



Rust and what's this thing for?



Abc Xyz
@dura_lex

1. Foreword

2. What is Rust?

3. (Un)safe

4. Syntax

5. Summary

Foreword

- Since 1.0.0
- Scope (by time)
 - Bindings (FFI – foreign function interface)
 - Analyzers
 - CLI (TUI) tools for PC and IoT
 - GUI for fun
 - Libraries
 - RE
- Nim, Crystal, Zig, Pony





What is Rust?

“Rust is a multi-paradigm systems programming language focused on safety, especially safe concurrency”.

— Wikipedia

“Rust is a systems programming language that runs blazingly fast, prevents nearly all segfaults, and guarantees thread safety”.

— www.rust-lang.org (2015)

“Empowering everyone to build reliable and efficient software”.

— www.rust-lang.org

What is Rust?

Quick facts about Rust

- Started by Mozilla (sponsorship & support) employee Graydon Hoare
- Influenced by C++ & Haskell and others
- First announced by Mozilla in 2010
- Community driven development
- 88,281 commits on GitHub
- First stable release: 1.0 in May 2015
- Latest stable release: 1.32

What is Rust?

Why Rust?

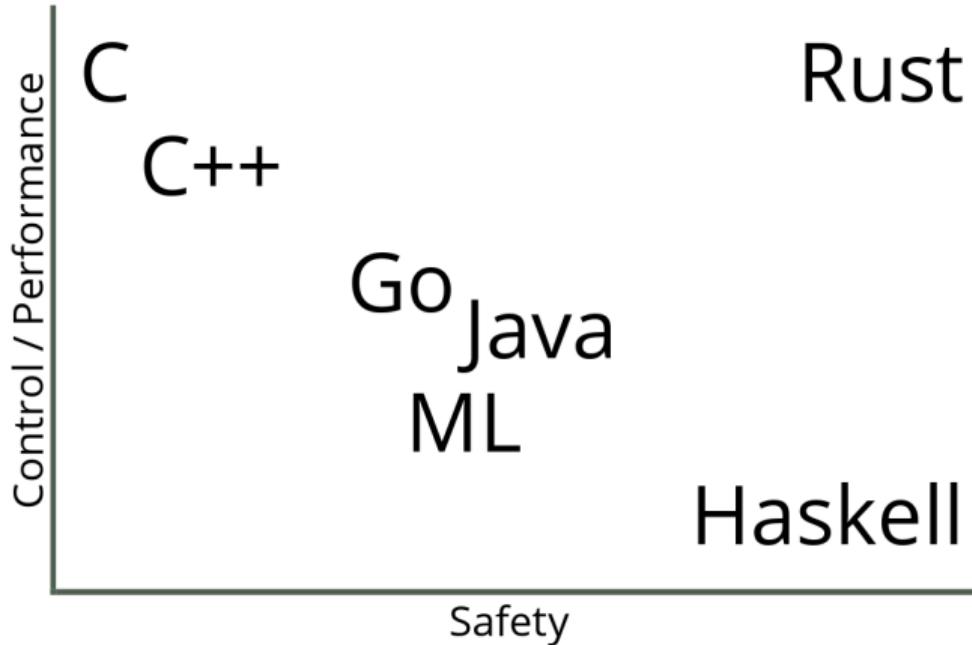


- Performance
 - Fast, memory-efficient
 - No runtime or garbage collector
 - Zero-cost abstractions
- Reliability
 - Rich type system
 - Ownership model
- Productivity
 - Documentation
 - Friendly compiler
 - Top-notch tooling

(Un)safe

(Un)safe

Control vs Safety



(Un)safe

What's wrong with systems languages?

What's wrong with systems languages?

- It's difficult to write secure code
- It's very difficult to write multithreaded code

Rust?

(Un)safe

Problems

Memory corruption

- Using uninitialized memory
- Using non-owned memory (null pointer, dangling pointer dereference, out of bounds error)
- Using memory beyond the memory that was allocated (buffer overflow)
- Faulty heap memory management (memory leaks, freeing non-heap or un-allocated memory)



(Un)safe

Ownership and Borrowing



Ownership and Borrowing

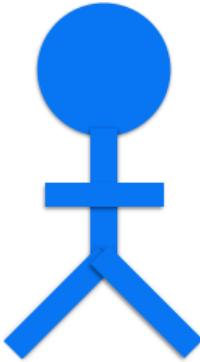
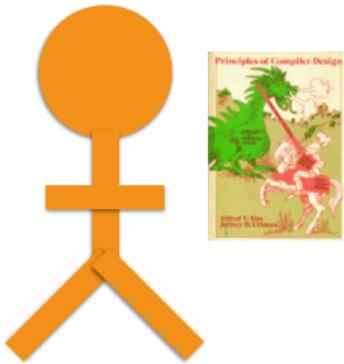
Nicholas Matsakis

Ownership

n. The act, state, or right of possessing something.

Borrow

v. To receive something with the promise of returning it.



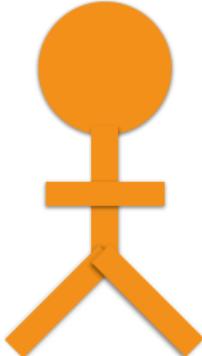
Ownership



Ownership

```
fn main() {  
    let name = format!("...");  
    helper(name);  
    helper(name);  
}
```

```
fn helper(name: String) {  
    println!(...);  
}
```



Ownership

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fn helper(name: String) {  
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}
```



Ownership

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fn main() {  
    let name = format!("...");  
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}
```



```
fn helper(name: String) {  
    println!(...);  
}
```

Take ownership
of a String



Ownership

```
fn main() {  
    let name = format!("...");  
    helper(name);  
    helper(name);  
}
```

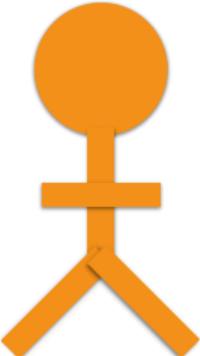


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fn helper(name: String) {  
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```



Ownership

```
fn main() {  
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}
```



Ownership

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fn main() {  
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}  
 
```

```
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```



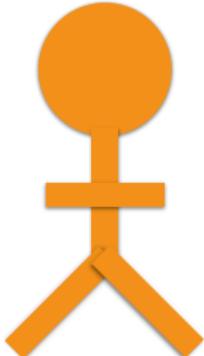
Ownership

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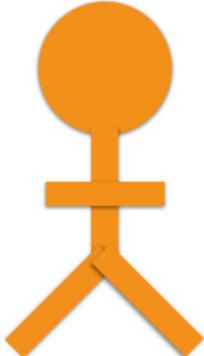
Ownership

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Ownership

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Ownership

```
fn main() {  
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    helper(name);  
}  
↑
```

```
fn helper(name: String) {  
    println!(...);  
}
```

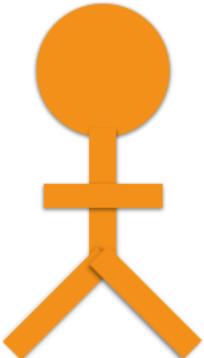
Error: use of moved value: `name`



Ownership

```
void main() {  
    Vector name = ...;  
    helper(name);  
    helper(name);  
}
```

```
void helper(Vector name) {  
    ...  
}
```



“Ownership” in Java

```
void main() {  
    Vector name = ...;  
    → helper(name);  
    helper(name);  
}
```

```
void helper(Vector name) {  
    ...  
}
```



“Ownership” in Java

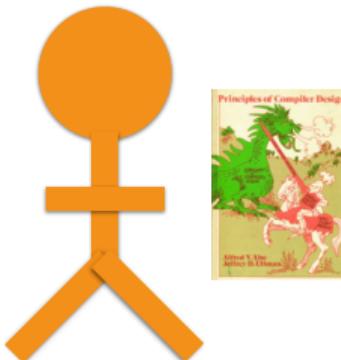
```
void main() {  
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}
```

```
void helper(Vector name) {
```

```
    ...  
}
```



Take reference
to Vector



“Ownership” in Java

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void main() {  
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“Ownership” in Java

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void main() {  
    Vector name = ...;  
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void helper(Vector name) {  
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“Ownership” in Java

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void main() {  
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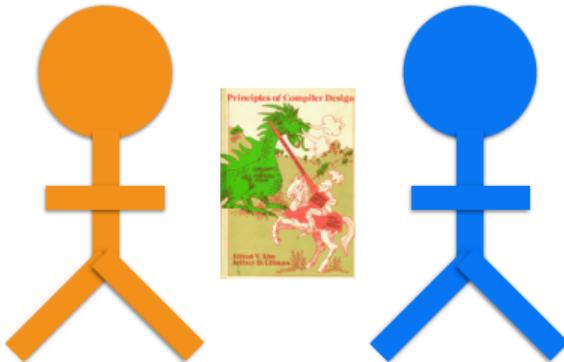


