



# Rust and what's this thing for?



Abc Xyz  
@dura\_lex

1. Foreword
2. What is Rust?
3. (Un)safe
4. Syntax
5. Ecosystem
6. Experience and Pitfalls
7. 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
- 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?

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## 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

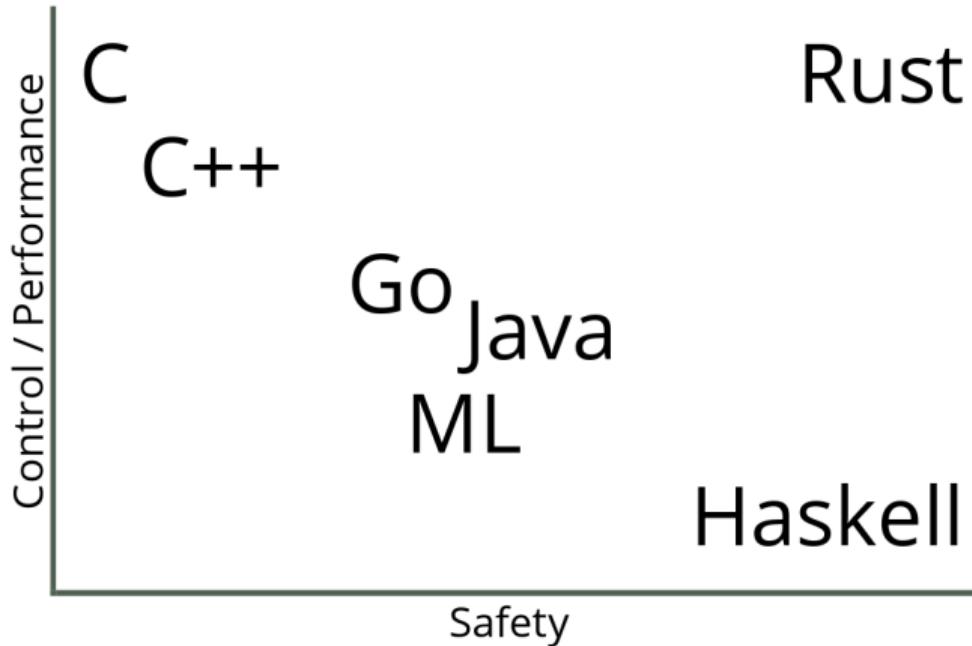
(Un)safe

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(Un)safe

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Control vs Safety



(Un)safe

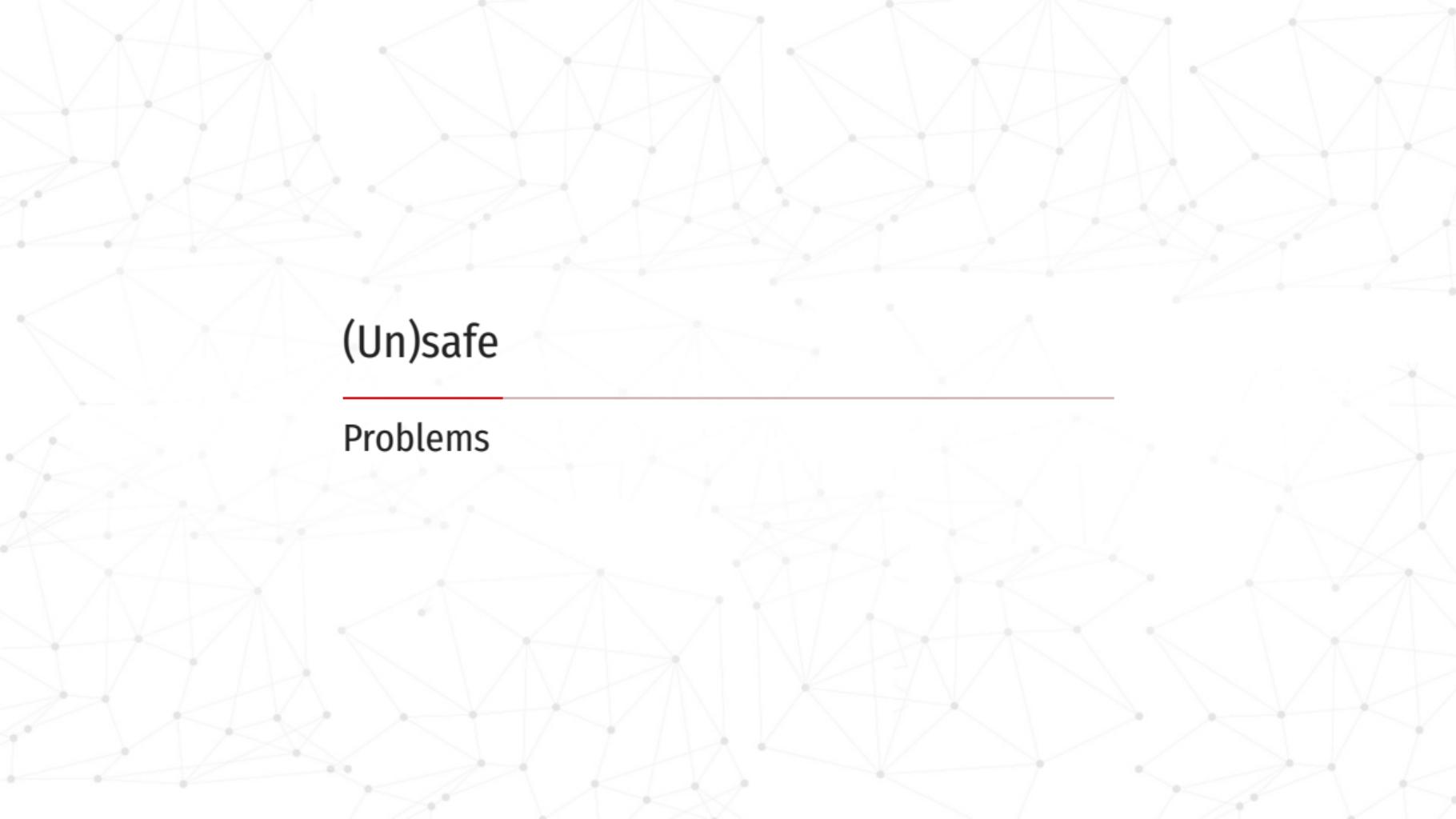
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What's wrong with systems languages?

