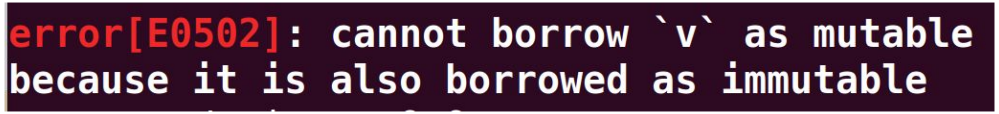
Lecture 3: Ownership

CIS198 Spring 2021

A Word of Warning



```
error[E0502]: cannot borrow `v` as mutable
because it is also borrowed as immutable
```

- Some learning curve!
- The compiler will complain about your code that would work in any other language
- Harder to appreciate if you have not spent time debugging C/C++

Ownership

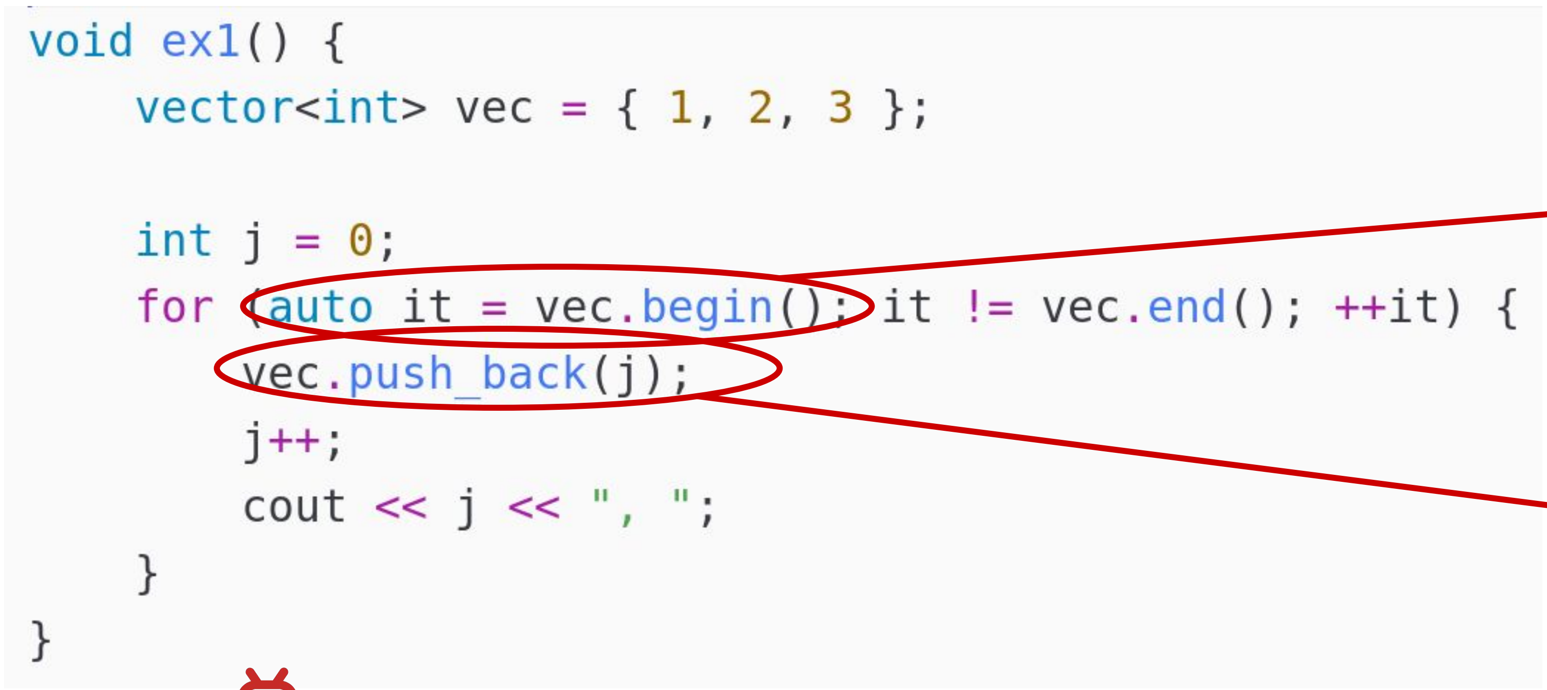
Memory management errors in languages like C and C++ can often be attributed to **ownership mistakes**

Ownership Mistakes: Quiz 1

```cpp
void ex1() {
    vector<int> vec = { 1, 2, 3 };

    int j = 0;
    for (auto it = vec.begin(); it != vec.end(); ++it) {
        vec.push_back(j);
        j++;
        cout << j << ", ";
    }
}
```

Ownership Mistakes: Quiz 1



```cpp
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    vector<int> vec = { 1, 2, 3 };

    int j = 0;
    for (auto it = vec.begin(); it != vec.end(); ++it) {
        vec.push_back(j);
        j++;
        cout << j << ", ";
    }
}
```

it expects temporary “ownership” over vec

vec retains ownership

Fails at runtime if vec is resized!