“Ownership” in Java

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}
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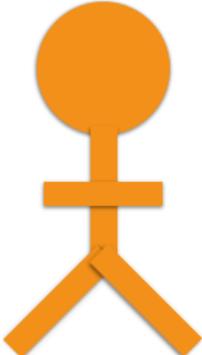


“Ownership” in Java

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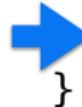


```
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```

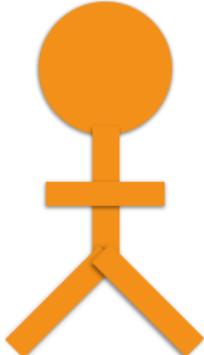


“Ownership” in Java

```
void main() {  
    Vector name = ...;  
    helper(name);  
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}
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```
void helper(Vector name) {  
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“Ownership” in Java

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“Ownership” in Java

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“Ownership” in Java

```
void main() {  
    Vector name = ...;  
    helper(name);  
    helper(name);  
}
```

```
void helper(Vector name) {  
    new Thread(...);  
}
```



“Ownership” in Java

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void main() {  
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“Ownership” in Java

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“Ownership” in Java

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“Ownership” in Java

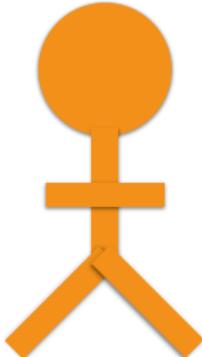
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    helper(name);  
    helper(name);  
}
```

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void helper(Vector name) {  
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}
```

Clone

```
fn main() {  
    let name = format!("...");  
    helper(name.clone());  
    helper(name);  
}
```

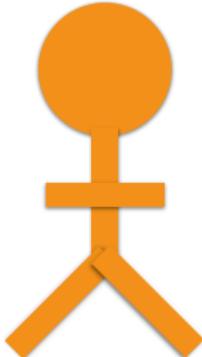
```
fn helper(name: String) {  
    println!(...);  
}
```



Clone

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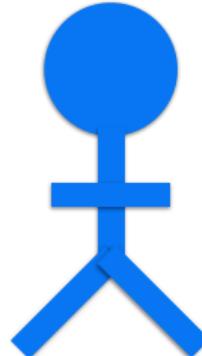
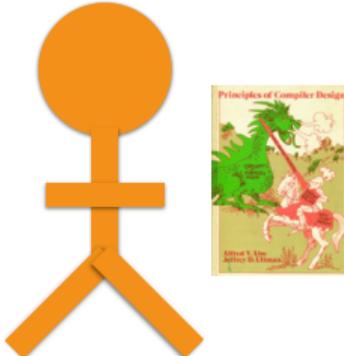


Clone

```
fn main() {  
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}
```

Copy the String

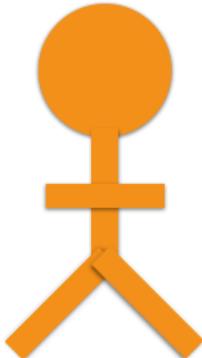
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Clone

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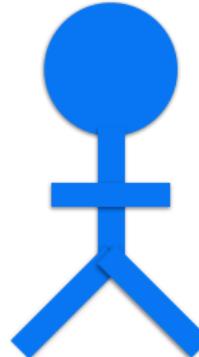
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Clone

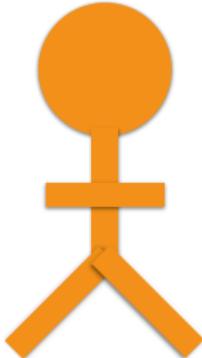
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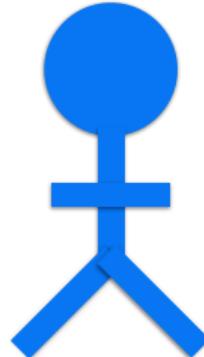
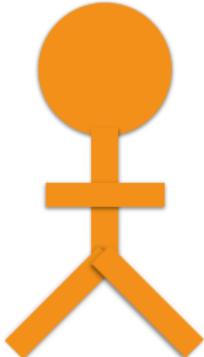


Clone

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    println!(...);  
}
```



Copy (auto-Clone)

```
fn main() {  
    let count = 22;  
    helper(count);  
    helper(count);  
}
```

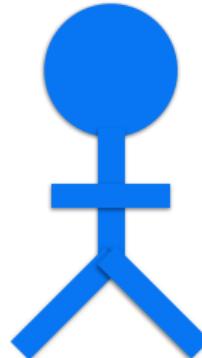
```
fn helper(count: i32) {  
    println!(..);  
}
```



Copy (auto-Clone)

```
fn main() {  
    let count = 22;  
    helper(count);  
    helper(count);  
}
```

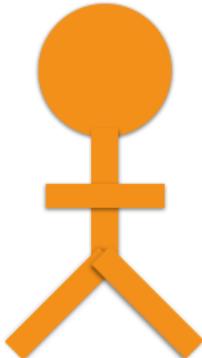
```
fn helper(count: i32) {  
    println!(..);  
}  
i32 is a Copy type
```



Copy (auto-Clone)

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fn main() {  
    let count = 22;  
    → helper(count);  
    helper(count);  
}
```

```
fn helper(count: i32) {  
    println!(..);  
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↑  
i32 is a Copy type
```



Copy (auto-Clone)

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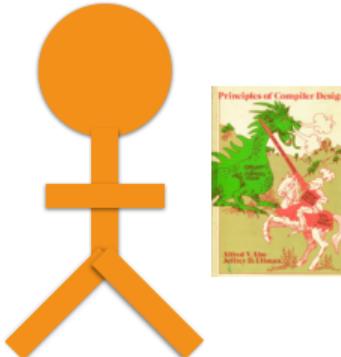
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Copy (auto-Clone)

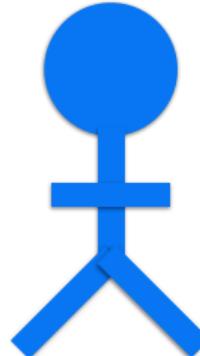
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i32 is a Copy type



Non-copyable: Values **move** from place to place.

Example: *money*

Clone: Run custom code to make a copy.

Example: *strings*

Copy: Type is implicitly copied when referenced.

Example: *integers or floating-point numbers*



Borrowing: Shared Borrows



Borrowing: Shared Borrows



Borrowing: Shared Borrows

```
fn main() {  
    let name = format!("...");  
    let reference = &name;  
    helper(reference);  
    helper(reference);  
}  
→
```

```
fn helper(name: &String) {  
    println!(...);  
}
```

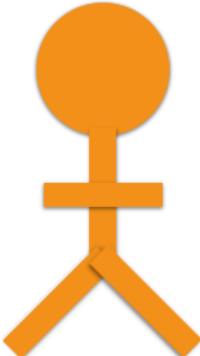


Shared borrow

```
fn main() {  
    let name = format!("...");  
    let reference = &name;  
    helper(reference);  
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```

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```

Change type to a
reference to a String



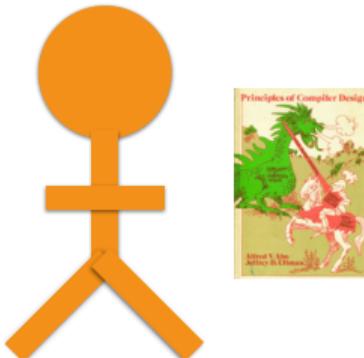
Shared borrow

```
fn main() {  
    let name = format!("...");  
    let reference = &name;  
    helper(reference);  
    helper(reference);  
}
```

Lend the string,
creating a reference

```
fn helper(name: &String) {  
    println!(...);  
}
```

Change type to a
reference to a String



Shared borrow

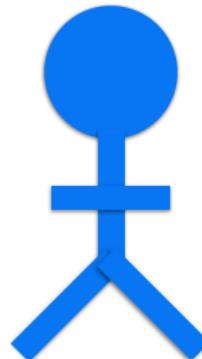
```
fn main() {  
    let name = format!("...");  
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    ➔ helper(reference);  
    helper(reference);  
}
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```
fn helper(name: &String) {  
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Shared borrow

