



# Rust and what's this thing for?



Abc Xyz  
@dura\_lex

1. Foreword

2. What is Rust?

3. (Un)safe

4. Summary

# Foreword

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- 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?

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«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](http://www.rust-lang.org) (2015)

«Empowering everyone to build reliable and efficient software».

— [www.rust-lang.org](http://www.rust-lang.org)

# What is Rust?

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Quick facts about Rust

- Started by Mozilla (sponsorship & support) employee Graydon Hoare
- 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

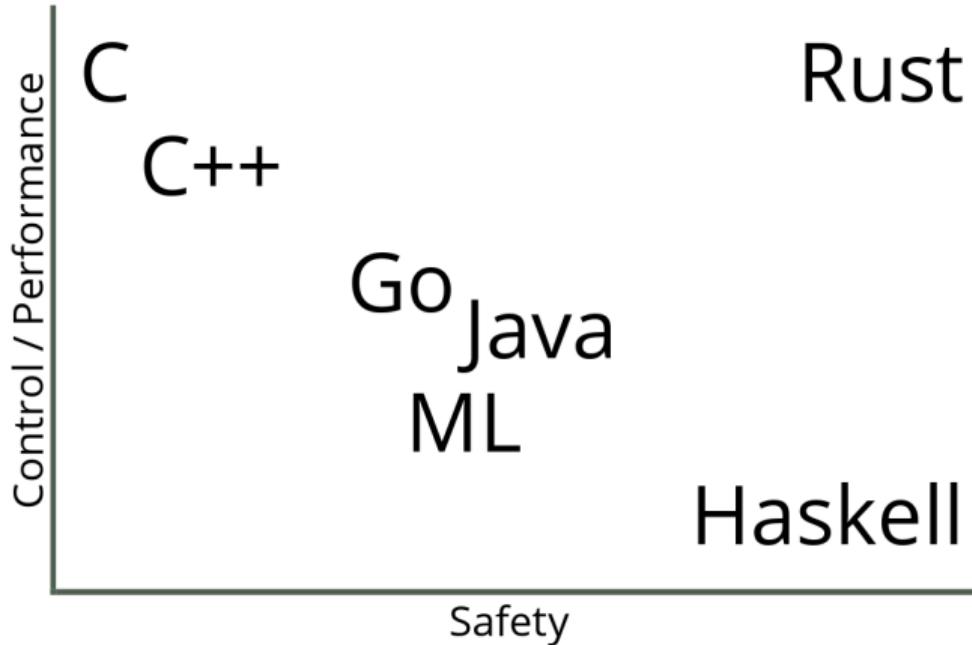
(Un)safe

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(Un)safe

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Control vs Safety



(Un)safe

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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

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Ownership and Borrowing



# *Ownership and Borrowing*

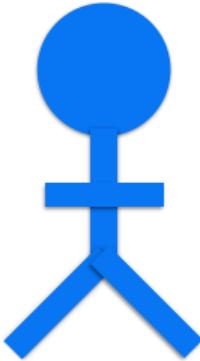
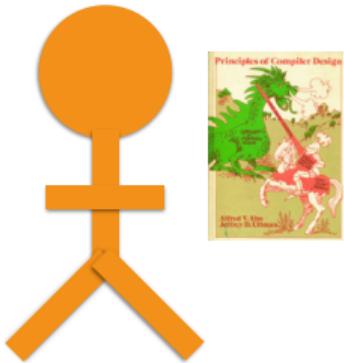
**Nicholas Matsakis**

# **Ownership**

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

# **Borrow**

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



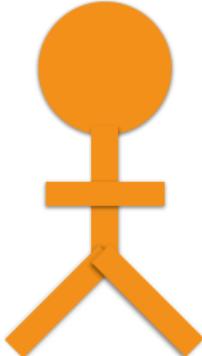
# Ownership



# Ownership

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

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



## Ownership

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



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



**Ownership**

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



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

Take ownership  
of a String



**Ownership**

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

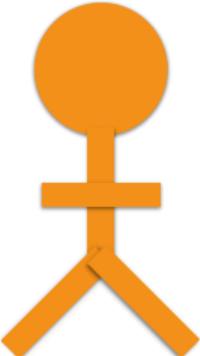


```
fn helper(name: String) {  
    println!(...);  
}
```



**Ownership**

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



## Ownership

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

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



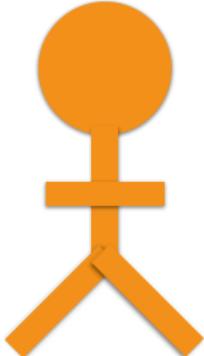
**Ownership**

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



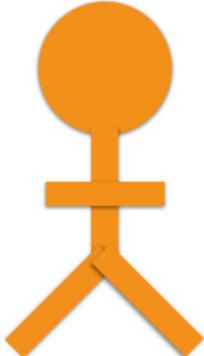
## Ownership

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



## Ownership

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



## Ownership

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

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

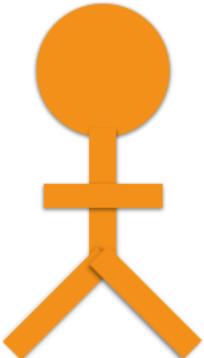
**Error:** use of moved value: `name`



**Ownership**

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

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



## “Ownership” in Java

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

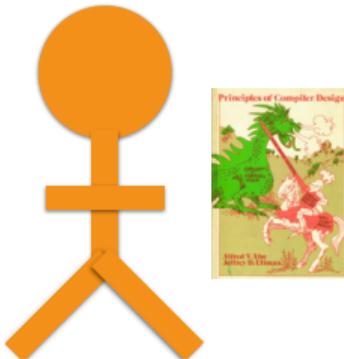
```
void helper(Vector name) {  
    ...  
}
```



“Ownership” in Java

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

```
void helper(Vector name) {  
    ...  
}  
↑  
Take reference  
to Vector
```



“Ownership” in Java

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



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

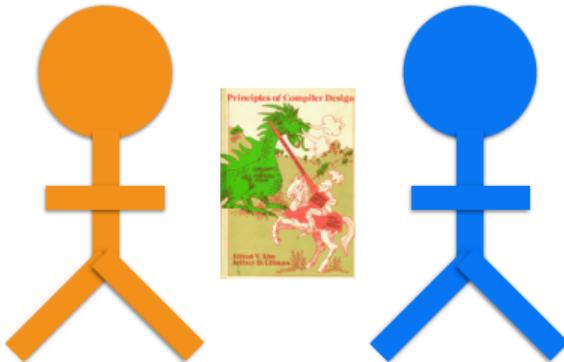


“Ownership” in Java

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



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

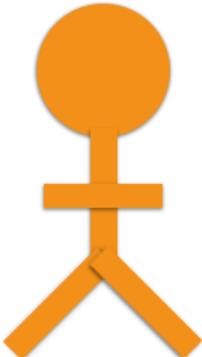


“Ownership” in Java

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

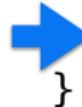


```
void helper(Vector name) {  
    ...  
}
```