Ownership Mistakes: Quiz 2

```cpp
void ex2() {
    vector<int> vec = { 1, 2, 3 };

    // Find location of 2
    std::vector<int>::iterator item;
    item = std::find(vec.begin(), vec.end(), 2);

    vec.clear();
    vec.push_back(4);
    vec.push_back(5);
    vec.push_back(6);

    std::cout << "Found:" << *item << std::endl;
}
```

Ownership Mistakes: Quiz 2

```
void ex2() {
    vector<int> vec = { 1, 2, 3 };

    // Find location of 2
    std::vector<int>::iterator item;
    item = std::find(vec.begin(), vec.end(), 2);

    vec.clear();
    vec.push_back(4);
    vec.push_back(5);
    vec.push_back(6);

    std::cout << "Found:" << *item << std::endl;
}
```

item expects temporary ownership

Original owner deletes element

Output: 5

Ownership Mistakes: Quiz 3

```cpp
void ex3() {
    vector<vector<int>*> grid;

    grid.push_back(new vector<int>({ 1, 2, 3 }));
    grid.push_back(new vector<int>({ 4, 5, 6 }));
    grid.push_back(new vector<int>({ 7, 8, 9 }));

    for (auto row: grid) {
        for (auto col: *row) {
            std::cout << col << " ";
        }
        std::cout << std::endl;
    }

    grid.clear();
}
```

Ownership Mistakes: Quiz 3

```
void ex3() {
    vector<vector<int>*> grid;

    grid.push_back(new vector<int>({ 1, 2, 3 }));
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    for (auto row: grid) {
        for (auto col: *row) {
            std::cout << col << " ";
        }
        std::cout << std::endl;
    }

    grid.clear();
}
```

Allocated vector expects grid to take ownership

grid doesn't assume ownership, releases resources

Memory leak

valgrind --leak-check=full ./example

```
LEAK SUMMARY:
   definitely lost: 72 bytes in 3 blocks
   indirectly lost: 36 bytes in 3 blocks
```

How can languages prevent memory management bugs?

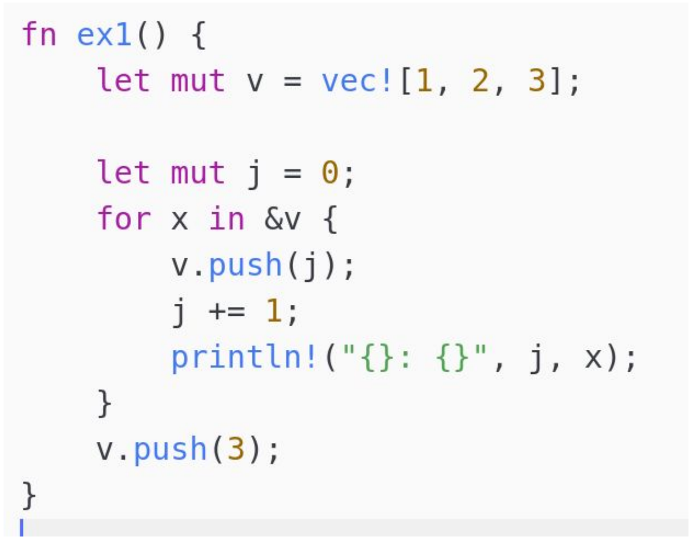
- **Garbage collection**
- **Recommend specific programming patterns**
- **Analyze code to catch bugs at compile time**

How can languages prevent memory management bugs?

- **In Rust, ownership is a static, syntactic property (like a type).**
- **Rust uses ownership to analyze code to catch bugs at compile time.**

What is Ownership?

1. Each value in Rust has a variable that’s called its owner.
2. There can only be one owner at a time.
3. When the owner goes out of scope, the value will be dropped.



```rust
fn ex1() {
    let mut v = vec![1, 2, 3];

    let mut j = 0;
    for x in &v {
        v.push(j);
        j += 1;
        println!("{}: {}", j, x);
    }
    v.push(3);
}
```

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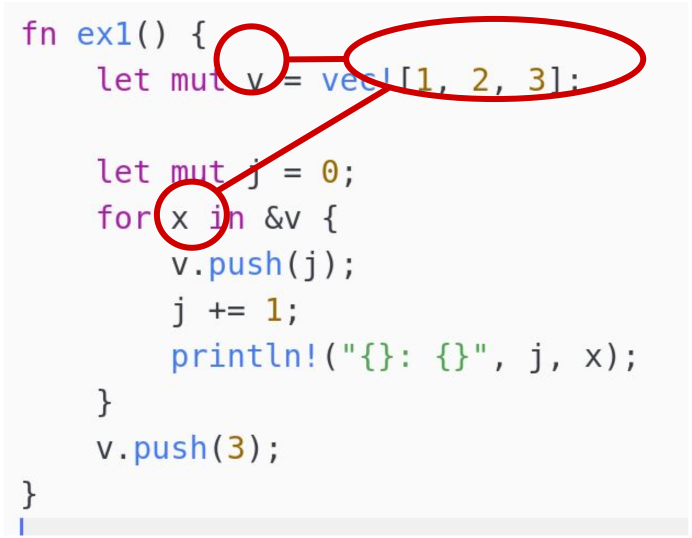