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fn main() {  
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    let reference = &name;  
    helper(reference);  
    helper(reference);  
}  
  
fn helper(name: &String) {  
    println!(...);  
}
```



Shared borrow

```
fn main() {  
    let name = format!("...");  
    let reference = &name;   
    helper(reference);  
    helper(reference);  
}  
  
fn helper(name: &String) {  
    println!(...);  
}
```



Shared borrow

```
fn main() {  
    let name = format!("...");  
    let reference = &name; ➔  
    helper(reference);  
    helper(reference);  
}  
  
fn helper(name: &String) {  
    println!(...);  
}
```



Shared borrow

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fn main() {  
    let name = format!("...");  
    let reference = &name;  
    helper(reference);  
    helper(reference);  
}  
  
fn helper(name: &String) {  
    println!(...);  
}
```



Shared borrow

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fn main() {  
    let name = format!("...");  
    let reference = &name;  
    helper(reference);  
    helper(reference);  
}  
  
→ }
```

```
fn helper(name: &String) {  
    println!(...);  
}
```

Shared borrow

Shared == Immutable

```
fn helper(name: &String) {  
    println!("{}", name);  
}
```

```
fn helper(name: &String) {  
    name.push_str("foo");  
}
```

Shared == Immutable

```
fn helper(name: &String) {  
    println!("{}", name); ← OK. Just reads.  
}
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fn helper(name: &String) {  
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Shared == Immutable

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Shared == Immutable

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```

```
error: cannot borrow immutable borrowed content `*name`  
      as mutable  
      name.push_str("s");  
      ^~~~
```

Shared == Immutable^{*}

```
fn helper(name: &String) {  
    println!("{}", name); ← OK. Just reads.  
}
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fn helper(name: &String) {  
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}
```

```
error: cannot borrow immutable borrowed content `*name`  
      as mutable  
      name.push_str("s");  
      ^~~~
```

* **Actually:** mutation only in **controlled circumstances**.

Play time



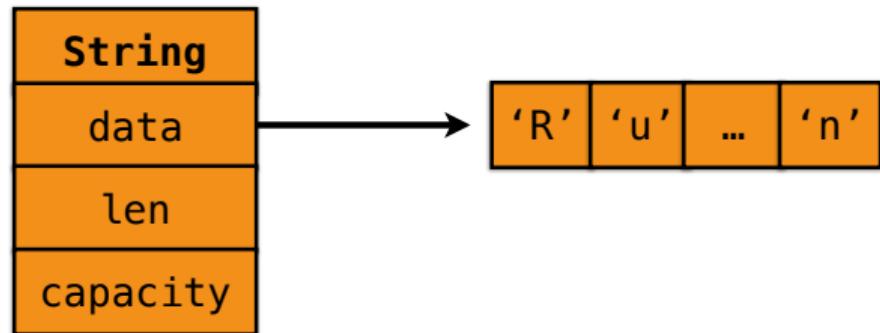
Waterloo, Cassius Coolidge, c. 1906

```
fn main() {  
    let name = format!("...");  
    helper(&name[1..]);  
    helper(&name);  
}  
  
fn helper(name: &str) {  
    println!(...);  
}
```

Looks like other languages:
• Python: name[1:]
• Ruby: name[1..-1]
But no copying at runtime.

```
fn main() {  
    let name = format!("...");  
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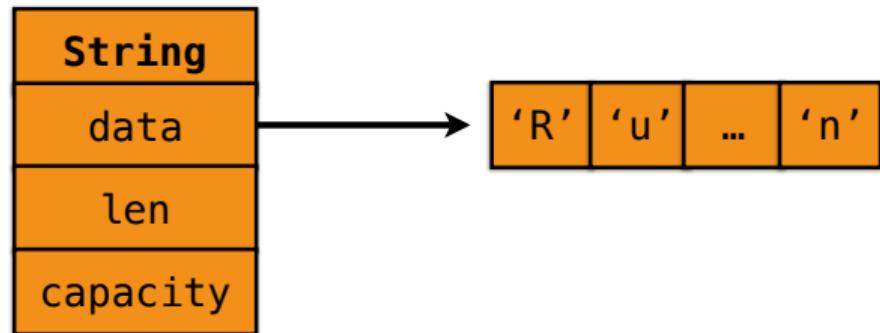
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Looks like other languages:
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}
```



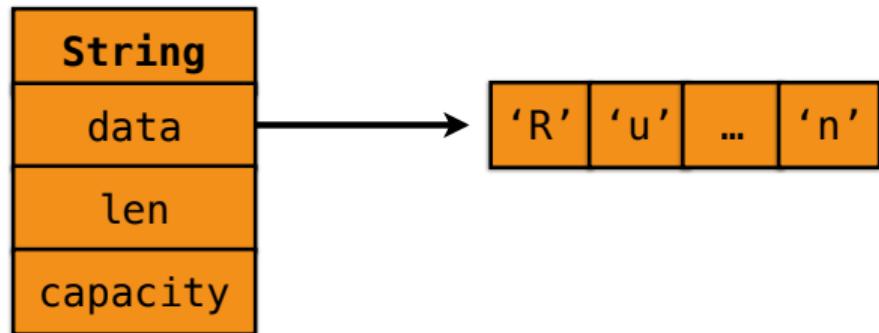
Looks like other languages:
• Python: `name[1:]`
• Ruby: `name[1..-1]`
But no copying at runtime.

```
fn main() {  
    let name = format!("...");  
    helper(&name[1..]);  
    helper(&name);  
}
```

```
fn helper(name: &str) {  
    println!(...);  
}
```

Change type from `&String`
to a **string slice**, `&str`

Looks like other languages:
• Python: name[1:]
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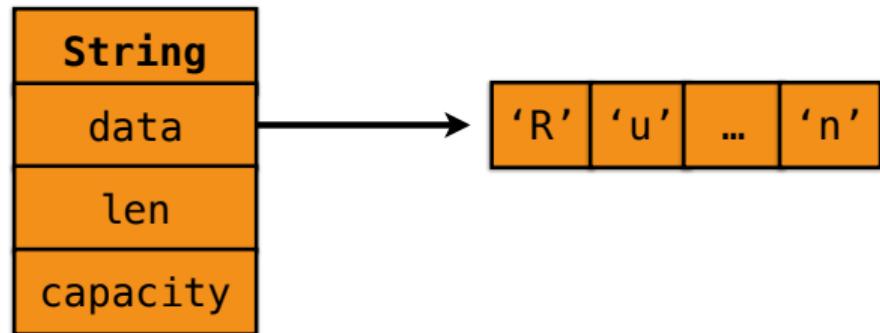


```
fn main() {  
    let name = format!("...");  
    helper(&name[1..]);  
    helper(&name);  
}
```

Lend some of
the string

```
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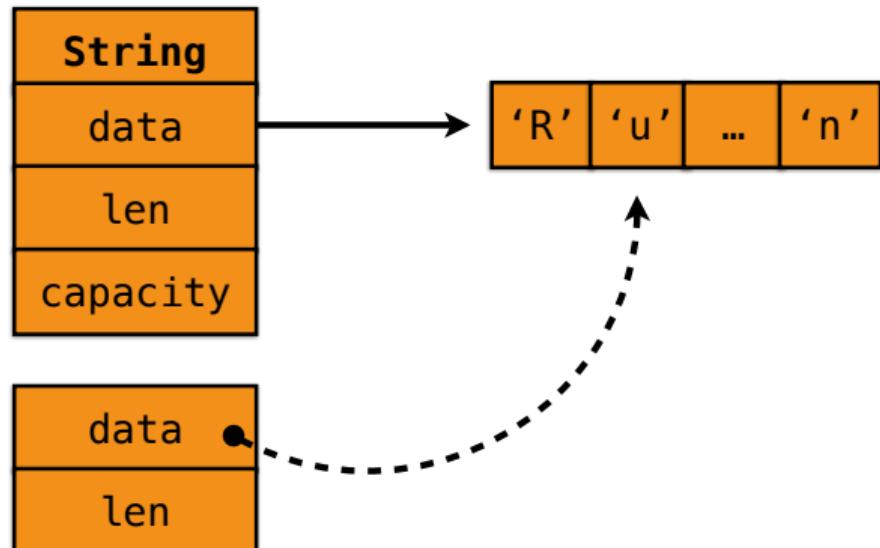
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    let name = format!("...");  
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}
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the string

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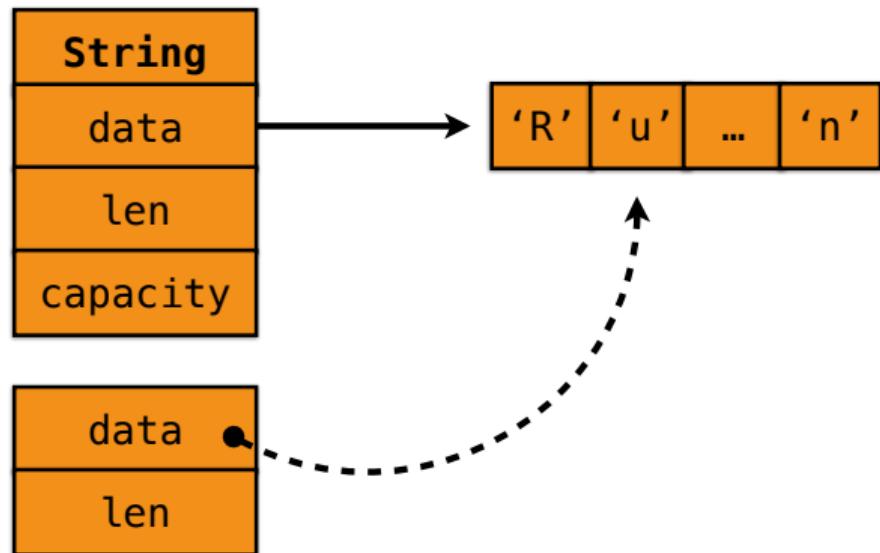


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    helper(&name[1..]);  
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}
```



```
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}
```