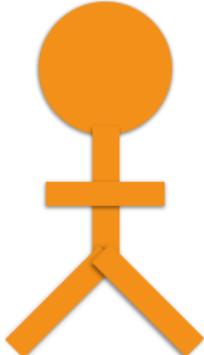


“Ownership” in Java

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



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



“Ownership” in Java

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

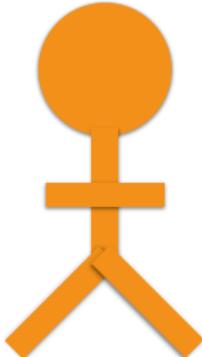
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    Vector name = ...;  
    helper(name);  
    helper(name);  
}
```

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

# Clone

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

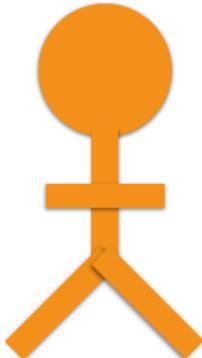
```
fn helper(name: String) {  
    println!(...);  
}
```



# Clone

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

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

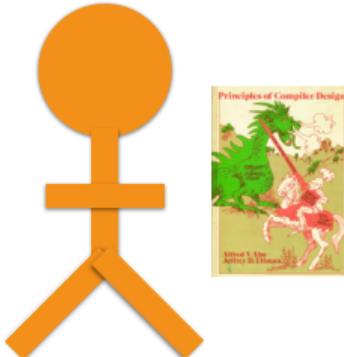


# Clone

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

Copy the String

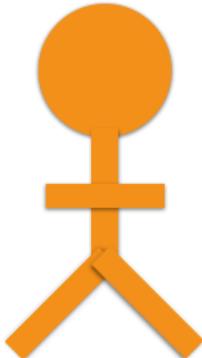
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# Clone

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}
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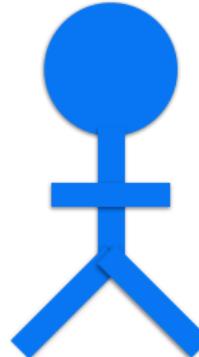
# Clone

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    helper(name.clone());  
    helper(name);  
}  
}
```



# Clone

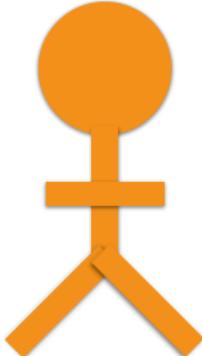
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# Clone

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



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



# Copy (auto-Clone)

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

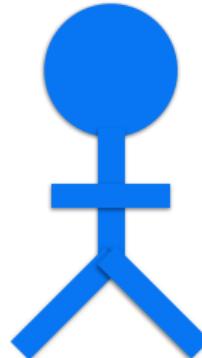
```
fn helper(count: i32) {  
    println!(..);  
}
```



# Copy (auto-Clone)

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

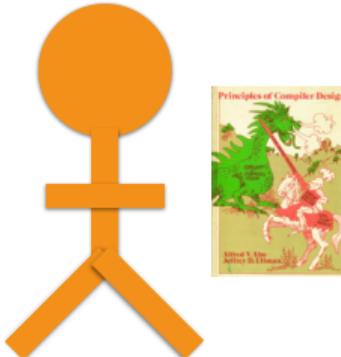
```
fn helper(count: i32) {  
    println!(..);  
}  
i32 is a Copy type
```



# Copy (auto-Clone)

```
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;  
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}
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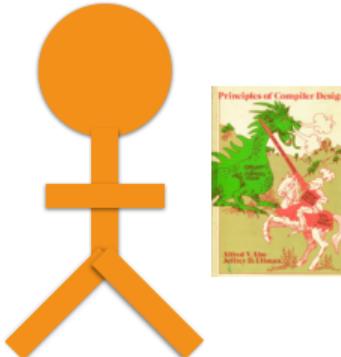
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    println!(..);  
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# Copy (auto-Clone)

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# Copy (auto-Clone)

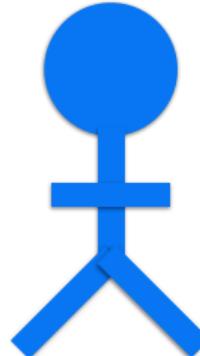
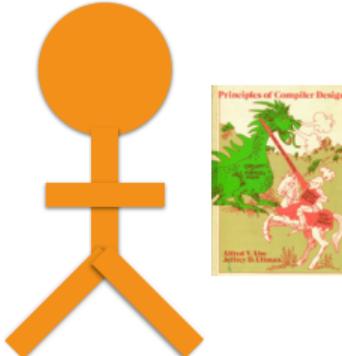
```
fn main() {  
    let count = 22;  
    helper(count);  
    helper(count);  
}
```



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



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);  
    helper(reference);  
}
```

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

Change type to a  
**reference** to a String



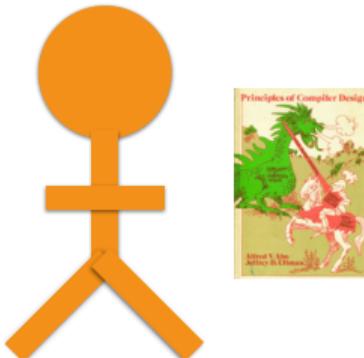
Shared borrow

```
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**

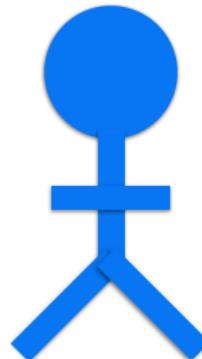
```
fn main() {  
    let name = format!("...");  
    let reference = &name;  
    ➔ helper(reference);  
    helper(reference);  
}
```

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



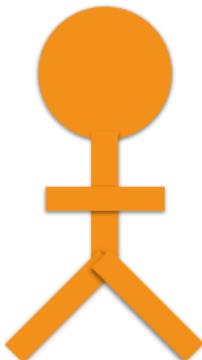
Shared borrow

