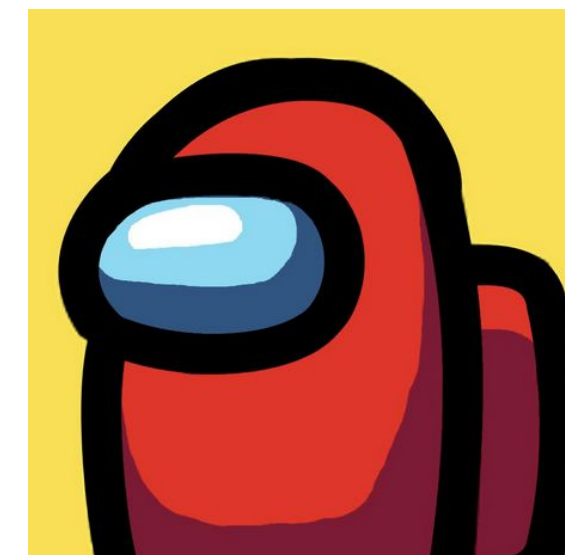
```
10110101  
01011010  
10011101  
10110001
```

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


GPU Programming



Even the masterpiece
among us





python 3.9 | 3.10 | 3.11 | 3.12 pypi package 2.18.0 DOI 10.5281/zenodo.4724125 openssf best practices passing
openssf scorecard 7.8 oss-fuzz build failing oss-fuzz build failing OSSRank #12 (Top 1%) Contributor Covenant v1.4 adopted
TF Official Continuous 6 passed, 0 failed TF Official Nightly 11 passed, 4 failed

Documentation

api reference

[TensorFlow](#) is an end-to-end open source platform for machine learning. It has a comprehensive, flexible ecosystem of [tools](#), [libraries](#), and [community](#) resources that lets researchers push the state-of-the-art in ML and developers easily build and deploy ML-powered applications.

TensorFlow was originally developed by researchers and engineers working within the Machine Intelligence team at Google Brain to conduct research in machine learning and neural networks. However, the framework is versatile enough to be used in other areas as well.

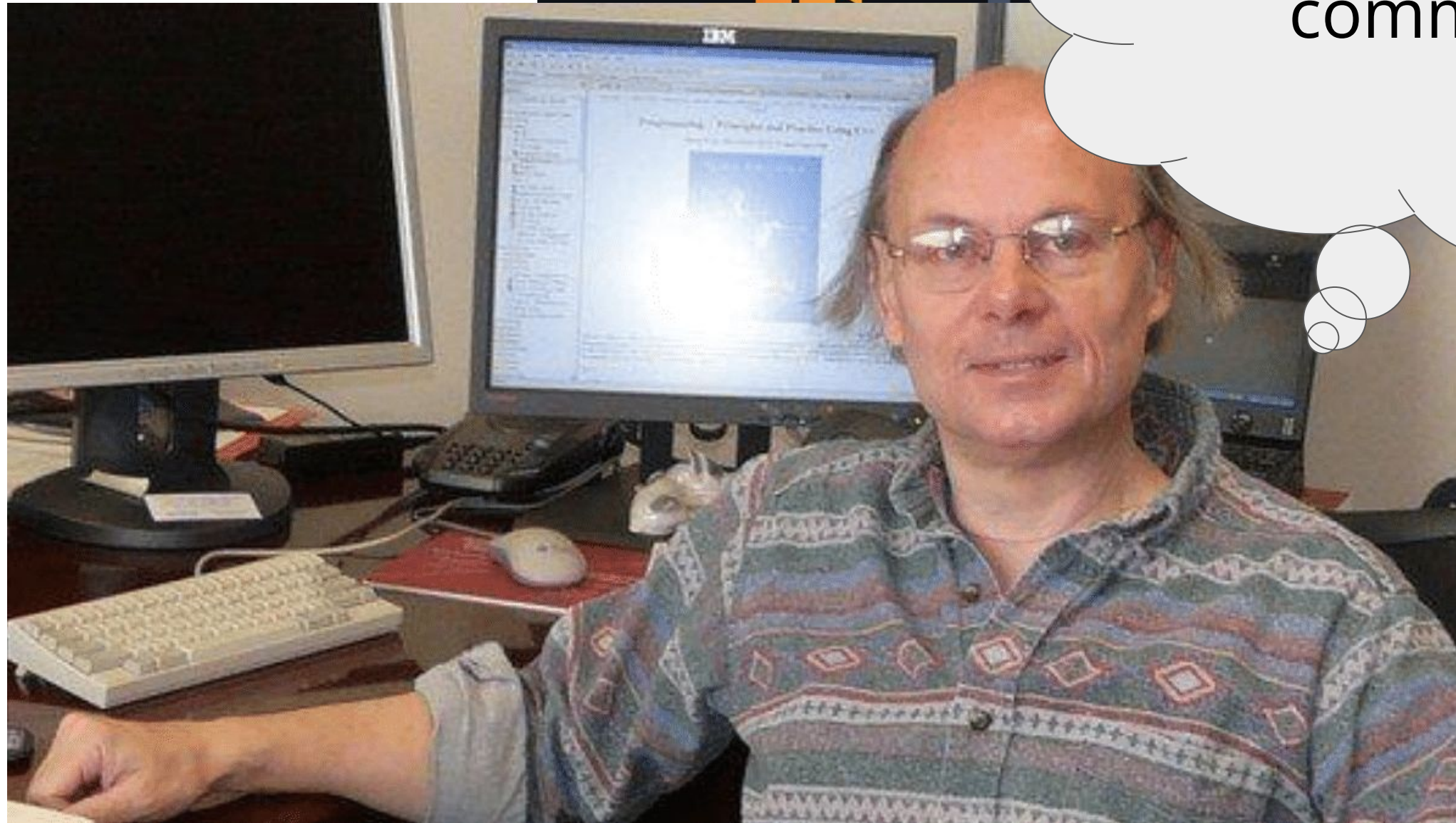
TensorFlow provides stable [Python](#) and [C++](#) APIs, as well as a non-guaranteed backward compatible API for [other languages](#).