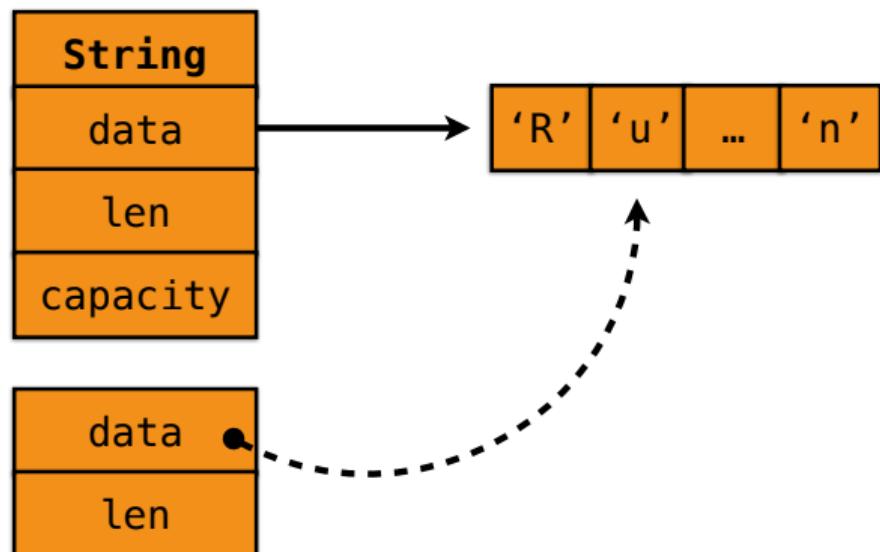
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    helper(&name[1..]);  
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}
```

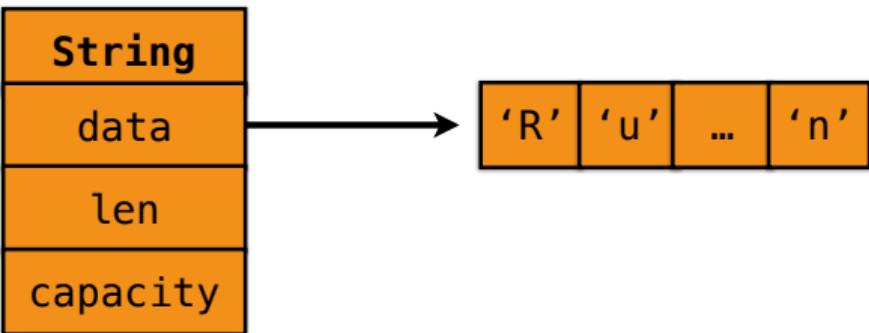
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}
```

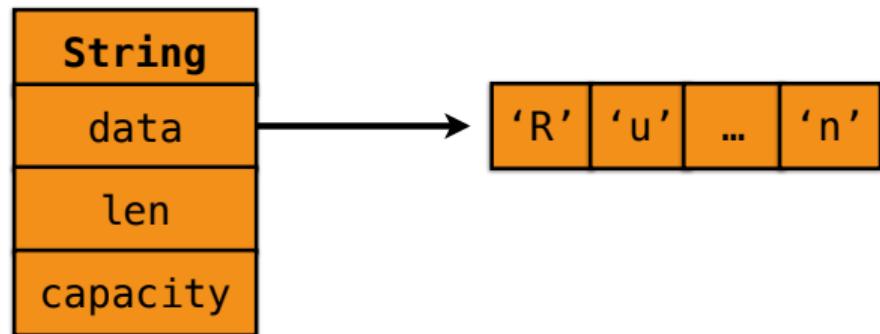
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}
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}
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Looks like other languages:
• Python: `name[1:]`
• Ruby: `name[1..-1]`
But no copying at runtime.

High-level code, low-level efficiency

```
for word in line.split(' ') {  
    sum += word.len();  
}
```

No copying, no allocations.

High-level code, low-level efficiency

```
for word in line.split(' ') {  
    sum += word.len();  
}
```

Iterator over slices
borrowed from `line`.

No copying, no allocations.

High-level code, low-level efficiency

```
for word in line.split(' ') {  
    sum += word.len();  
}
```

Iterator over slices
borrowed from `line`.

String
data
len
capacity

→ “Sing, Goddess, of Achilles’ rage, black and murderous...

No copying, no allocations.

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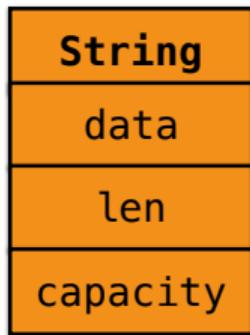
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```
for word in line.split(' ') {  
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→ "Sing, Goddess, of Achilles' rage, black and murderous..."



No copying, no allocations.



Borrowing: Mutable Borrows



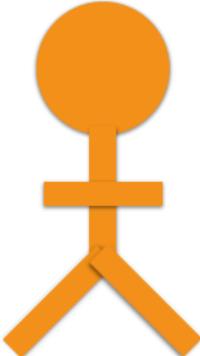
Borrowing: Mutable Borrows



Borrowing: Mutable Borrows

```
fn main() {  
    let mut name = ...;  
    update(&mut name);  
    println!("{}", name);  
}
```

```
fn update(name: &mut String) {  
    name.push_str("...");  
}
```



Mutable borrow

```
fn main() {  
    let mut name = ...;  
    update(&mut name);  
    println!("{}", name);  
}
```



```
fn update(name: &mut String) {  
    name.push_str("...");  
}
```

Take a **mutable** reference to a String



Mutable borrow

```
fn main() {  
    let mut name = ...;  
    update(&mut name);  
    println!("{}", name);  
}
```



Lend the string
mutably

```
fn update(name: &mut String) {  
    name.push_str("...");  
}
```

Take a **mutable**
reference to a String



Mutable borrow

```
fn main() {  
    let mut name = ...;  
    update(&mut name);  
    println!("{}", name);  
}
```

Lend the string
mutably

```
fn update(name: &mut String) {  
    name.push_str("...");  
}
```

Take a **mutable**
reference to a String



Mutable borrow

```
fn main() {  
    let mut name = ...;  
    update(&mut name);  
    println!("{}", name);  
}
```



```
fn update(name: &mut String) {  
    name.push_str("...");  
}
```

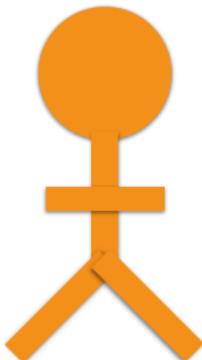


Mutable borrow

```
fn main() {  
    let mut name = ...;  
    update(&mut name);  
    println!("{}", name);  
}
```

```
fn update(name: &mut String) {  
    name.push_str("...");  
}
```

Mutate string
in place



Mutable borrow

```
fn main() {  
    let mut name = ...;  
    update(&mut name);  
    println!("{}", name);  
}
```

```
fn update(name: &mut String) {  
    name.push_str("...");  
}
```



Mutable borrow

```
fn main() {  
    let mut name = ...;  
    update(&mut name);  
    println!("{}", name);  
}
```

```
fn update(name: &mut String) {  
    name.push_str("...");  
}
```



Mutable borrow

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fn main() {  
    let mut name = ...;  
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}
```

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fn update(name: &mut String) {  
    name.push_str("...");  
}
```



Mutable borrow

```
fn main() {  
    let mut name = ...;  
    update(&mut name);  
    println!("{}", name);  
}
```

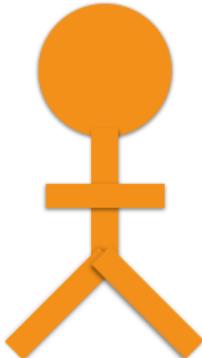
```
fn update(name: &mut String) {  
    name.push_str("...");  
}
```

Prints the
updated string.