# What's wrong with systems languages?

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

Rust?

A faint, light-gray background network graph consisting of numerous small, semi-transparent gray dots connected by thin white lines, forming a complex web of triangles and quadrilaterals.

(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.



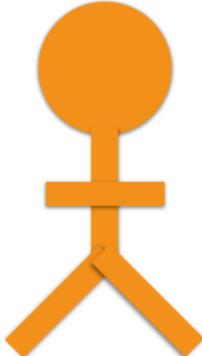
# Ownership



# 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);  
}
```

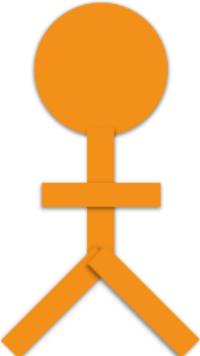


```
fn helper(name: String) {  
    println!(...);  
}
```



**Ownership**

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



## Ownership

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

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



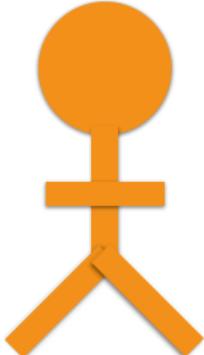
**Ownership**

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



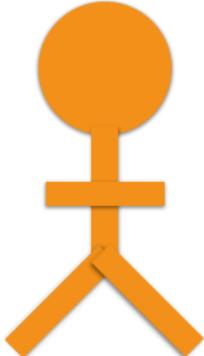
## Ownership

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



## Ownership

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



## Ownership

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

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

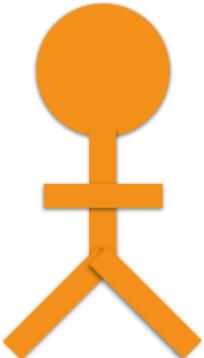
**Error:** use of moved value: `name`



**Ownership**

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

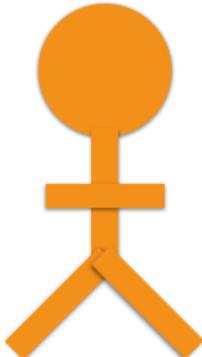
```
void helper(Vector name) {  
    ...  
}
```



## “Ownership” in Java

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

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



“Ownership” in Java

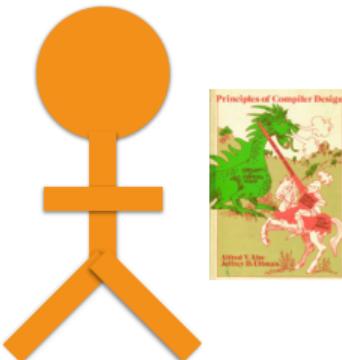
```
void main() {  
    Vector name = ...;  
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    helper(name);  
}
```

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

```
    ...  
}
```



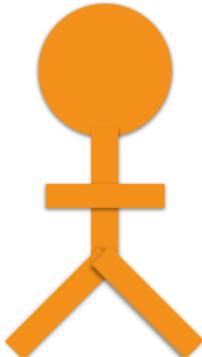
Take reference  
to Vector



“Ownership” in Java

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



```
void helper(Vector name) {  
    ...  
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“Ownership” in Java

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

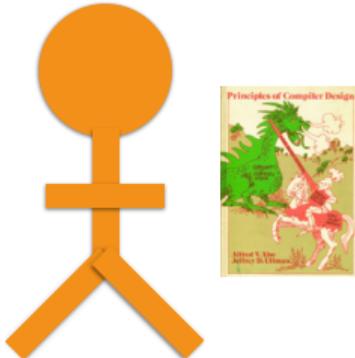


“Ownership” in Java

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

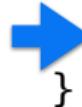


```
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    ...  
}
```

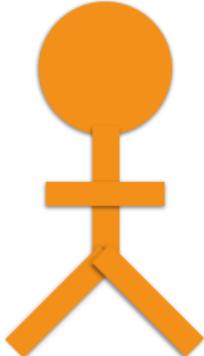


“Ownership” in Java

```
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) {  
    new Thread(...);  
}
```