```
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

```
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

# 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.  
}
```

```
fn helper(name: &String) {  
    name.push_str("foo");  
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# Shared == Immutable

```
fn helper(name: &String) {  
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# Shared == Immutable

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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");  
      ^~~~
```

# Shared == Immutable<sup>\*</sup>

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

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

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

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

# Play time



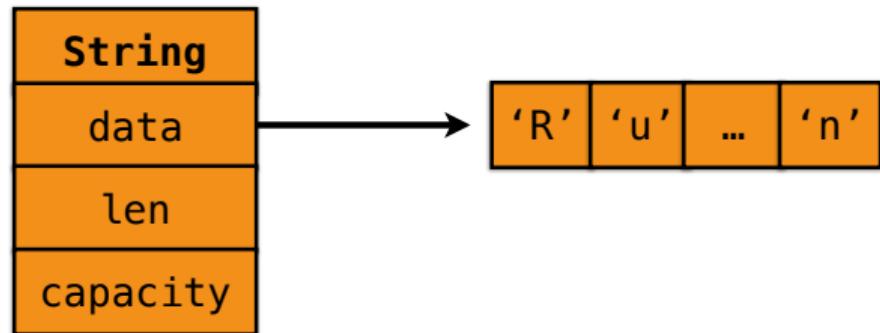
Waterloo, Cassius Coolidge, c. 1906

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

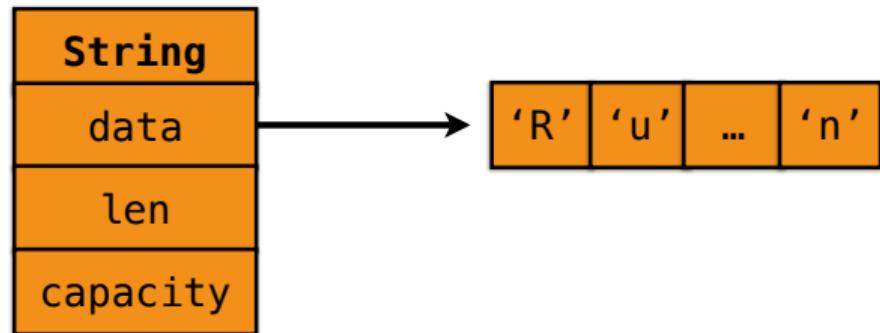
```
fn helper(name: &str) {  
    println!(...);  
}
```



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

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fn main() {  
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}
```

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



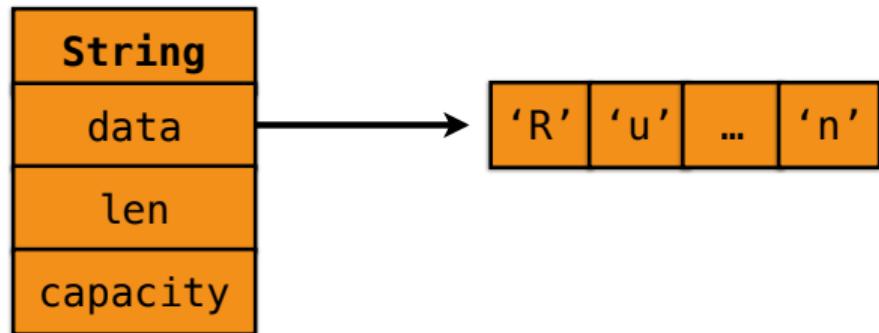
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• Python: `name[1:]`  
• Ruby: `name[1..-1]`  
**But no copying** at runtime.

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

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

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

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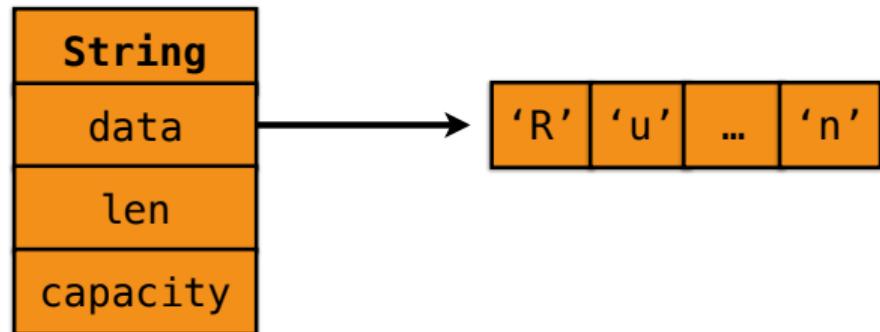


```
fn main() {  
    let name = format!("...");  
    helper(&name[1..]);  
    helper(&name);  
}
```

Lend some of  
the string

```
fn helper(name: &str) {  
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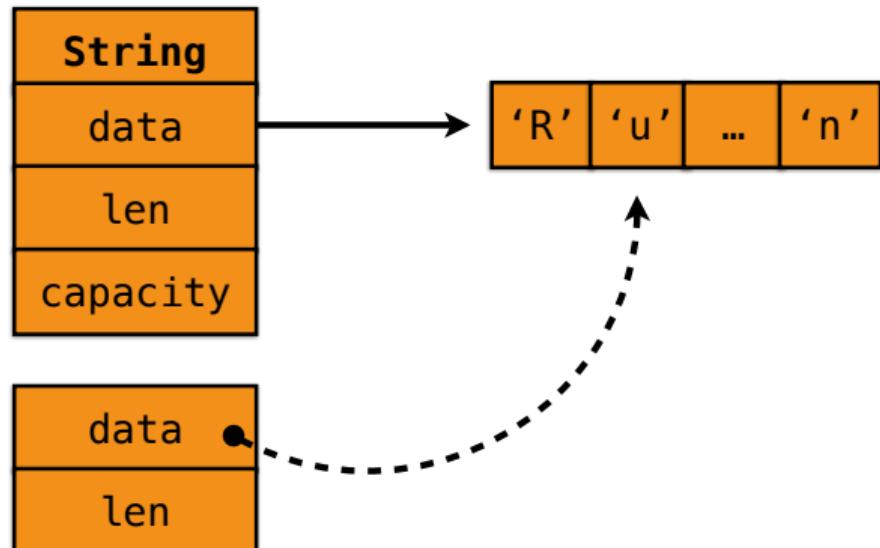
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    let name = format!("...");  
    helper(&name[1..]);  
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}
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Lend some of  
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Looks like other languages:  
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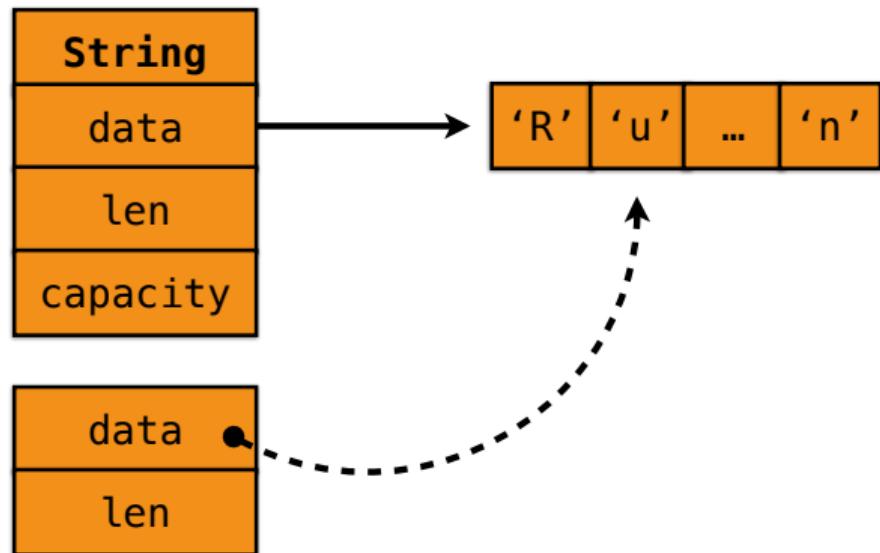


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    helper(&name[1..]);  
    helper(&name);  
}
```