Mutable borrow

```
fn main() {  
    let mut name = ...;  
    update(&mut name);  
    println!("{}", name);  
}  
  
fn update(name: &mut String) {  
    name.push_str("...");  
}
```



Mutable borrow

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fn main() {  
    let mut name = ...;  
    update(&mut name);  
    println!("{}", name);  
}  
  
fn update(name: &mut String) {  
    name.push_str("...");  
}
```



Mutable borrow

`name: String`

Ownership:

control all access, will free when done

`name: &String`

Shared reference:

many readers, no writers

`name: &mut String`

Mutable reference:

no readers, one writer



`name: String`

Ownership:

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`name: String`

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→ `name: &String`

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no readers, one writer

`name: String`

Ownership:

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`name: &String`

Shared reference:

many readers, no writers



`name: &mut String`

Mutable reference:

no readers, one writer

(Un)safe

How do we get safety?

How do we get safety?



```
fn main() {
    let r;
    {
        let name = format!("...");
        r = &name;
    }
    println!("{}", r);
}
```

```
fn main() {  
    let r;  
    {  
        let name = format!("...");  
        r = &name;  
    }  
    println!("{}", r);  
}
```

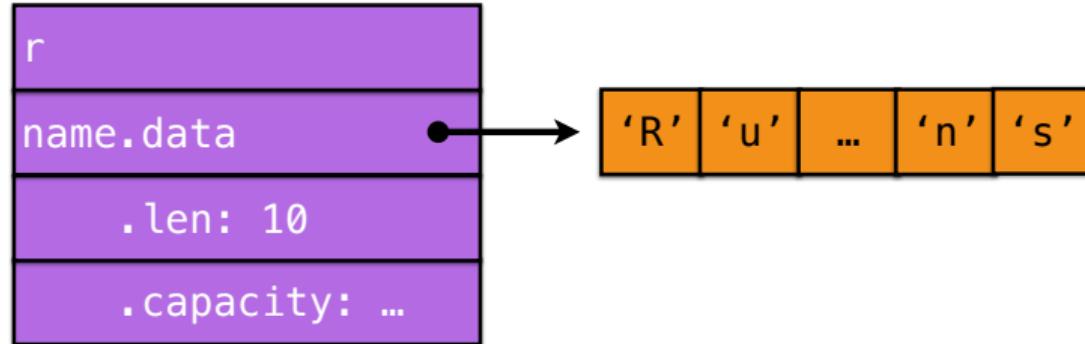
```
fn main() {  
    let r;  
    {  
        let name = format!("...");  
        r = &name;  
    }  
    println!("{}", r);  
}
```

r

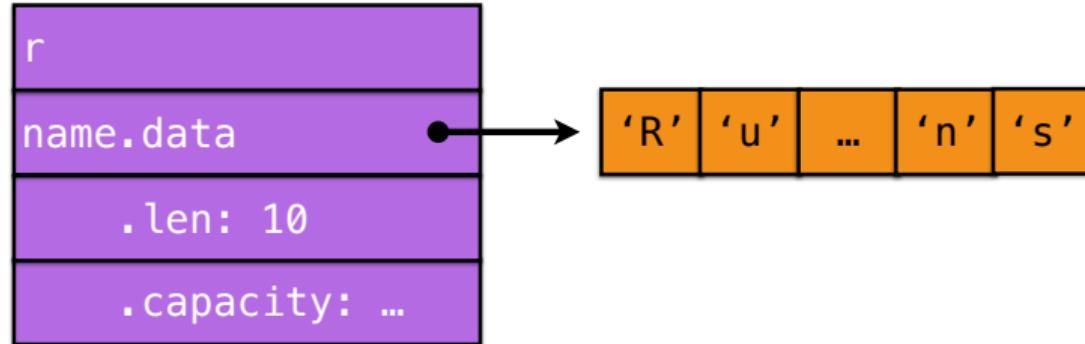
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fn main() {  
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    {  
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        r = &name;  
    }  
    println!("{}", r);  
}
```

r

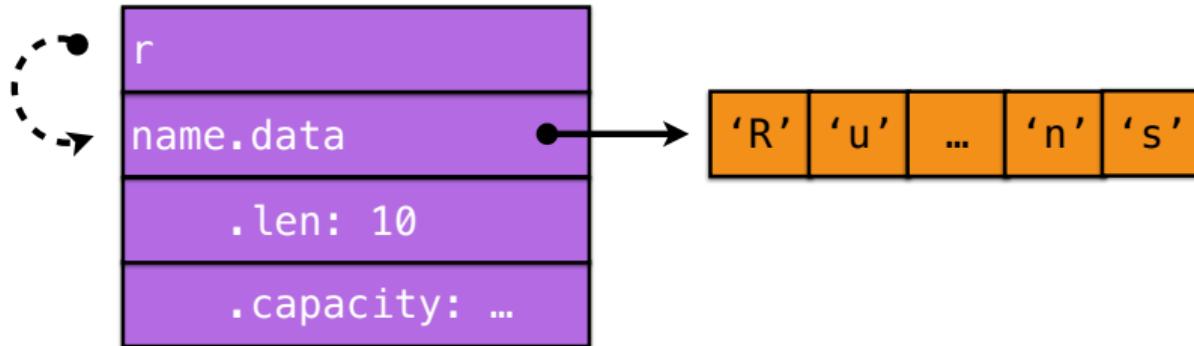
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    let r;  
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        r = &name;  
    }  
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}
```



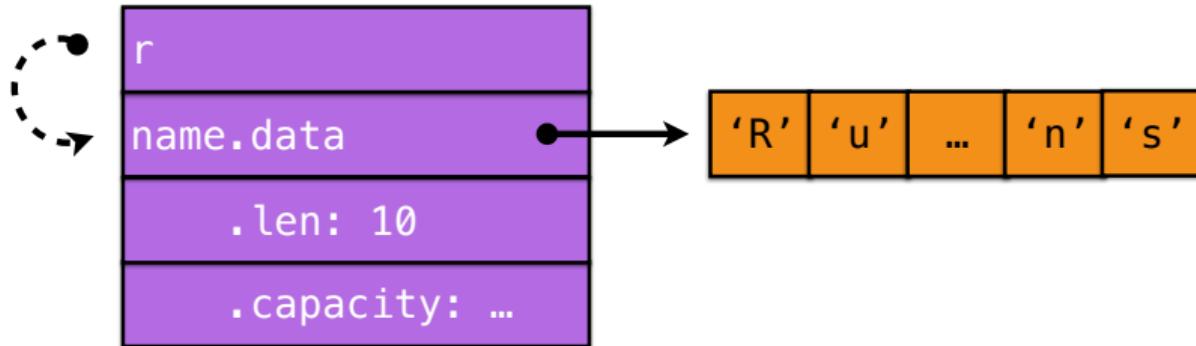
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    {  
        let name = format!("...");  
        r = &name;  
    }  
    println!("{}", r);  
}
```



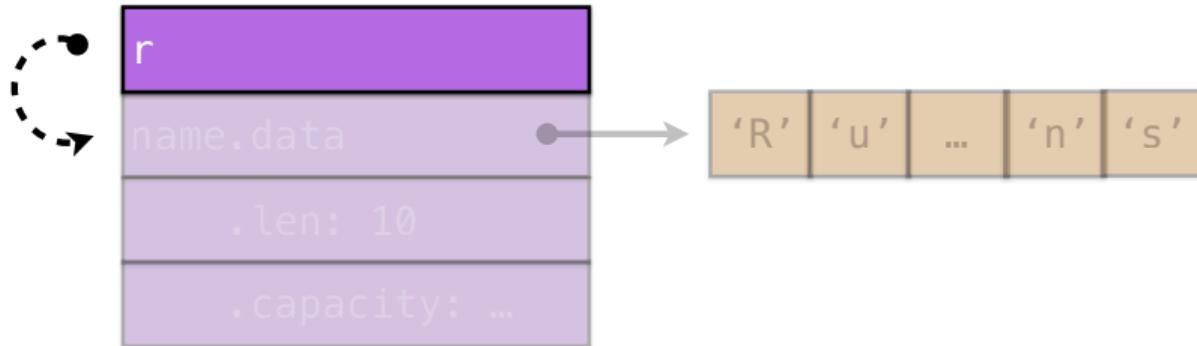
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fn main() {  
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    {  
        let name = format!("...");  
        r = &name;  
    }  
    println!("{}", r);  
}
```



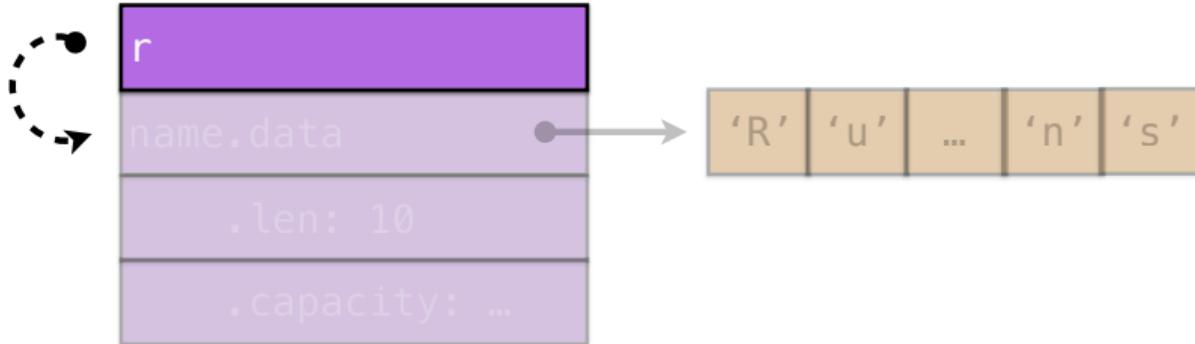
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fn main() {
    let r;
    {
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    }
    println!("{}{}", r);
}
```