## “Ownership” in Java

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

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## “Ownership” in Java

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## “Ownership” in Java

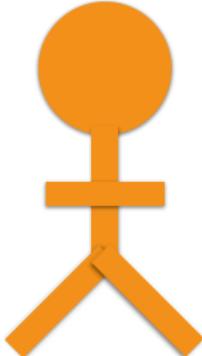
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    helper(name);  
}
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void helper(Vector name) {  
    new Thread(...);  
}
```

# Clone

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

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



# Clone

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    let name = format!("...");  
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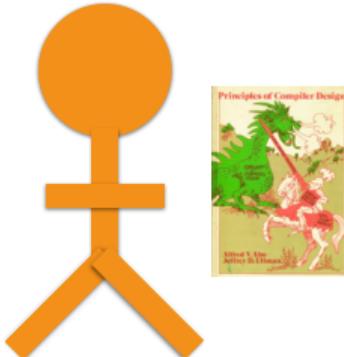


# Clone

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

Copy the String

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



# Clone

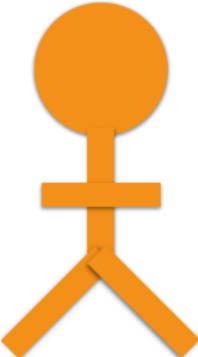
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    helper(name);  
}
```

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



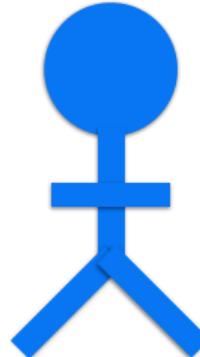
# Clone

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



# Clone

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

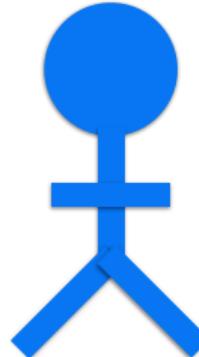
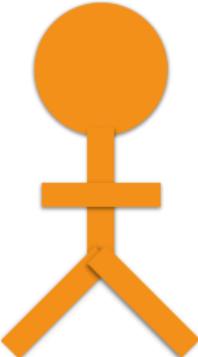


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→

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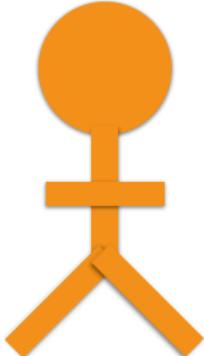


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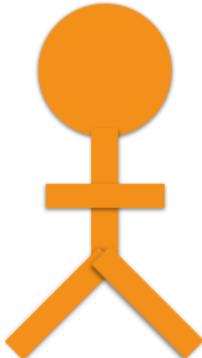
```
fn helper(name: String) {  
    println!(...);  
}
```



# Copy (auto-Clone)

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

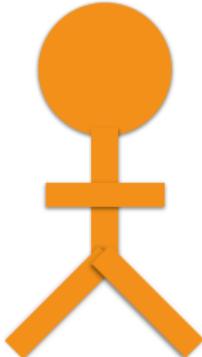
```
fn helper(count: i32) {  
    println!(..);  
}
```



# Copy (auto-Clone)

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

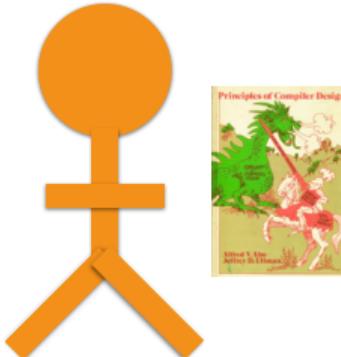
```
fn helper(count: i32) {  
    println!(..);  
}  
i32 is a Copy type
```



# Copy (auto-Clone)

```
fn main() {  
    let count = 22;  
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    helper(count);  
}
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```
fn helper(count: i32) {  
    println!(..);  
}  
↑  
i32 is a Copy type
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# Copy (auto-Clone)

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fn main() {  
    let count = 22;  
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    helper(count);  
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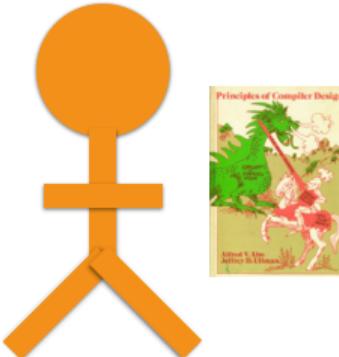
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# Copy (auto-Clone)

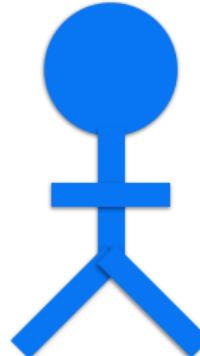
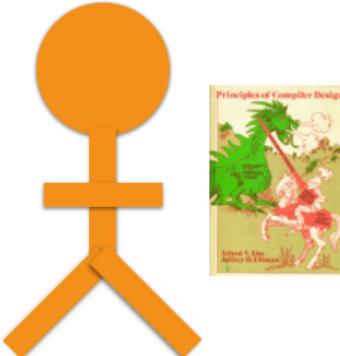
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    let count = 22;  
    helper(count);  
    helper(count);  
}
```



```
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



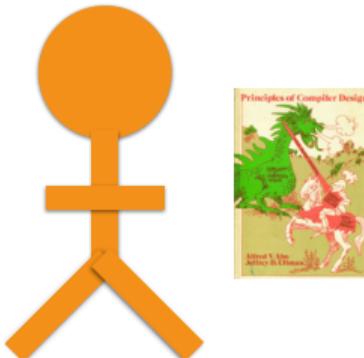
Shared borrow

```
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**

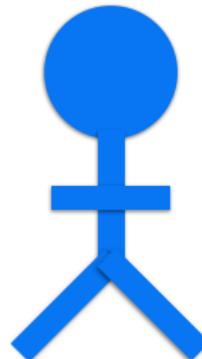
```
fn main() {  
    let name = format!("...");  
    let reference = &name;  
    ➔ helper(reference);  
    helper(reference);  
}
```