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

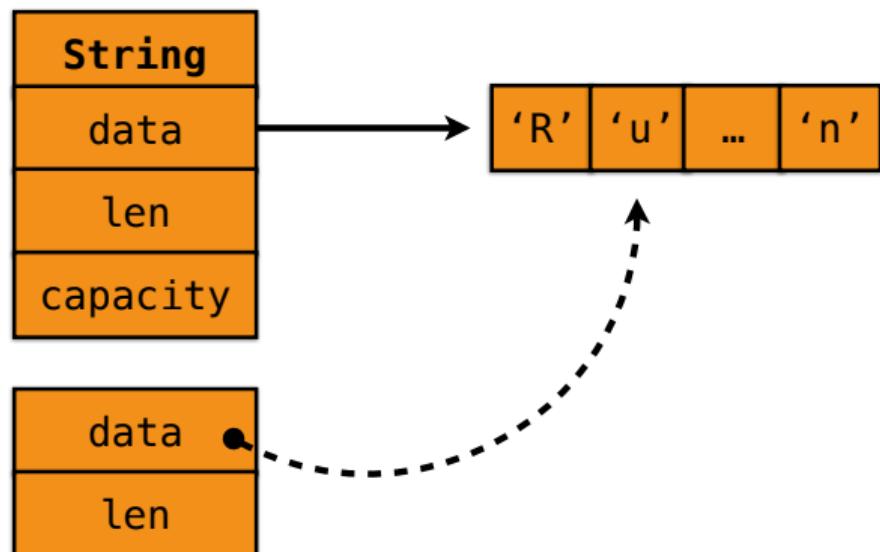
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```
fn main() {  
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}
```

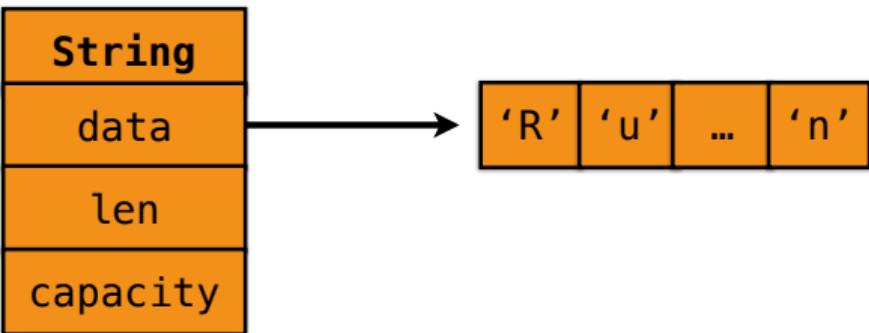
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    println!(...);  
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    helper(&name);  
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```

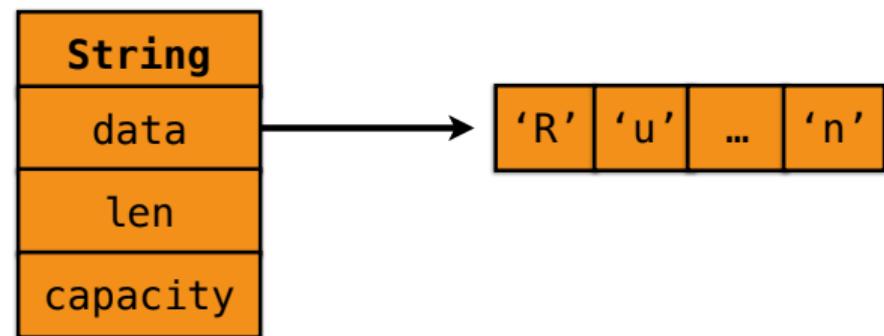
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}
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Looks like other languages:  
• Python: `name[1:]`  
• Ruby: `name[1..-1]`  
**But no copying** at runtime.

# 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(' ') {  
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```

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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for word in line.split(' ') {  
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String
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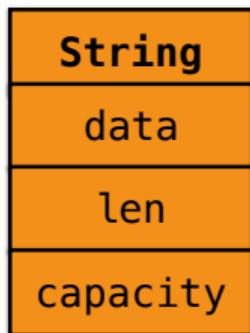
data
len

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# High-level code, low-level efficiency

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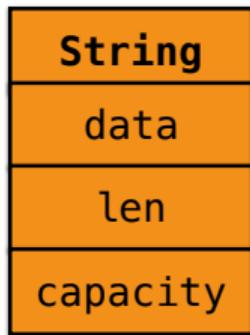


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# High-level code, low-level efficiency

```
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→ "Sing, Goddess, of Achilles' rage, black and murderous..."