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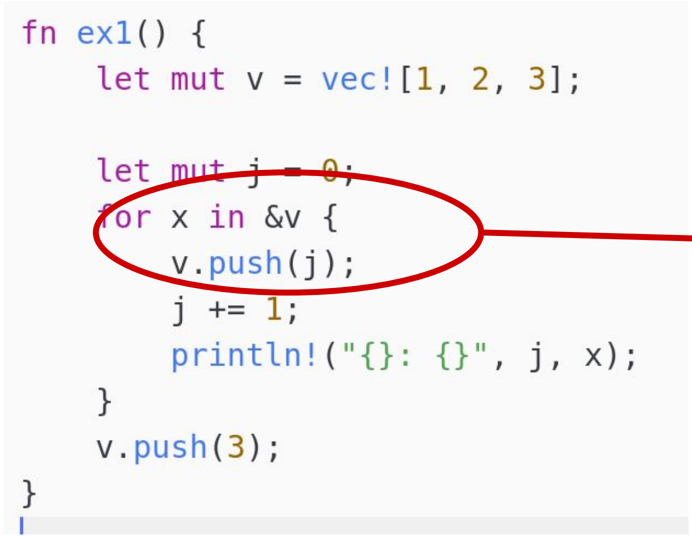

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Type Error

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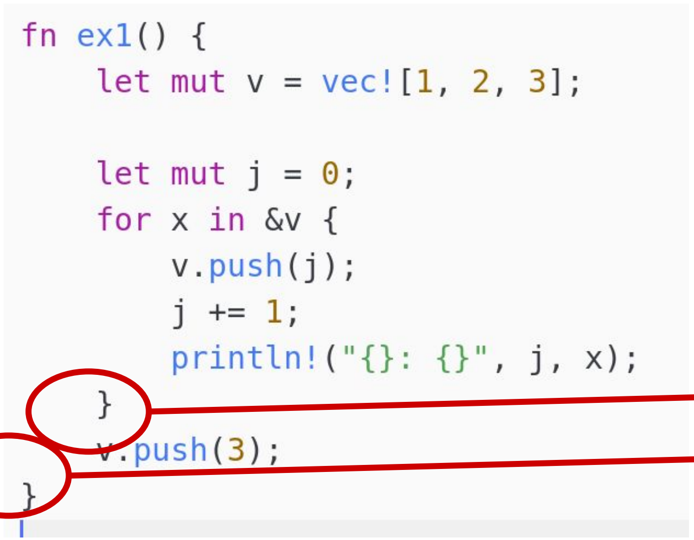

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```

_it dropped

v dropped

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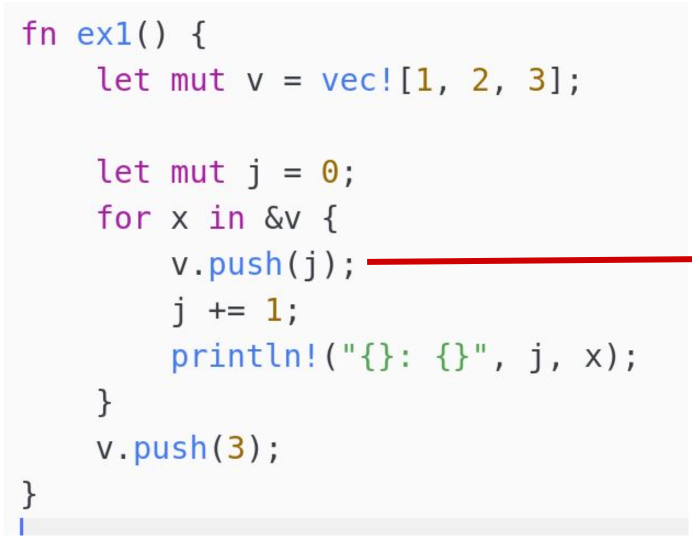

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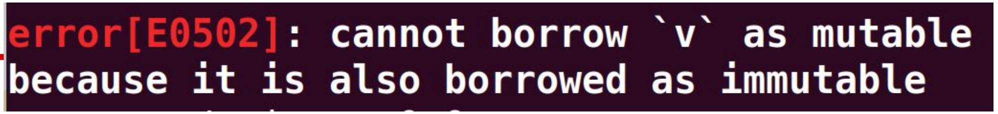

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Final notes: Ownership

- **Safety**
- **Errors at compile time**
- **Zero overhead abstraction**
- **Opt-out**
    - Rust interfaces with C code
    - Unsafe code
    - Abstractions to hide ownership

More on this in later lectures

Today: Use ownership to understand:

- References and borrowing
- Fixing the quiz examples

Demo / Coding

References

https://stackoverflow.com/questions/5638323

https://doc.rust-lang.org/book/ch04-01-what-is-ownership.html

https://jaxenter.com/most-difficult-programming-languages-152590.html