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



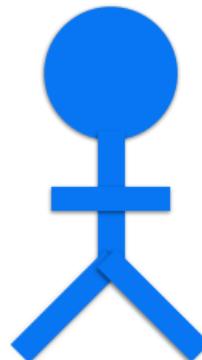
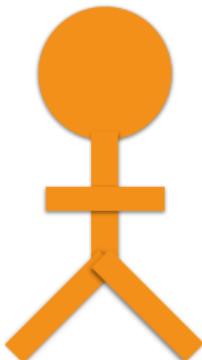
Shared borrow

```
fn main() {  
    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

```
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");  
}
```

# Shared == Immutable

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

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

```
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



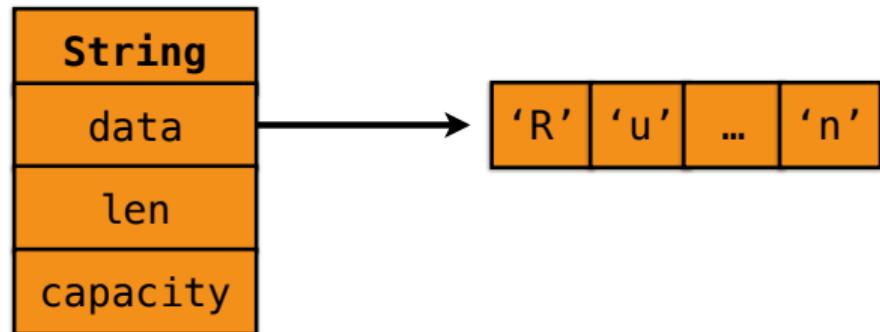
Waterloo, Cassius Coolidge, c. 1906

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

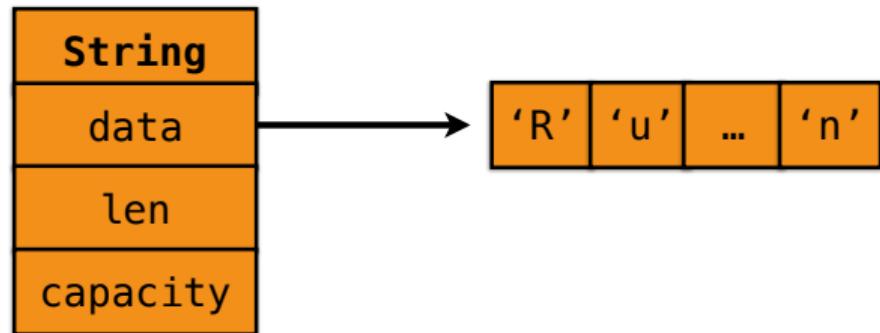
```
fn helper(name: &str) {  
    println!(...);  
}
```



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

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

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



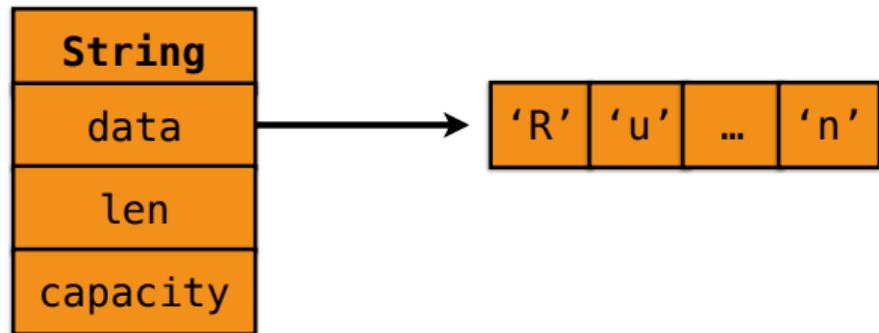
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```

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

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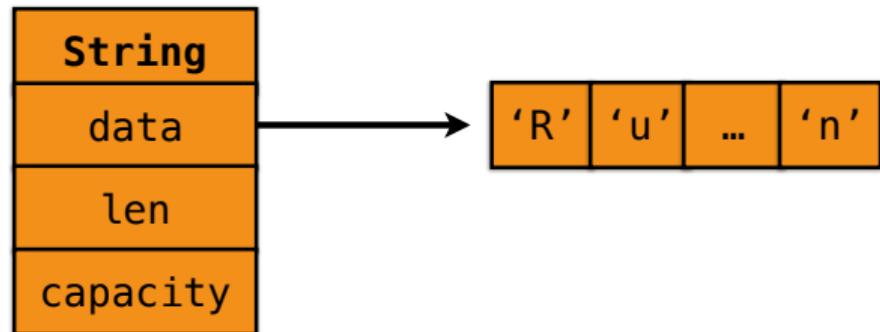


```
fn main() {  
    let name = format!("...");  
    helper(&name[1..]);  
    helper(&name);  
}
```