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## Borrowing: Mutable Borrows



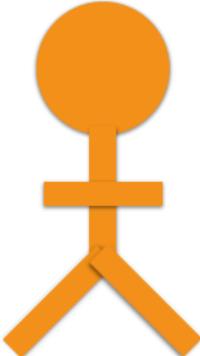
## Borrowing: Mutable Borrows



## 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("...");  
}
```

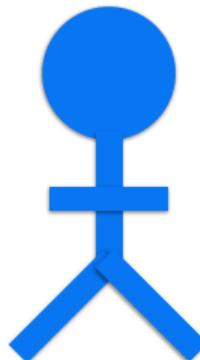
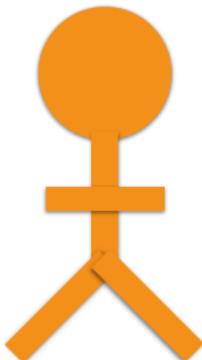


Mutable borrow

```
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);  
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fn update(name: &mut String) {  
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```



## Mutable borrow

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

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



## Mutable borrow

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

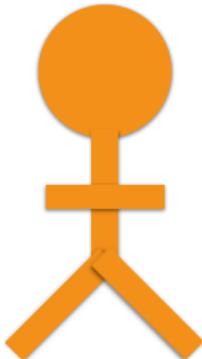
```
fn update(name: &mut String) {  
    name.push_str("...");  
}
```

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

```
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



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**Ownership:**

control all access, will free when done

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`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);  
}
```

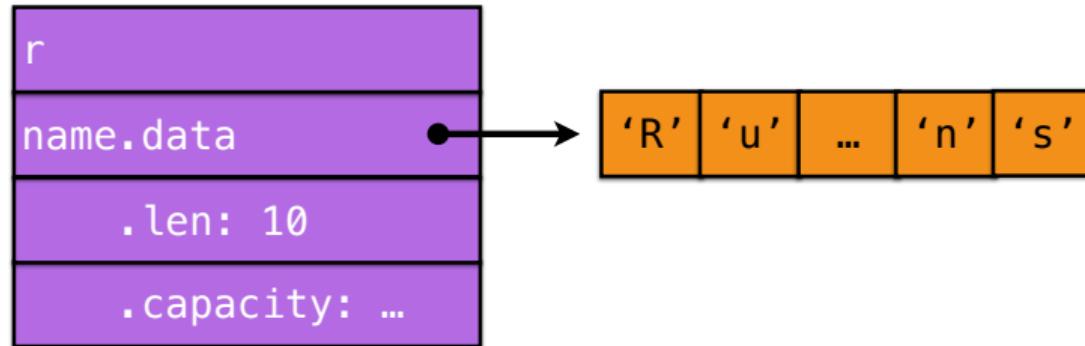
```
fn main() {  
    let r;  
    {  
        let name = format!("...");  
        r = &name;  
    }  
    println!("{}", r);  
}
```

r

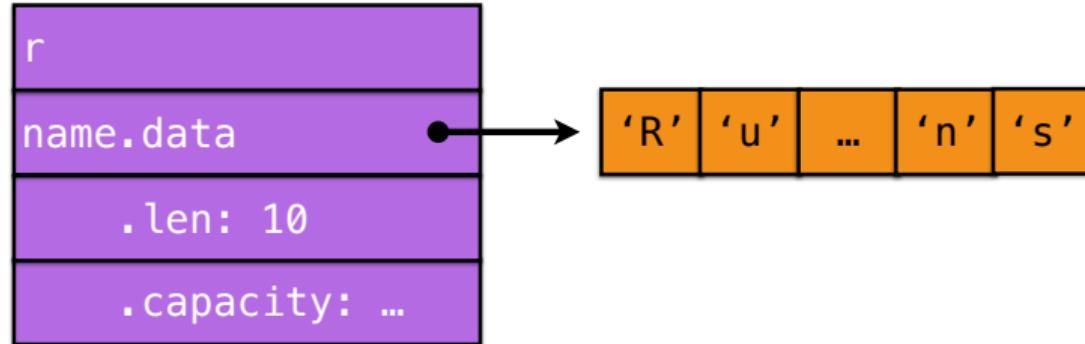
```
fn main() {  
    let r;  
    {  
        let name = format!("...");  
        r = &name;  
    }  
    println!("{}", r);  
}
```

r

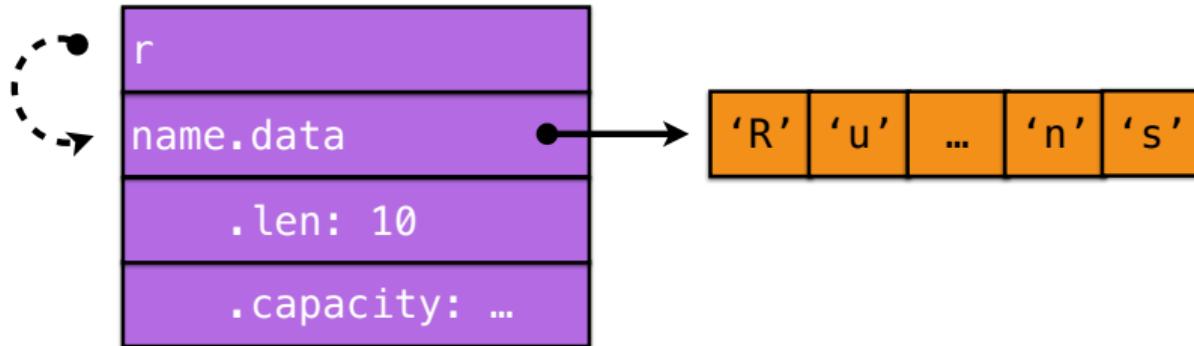
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fn main() {  
    let r;  
    {  
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    }  
    println!("{}", r);  
}
```



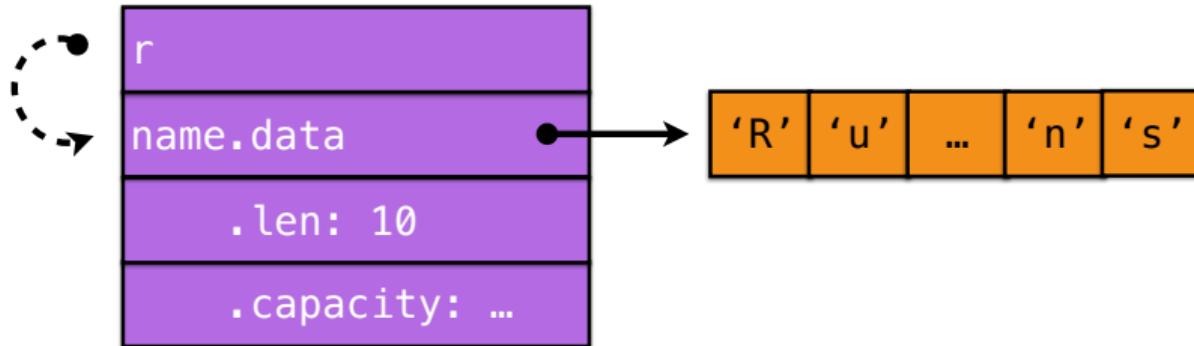
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fn main() {  
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        r = &name;  
    }  
    println!("{}", r);  
}
```