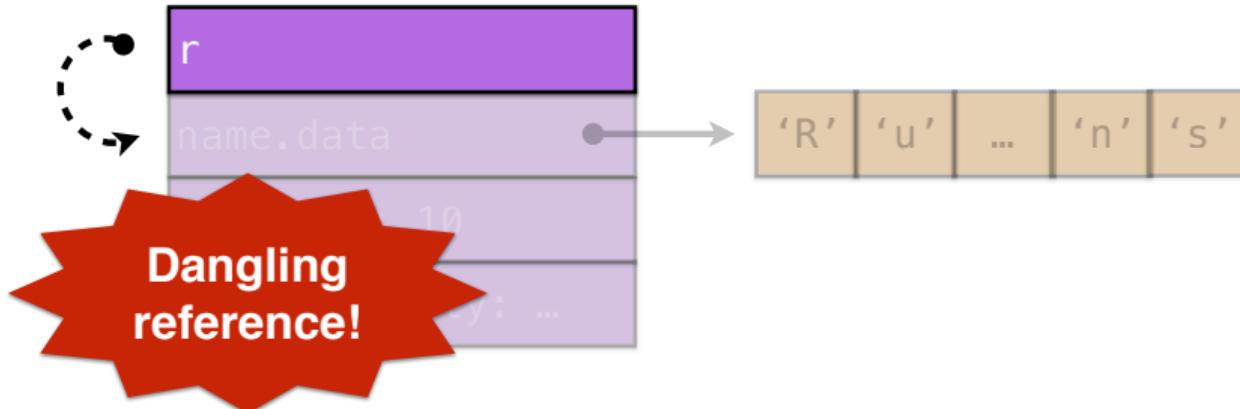
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    }
    println!("{}{}", r);
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```
fn main() {  
    let r;  
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fn main() {  
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}
```



```
fn main() {
    let r;
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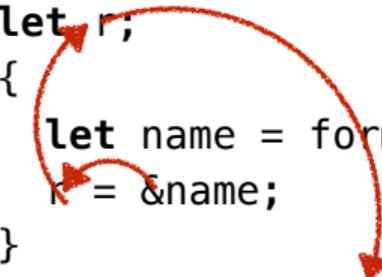
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    }
    println!("{}", r);
}
```

Lifetime: span of code where reference is used.

```
fn main() {  
    let r;  
    {  
        let name = format!("...");  
        r = &name;  
    }  
    println!("{}", r);  
}
```

Lifetime: span of code where reference is used.

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fn main() {  
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    }  
    println!("{}{}", r);  
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```



Lifetime: span of code where reference is used.

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        r = &name;  
    }  
    println!("{}", r);  
}
```

Lifetime: span of code where reference is used.

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fn main() {  
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    }  
    println!("{}", r);  
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```

Lifetime: span of code where reference is used.

compared against

Scope of data being borrowed (here, `name`)

```
fn main() {  
    let r;  
    {  
        let name = format!("...");  
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    }  
    println!("{}", r);  
}
```

Lifetime: span of code where reference is used.

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Scope of data being borrowed (here, `name`)

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    }  
    println!("{}", r);  
}
```

Lifetime: span of code where reference is used.

compared against

Scope of data being borrowed (here, `name`)

```
error: `name` does not live long enough  
r = &name;  
     ^~~~
```

```
use std::thread;

fn helper(name: &String) {
    thread::spawn(move || {
        use(name);
    });
}
```

```
use std::thread;  
  
fn helper(name: &String) {  
    thread::spawn(move || {  
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}
```

name` can only be used within this fn



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use std::thread;  
  
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`name` can only be used within this fn

Might escape
the function!

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Might escape
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error: the type ` [...]` does not fulfill the required lifetime  
    thread::spawn(move || {  
        ^~~~~~  
note: type must outlive the static lifetime
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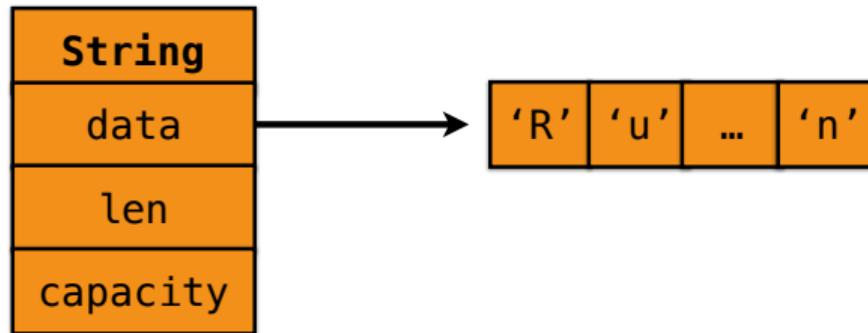
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    thread::spawn(move || {  
        ^~~~~~  
note: type must outlive the static lifetime
```

Dangers of mutation

```
let mut buffer: String = format!("Rustacean");
let slice = &buffer[1..];
buffer.push_str("s");
println!("{:?}", slice);
```