Lend some of  
the string

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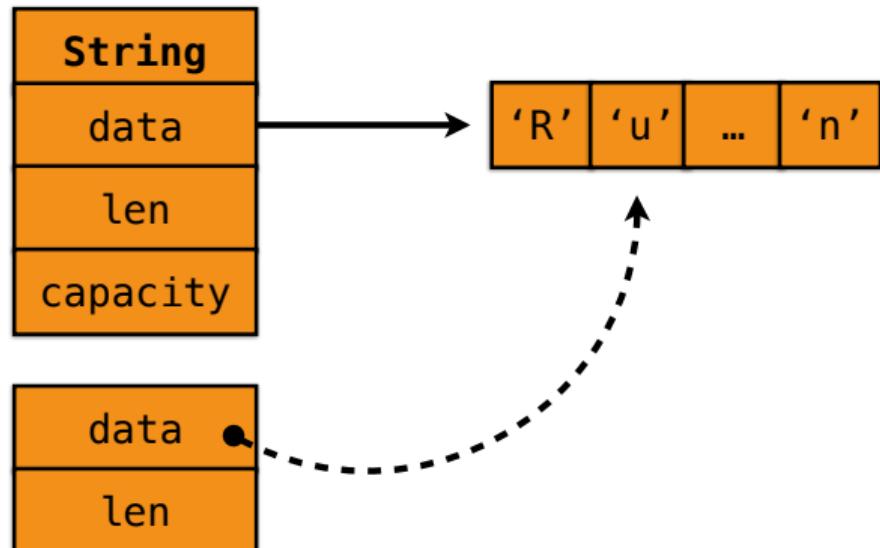
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    let name = format!("...");  
    helper(&name[1..]);  
    helper(&name);  
}
```

Lend some of  
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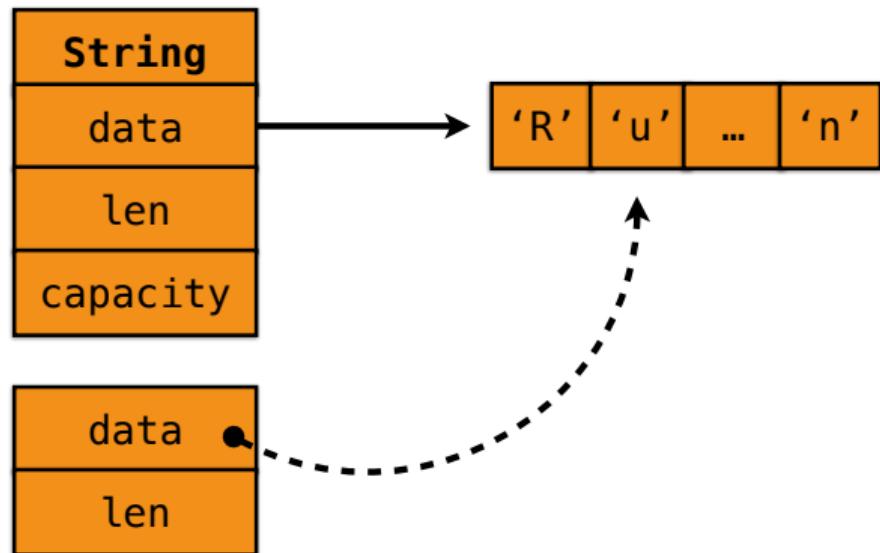


```
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    let name = format!("...");  
    helper(&name[1..]);  
    helper(&name);  
}
```



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

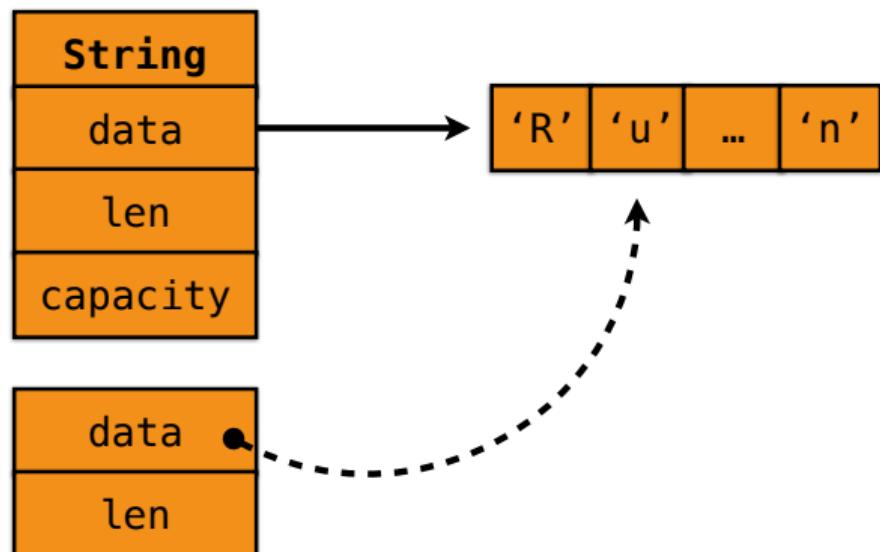
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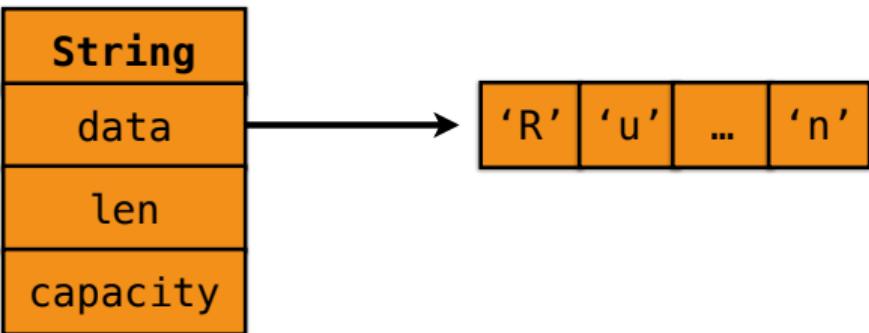
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}
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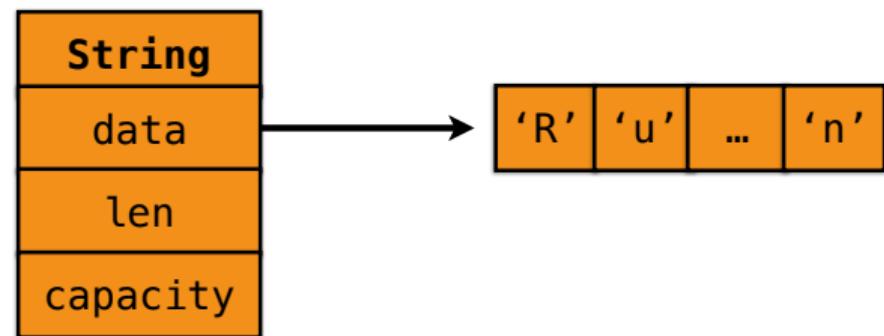
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Looks like other languages:  
• Python: `name[1:]`  
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**But no copying** at runtime.

# 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.

# High-level code, low-level efficiency

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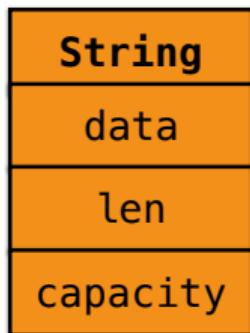
data
len

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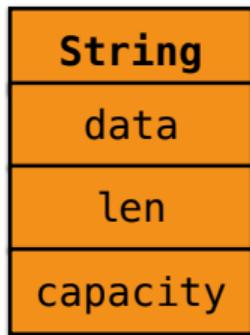


No copying, no allocations.

# High-level code, low-level efficiency