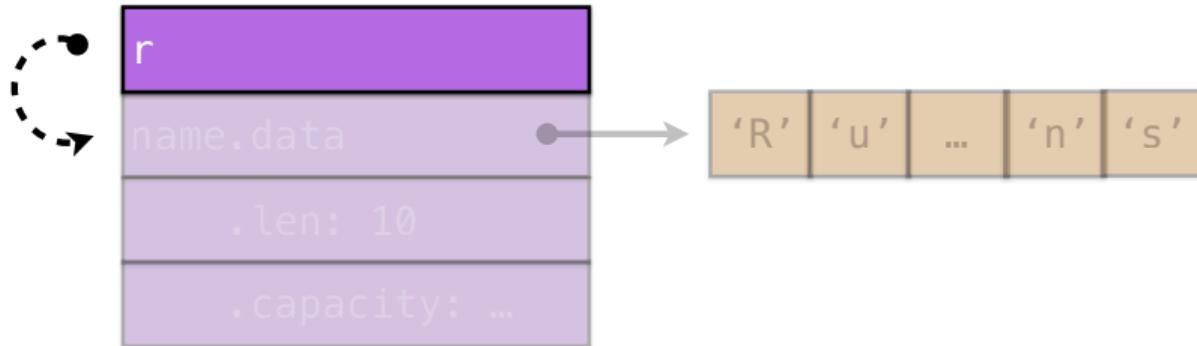
```
fn main() {  
    let r;  
    {  
        let name = format!("...");  
        r = &name;  
    }  
    println!("{}", r);  
}
```



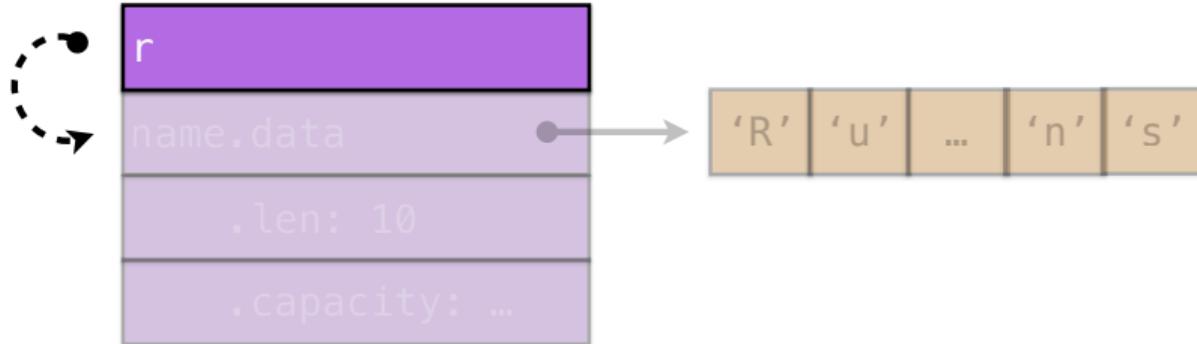
```
fn main() {
    let r;
    {
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        r = &name;
    }
    println!("{}", r);
}
```



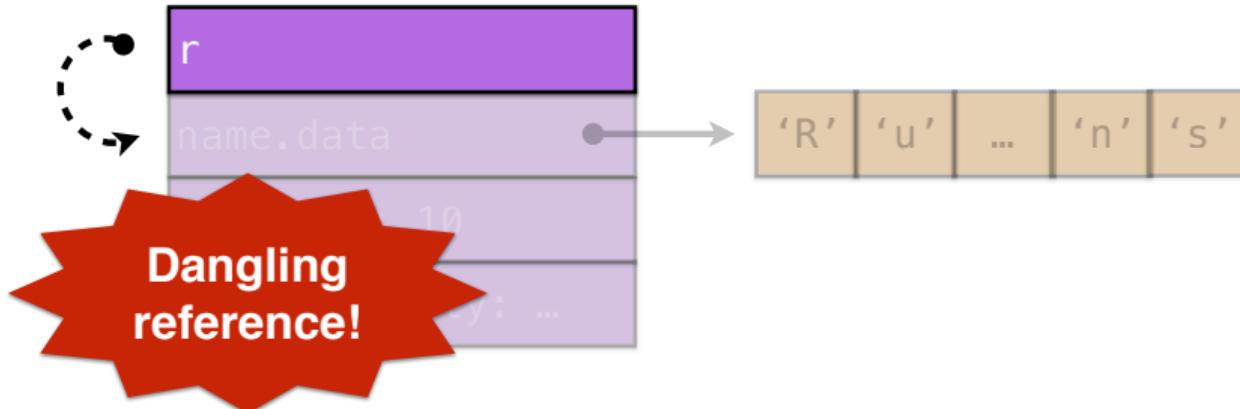
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fn main() {
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        r = &name;
    }
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}
```



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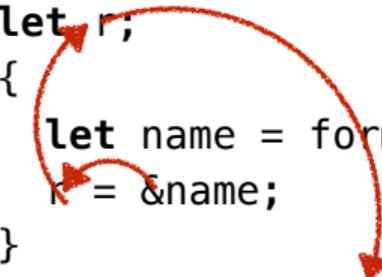
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fn main() {
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        r = &name;
    }
    println!("{}", r);
}
```