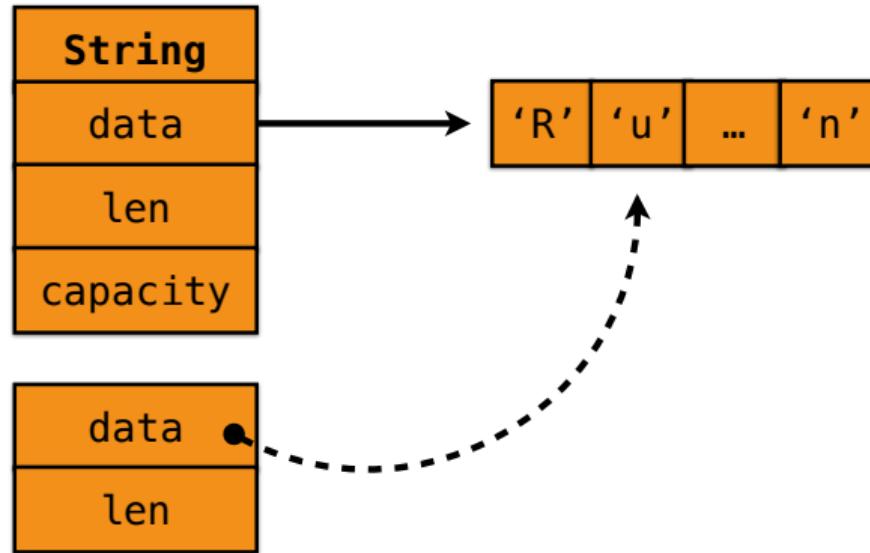
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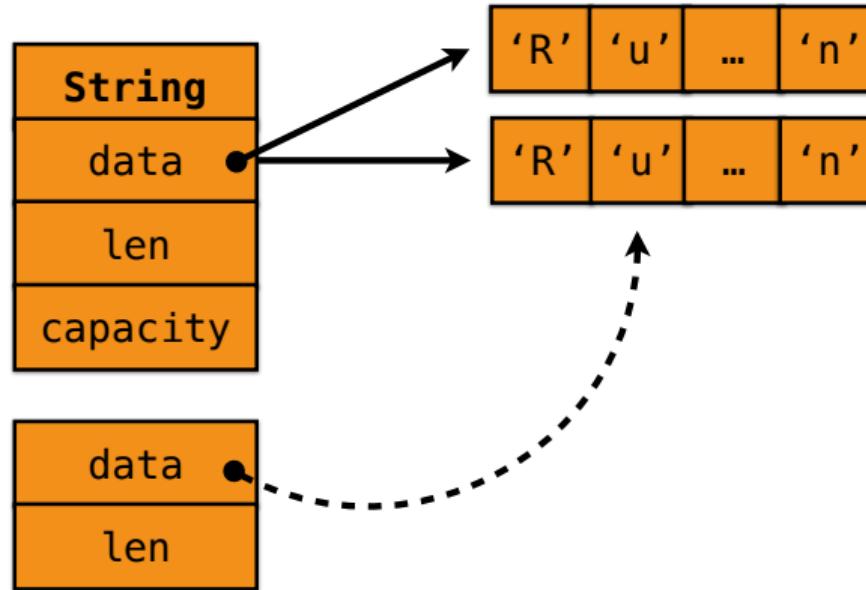
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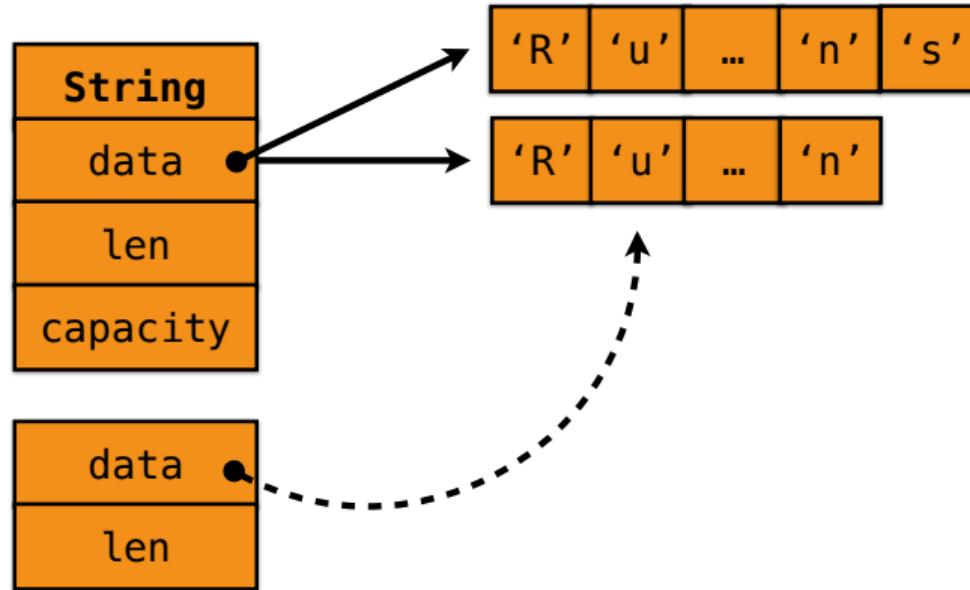
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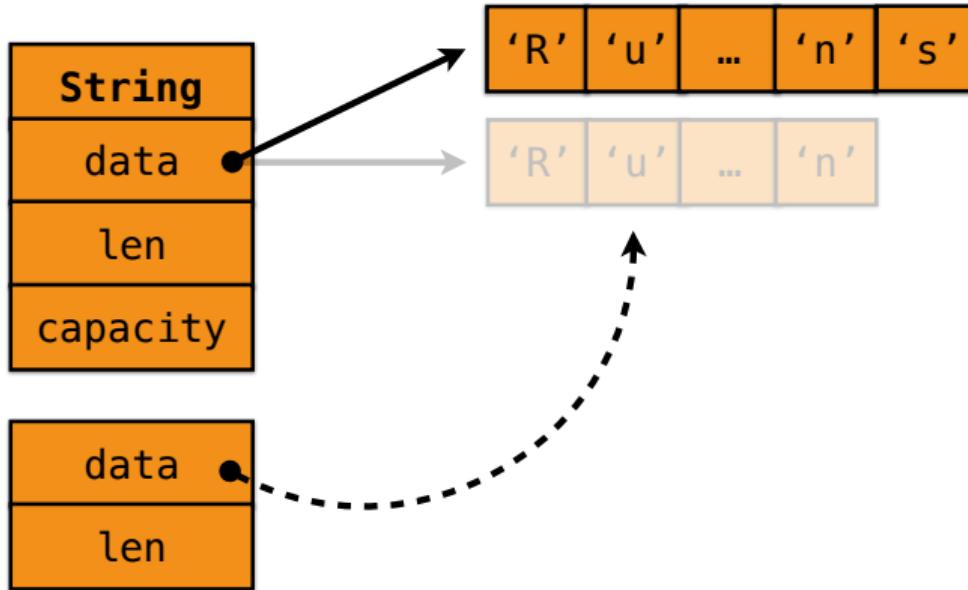
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```



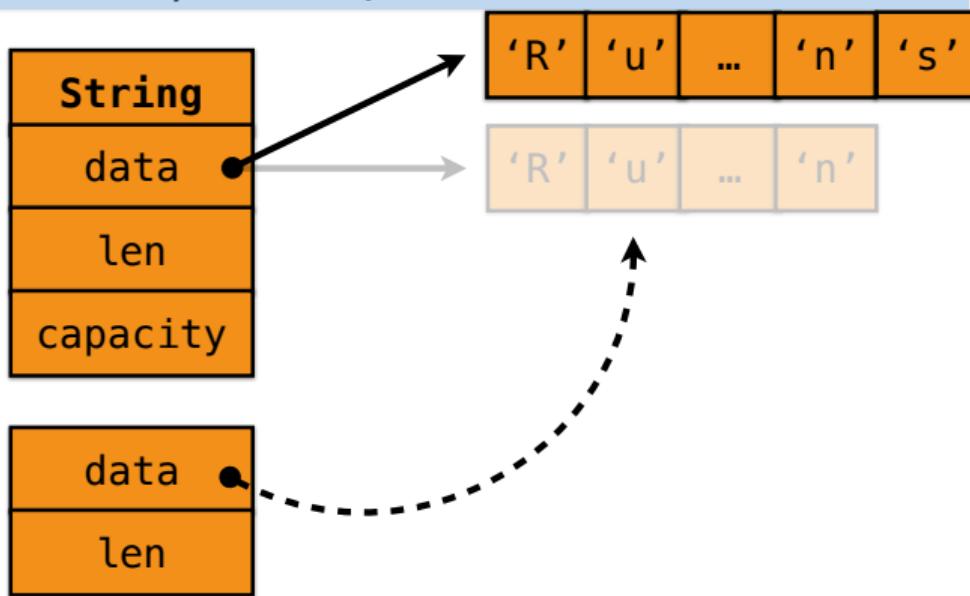
Dangers of mutation

```
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let slice = &buffer[1..];
buffer.push_str("s");
println!("{}:?}", slice);
```



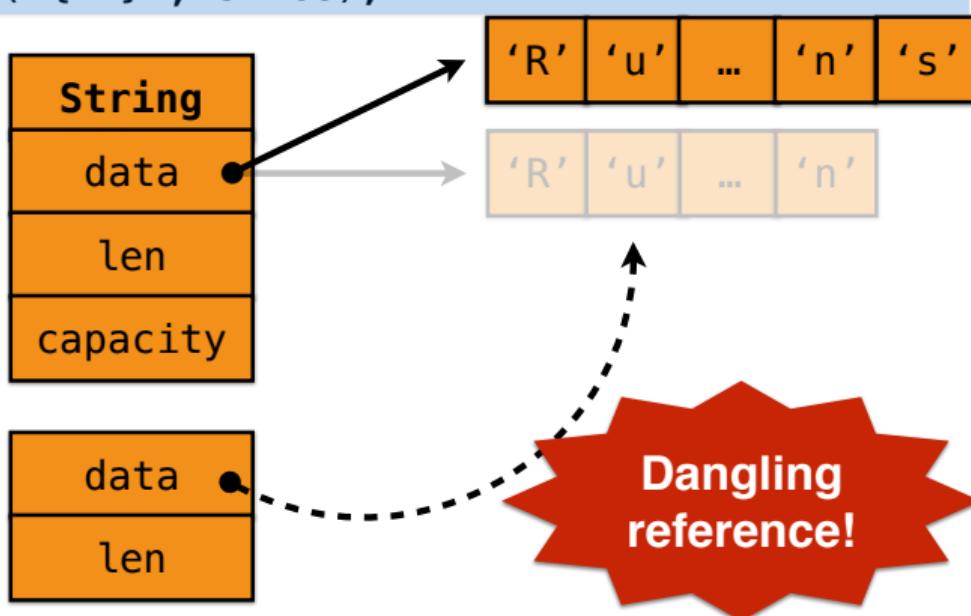
Dangers of mutation

```
let mut buffer: String = format!("Rustacean");
let slice = &buffer[1..];
buffer.push_str("s");
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```



Dangers of mutation