```
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}
```

Iterator over slices  
borrowed from `line`.



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



No copying, no allocations.



## Borrowing: Mutable Borrows



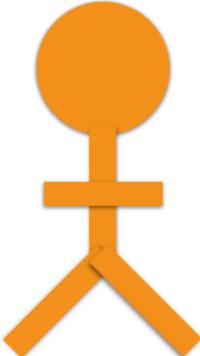
## Borrowing: Mutable Borrows



## 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

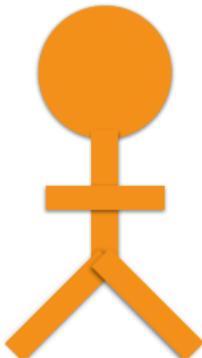
```
fn main() {  
    let mut name = ...;  
    update(&mut name);  
    println!("{}", name);  
}
```



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

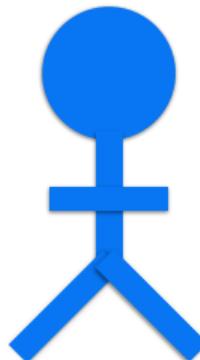
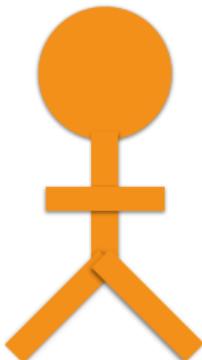


Mutable borrow

```
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);  
}
```

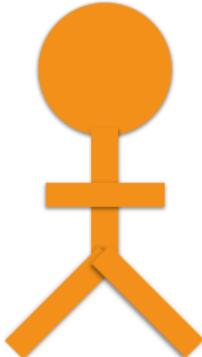
```
fn update(name: &mut String) {  
    name.push_str("...");  
}
```



## Mutable borrow

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

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

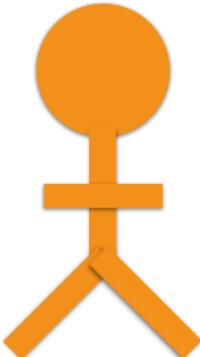


## Mutable borrow

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

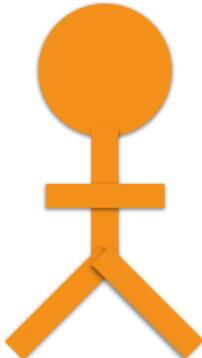
```
fn update(name: &mut String) {  
    name.push_str("...");  
}
```

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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`name: String`

**Ownership:**

control all access, will free when done

→ `name: &String`

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no readers, one writer

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**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

(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);  
}
```

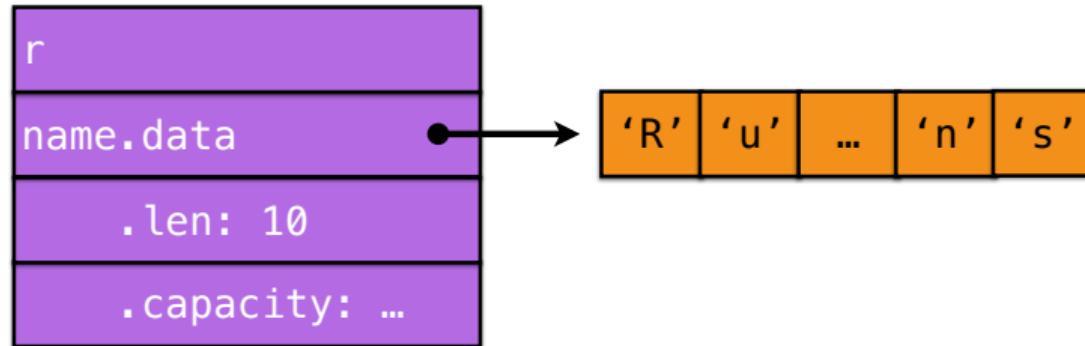
```
fn main() {  
    let r;  
    {  
        let name = format!("...");  
        r = &name;  
    }  
    println!("{}", r);  
}
```