**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.

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

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

**Lifetime:** span of code where reference is used.

*compared against*

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

```
fn main() {  
    let r;  
    {  
        let name = format!("...");  
        r = &name;  
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    println!("{}", r);  
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**Lifetime:** span of code where reference is used.

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

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        r = &name;  
    }  
    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) {  
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}
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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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use std::thread;  
  
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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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name` can only be used within this fn

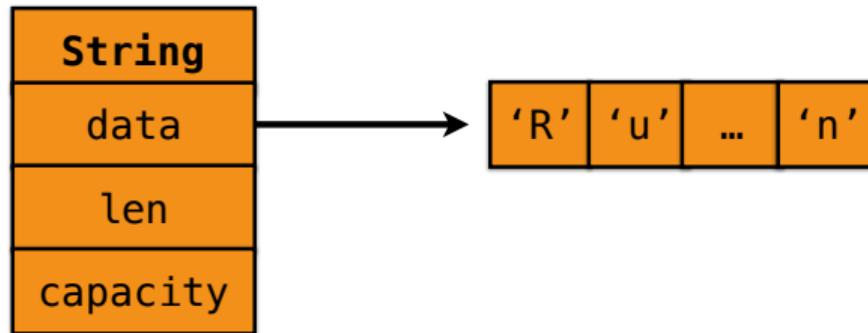
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error: the type ` [...]` does not fulfill the required lifetime  
    thread::spawn(move || {  
        ^~~~~~  
note: type must outlive the static lifetime
```

# Dangers of mutation

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

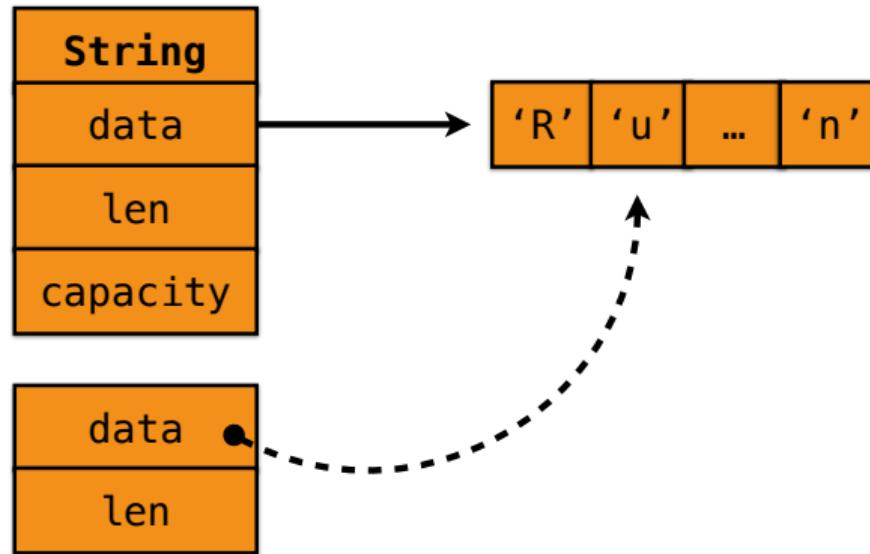
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```



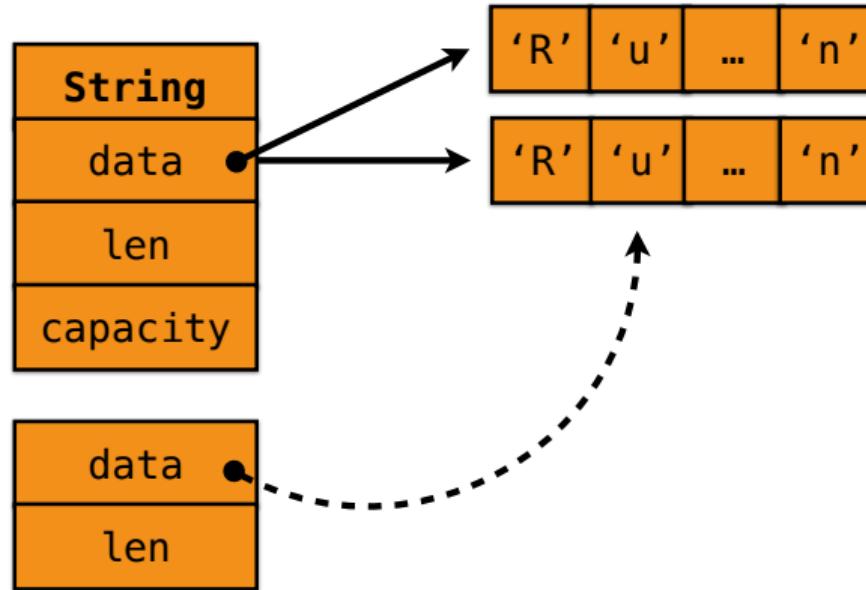
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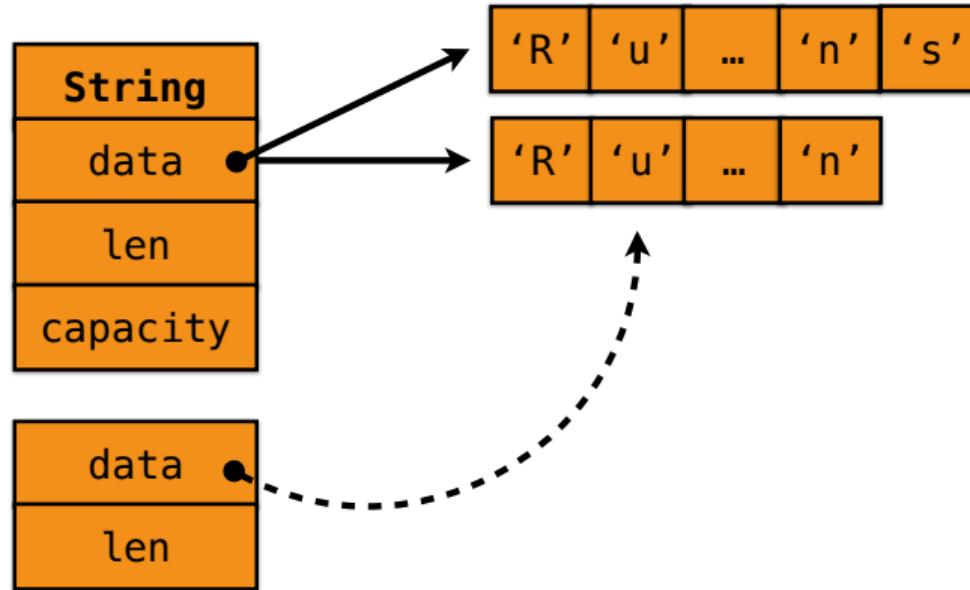
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let slice = &buffer[1..];
buffer.push_str("s");
println!("{}:?}", slice);
```



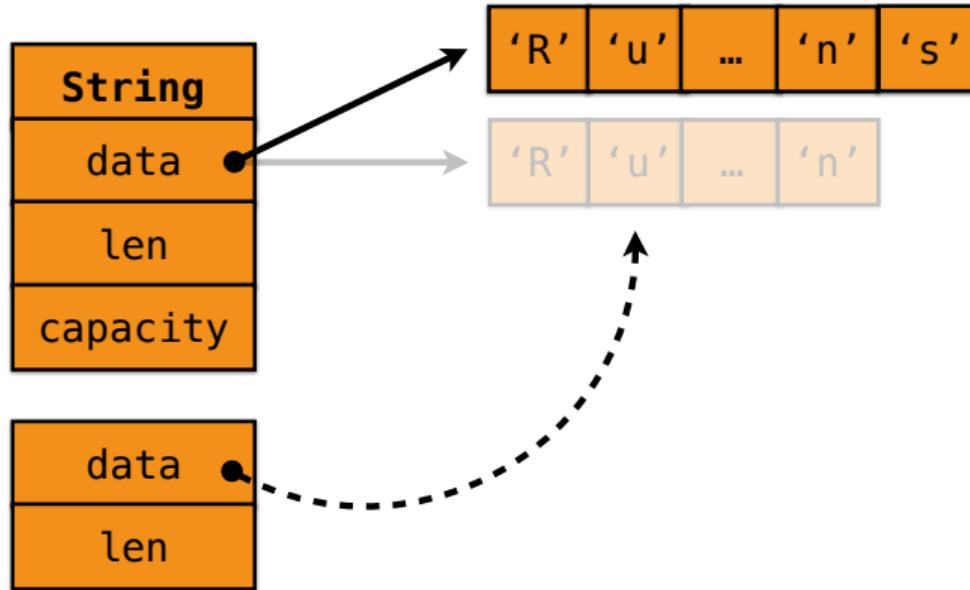
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let slice = &buffer[1..];
buffer.push_str("s");
println!("{}:?}", slice);
```