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



T

Lol, that's a cute
command 😭

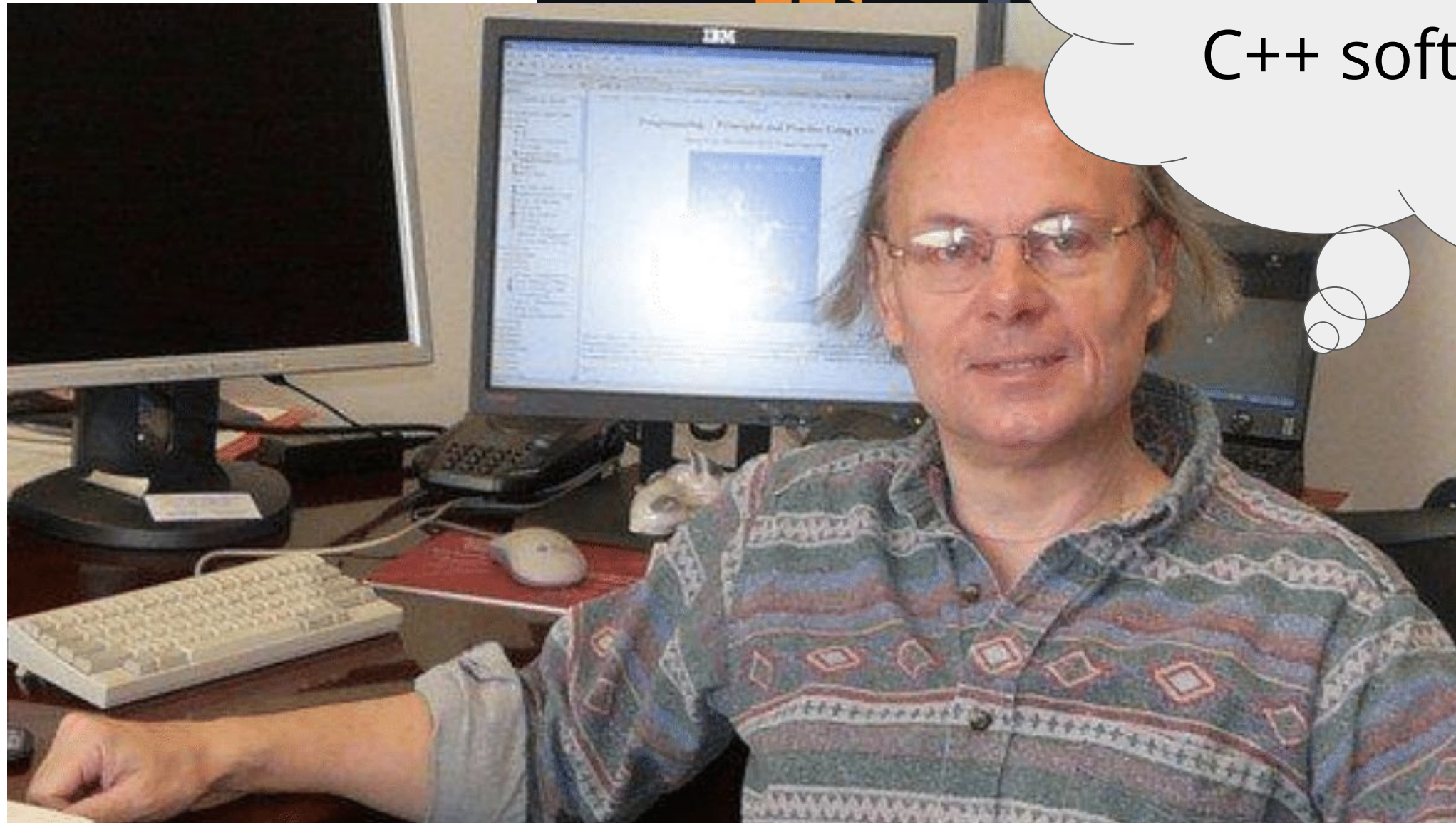


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```
$ g++ main.cpp -o main    # g++ is the compiler, outputs binary to main
$ ./main                  # This actually runs our program
```




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



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

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

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