r

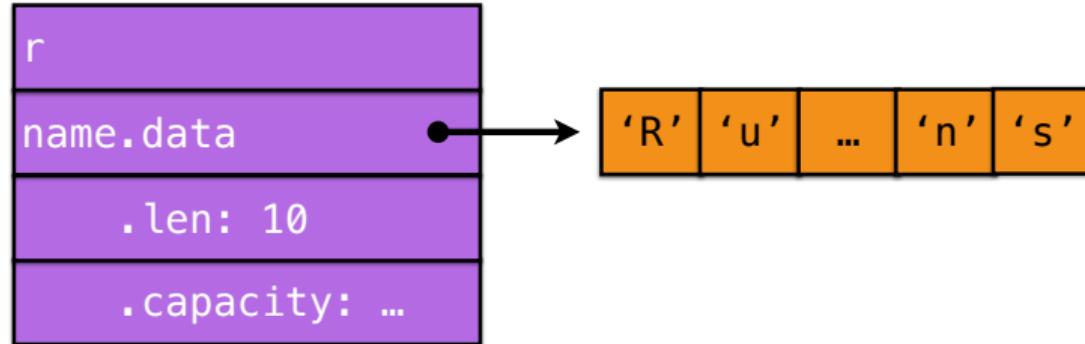
```
fn main() {  
    let r;  
    {  
        let name = format!("...");  
        r = &name;  
    }  
    println!("{}", r);  
}
```

r

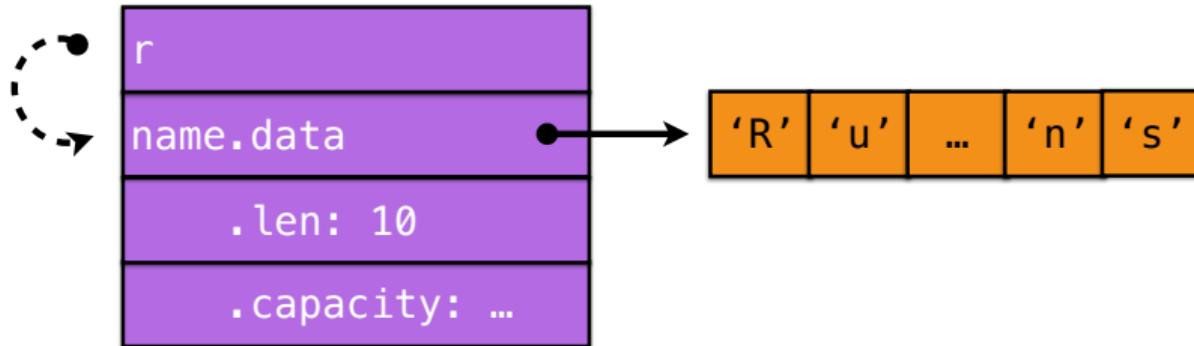
```
fn main() {  
    let r;  
    {  
        let name = format!("...");  
        r = &name;  
    }  
    println!("{}", r);  
}
```



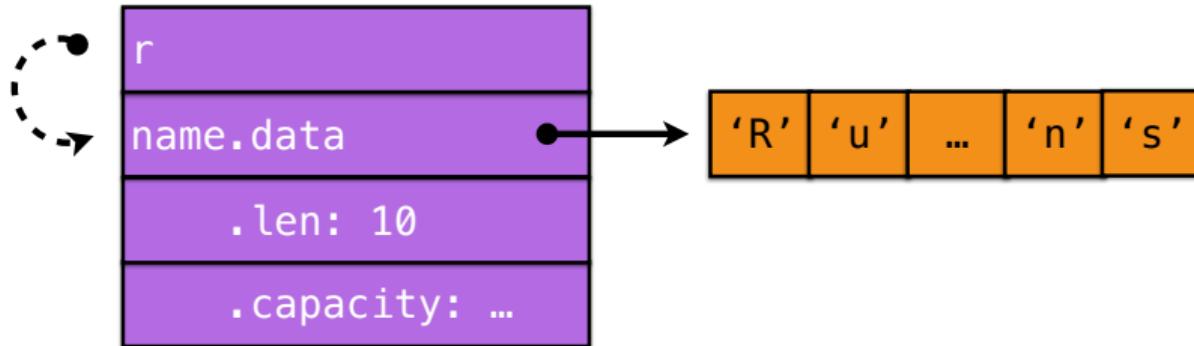
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    }  
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}
```



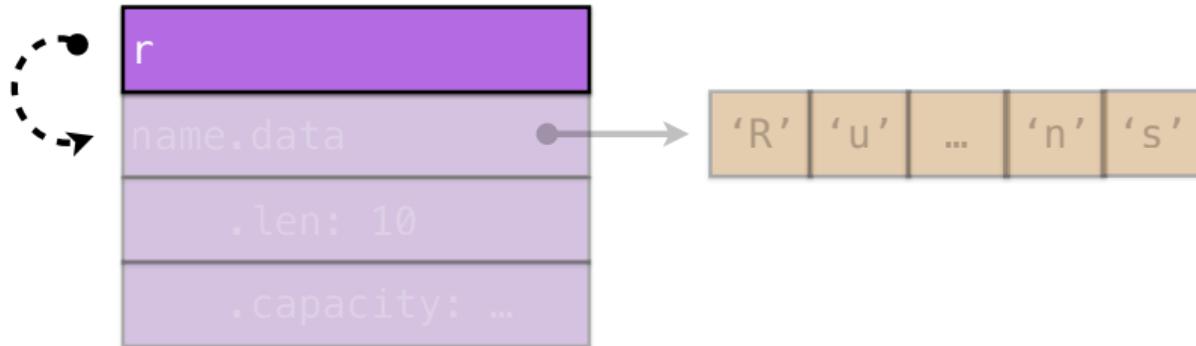
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fn main() {  
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    {  
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    }  
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}
```