```
let mut buffer: String = format!("Rustacean");
let slice = &buffer[1..];
buffer.push_str("s");
println!("{}:?", slice);
```



Rust solution

Compile-time read-write-lock:

Creating a shared reference to X “**read locks**” X.

- Other readers OK.
- No writers.
- Lock lasts until reference goes out of scope.

Creating a mutable reference to X “**writes locks**” X.

- No other readers or writers.
- Lock lasts until reference goes out of scope.

Never have a reader/writer at same time.

Dangers of mutation

```
fn main() {  
    let mut buffer: String = format!("Rustacean");  
    let slice = &buffer[1..];  
    buffer.push_str("s");  
    println!("{}:?", slice);  
}
```

Dangers of mutation

```
fn main() {  
    let mut buffer: String = format!("Rustacean");  
    let slice = &buffer[1..];  
    buffer.push_str("s");  
    println!("{}:?", slice);  
}
```



Borrow “locks”
`buffer` until `slice`
goes out of scope

Dangers of mutation

```
fn main() {  
    let mut buffer: String = format!("Rustacean");  
    let slice = &buffer[1..];  
    buffer.push_str("s");  
    println!("{}:?", slice);  
}
```



Borrow “locks”
`buffer` until `slice`
goes out of scope

Dangers of mutation

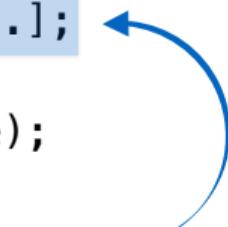
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    let mut buffer: String = format!("Rustacean");  
    let slice = &buffer[1..];  
    buffer.push_str("s");  
    println!("{}:?", slice);  
}
```

Borrow “locks”
`buffer` until `slice`
goes out of scope

```
error: cannot borrow `buffer` as mutable  
       because it is also borrowed as immutable  
           buffer.push_str("s");  
           ^~~~~~
```

```
fn main() {
    let mut buffer: String = format!("Rustacean");
    for i in 0 .. buffer.len() {
        let slice = &buffer[i..];
        buffer.push_str("s");
        println!("{}:?", slice);
    }
    buffer.push_str("s");
}
```

```
fn main() {  
    let mut buffer: String = format!("Rustacean");  
    for i in 0 .. buffer.len() {  
        let slice = &buffer[i..];  
        buffer.push_str("s");  
        println!("{}:{}?", slice);  
    }  
    buffer.push_str("s");  
}
```



Borrow “locks”
`buffer` until `slice`
goes out of scope

```
fn main() {  
    let mut buffer: String = format!("Rustacean");  
    for i in 0 .. buffer.len() {  
        let slice = &buffer[i..];  
        buffer.push_str("s");  
        println!("{}:?", slice);  
    }  
    buffer.push_str("s");  
}
```

Borrow “locks”
`buffer` until `slice`
goes out of scope

```
fn main() {  
    let mut buffer: String = format!("Rustacean");  
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    }  
    buffer.push_str("s");  
}
```

Borrow “locks”
`buffer` until `slice`
goes out of scope

OK: `buffer` is not borrowed here

(Un)safe

Comparison

C

```
1 uint8_t* pointer = (uint8_t*) malloc(SIZE); // Might return NULL
2 for(int i = 0; i < SIZE; ++i) {
3     pointer[i] = i; // Might cause a Segmentation Fault
4 }
```

Rust

```
1 let mut vec = vec![0 as u8; SIZE];
2 for i in 0..SIZE { // As C code
3     vec[i] = i;
4 }
```

Functional Rust

```
1 let vec: Vec<u8> = (0..10).collect();
```

Rust References

```
1 let my_var: u32 = 42;
2 let my_ref: &u32 = &my_var; // References ALWAYS point
3 // to valid data
4 let my_var2 = *my_ref; // An example for a Dereference
```

```
1  uint8_t* pointer = (uint8_t*) malloc(SIZE); C
2  // ...
3  if (err) {
4      abort = 1;
5      free(pointer);
6  }
7  // ...
8  if (abort) {
9      logError("operation aborted", pointer);
10 }
```

Rust

```
1 let vec: Vec<u32> = Vec::new();
2 {
3     {
4         let vec_1 = vec; // vec's ownership has been moved
5     } // the Vec will be freed (dropped) here
6 }
```

```
1 uint8_t* get_dangling_pointer(void) {
2     uint8_t array[4] = {0};
3     return &array[0];
4 }
```

```
Rust
1 fn get_dangling_pointer() -> &u8 {
2     let array = [0; 4];
3     &array[0]
4 }
```

Compile time error

```
1 | fn get_dangling_pointer() -> &u8 {  
| | ^ help: consider giving it a  
| | 'static lifetime: `&'static`  
| |  
= help: this function's return type contains a borrowed value,  
| | but there is no value for it to be borrowed from
```

```
1 void print_out_of_bounds(void) { C
2     uint8_t array[4] = {0};
3     printf("%u\r\n", array[4]);
4 }
5 // prints memory that's outside `array` (on the stack)
```

Rust

```
1 fn print_panics() {  
2     let array = [0; 4];  
3     println!("{}", array[4]);  
4 }
```

```
Compile time error  
error: index out of bounds: the len is 4 but the index is 4  
--> test.rs:8:20
```

```
|  
3 |     println!("{}", array[4]);  
|           ^^^^^^  
|  
|= note: #[deny(const_err)] on by default
```

(Un)safe

Concurrency

Originally: Rust had message passing built into the language

Now: library-based, multi-paradigm

- rayon (parallel processing, thread pool)
- tokio, futures (I/O, async)
- coroutine, coio (coroutine)
- crossbeam, mio (low-level concurrency)

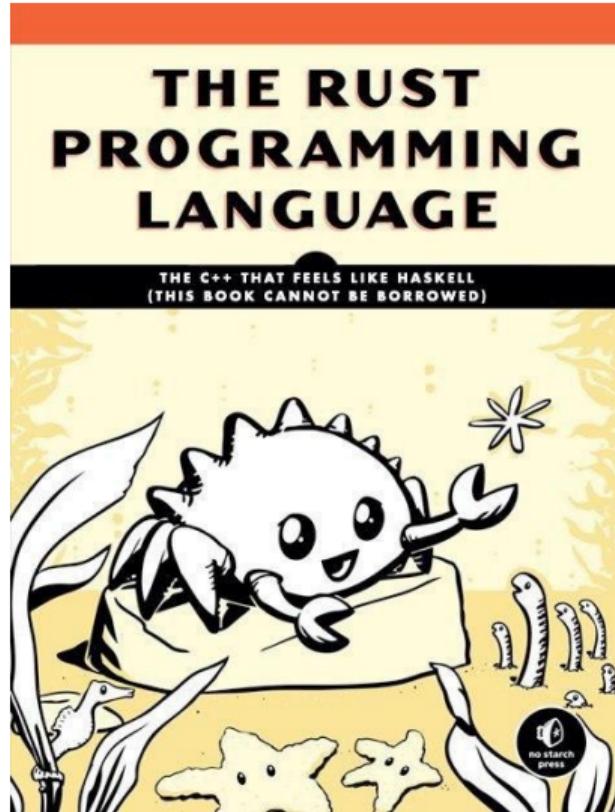
Libraries leverage **ownership and traits** to avoid data races



Rust

```
1 fn qsort(vec: &mut [i32]) {  
2     if vec.len() <= 1 { return; }  
3     let pivot = vec[random(vec.len())];  
4     let mid = vec.partition(vec, pivot);  
5     let (less, greater) = vec.split_at_mut(mid);  
6  
7     rayon::join(|| qsort(less),  
8                 || qsort(greater));  
9  
10 }
```

Syntax



Syntax

Concepts

```
1  //! # Main
2  //! Module docs
3
4  /// Docs
5  // Comments
6  fn main() {
7      let x = 31337;
8      println!("The value of x is: {}", x); // 31337
9      let mut y: u8 = 5;
10     y = x as u8;
11     println!("The value of y is: {}", y); // 105
12 }
```

```
1 fn nsa(is_hack: bool, backdoor: &str, blue_pill: String) -> f64 {
2     for c in blue_pill.chars() {
3         print!("{}", c);
4     }
5     if is_hack {
6         loop { break 3.1337; }
7     } else if backdoor.len() > 3 {
8         42.0
9     } else {
10        3.14
11    }
12 }
```

Summary

Questions?