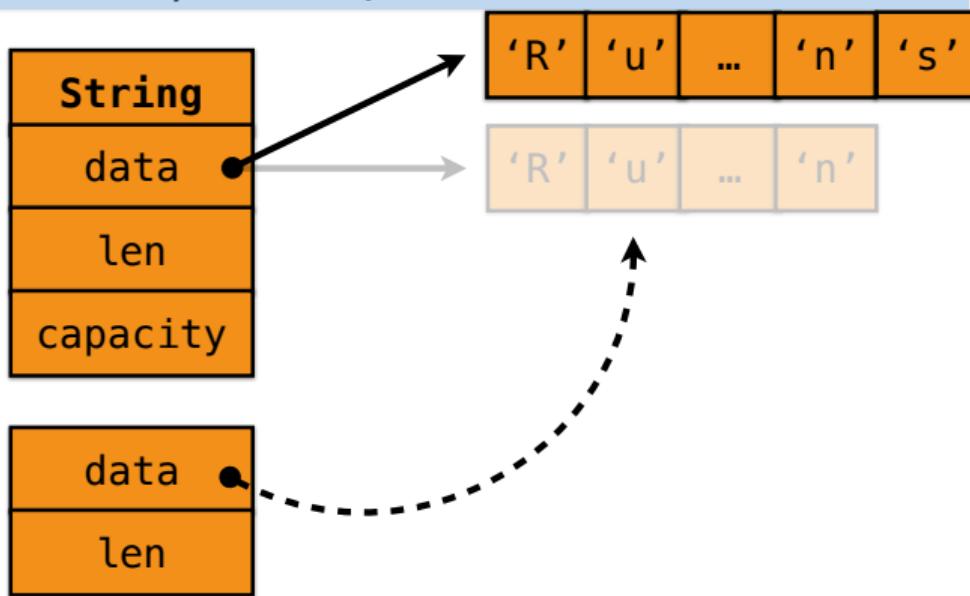
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```
let mut buffer: String = format!("Rustacean");
let slice = &buffer[1..];
buffer.push_str("s");
println!("{}:?", slice);
```



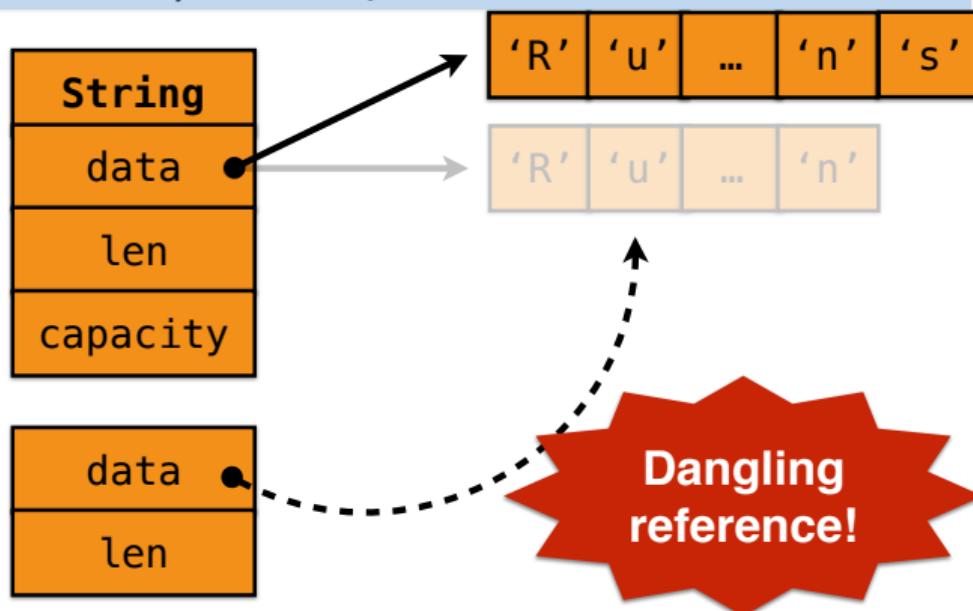
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let mut buffer: String = format!("Rustacean");
let slice = &buffer[1..];
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```



# 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

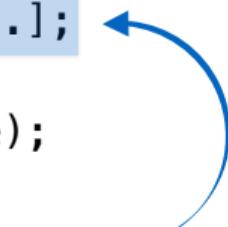
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    let mut buffer: String = format!("Rustacean");  
    let slice = &buffer[1..];  
    buffer.push_str("s");  
    println!("{}:?", slice);  
}
```

**Borrow** “locks”  
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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");
}
```

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    let mut buffer: String = format!("Rustacean");  
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        let slice = &buffer[i..];  
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**Borrow** “locks”  
`buffer` until `slice`  
goes out of scope

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```

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

**OK:** `buffer` is not borrowed here

## Summary

---



Questions?