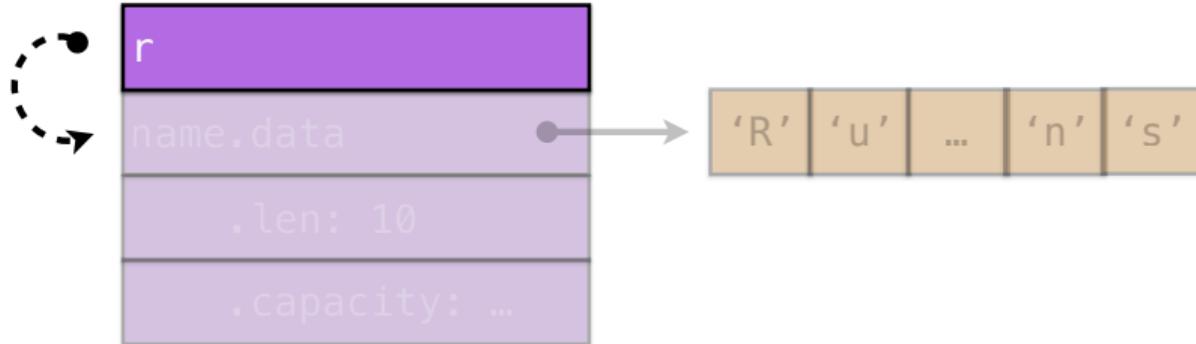
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fn main() {
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    {
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        r = &name;
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    println!("{}", r);
}
```



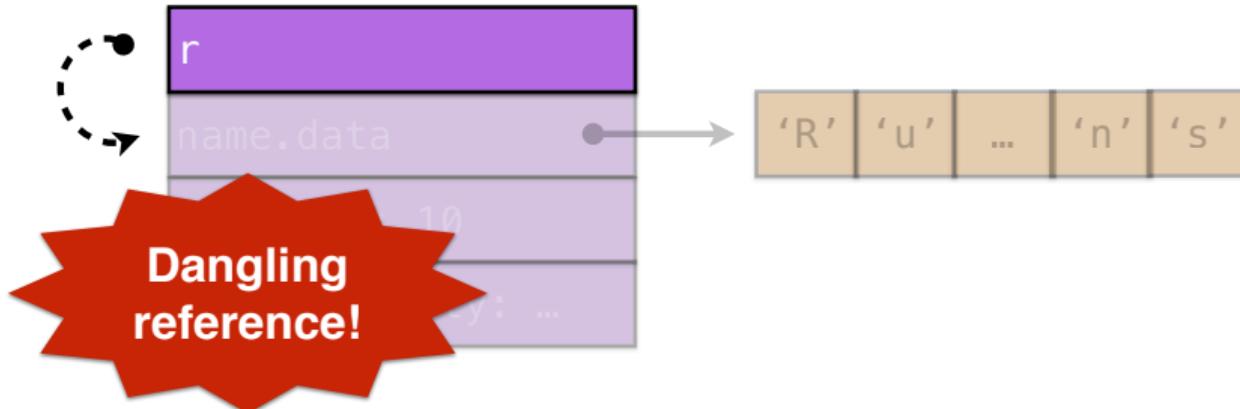
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    }
    println!("{}{}", r);
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```
fn main() {  
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}
```



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

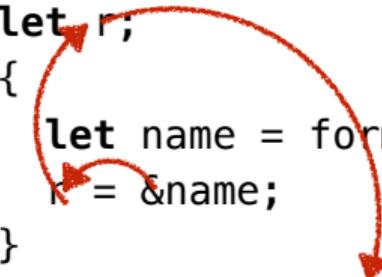
```
fn main() {
    let r;
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        r = &name;
    }
    println!("{}", r);
}
```

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

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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!

```
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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    });  
}
```

name` can only be used within this fn

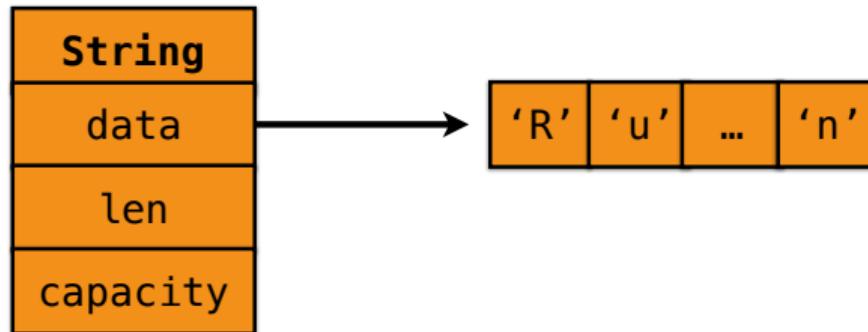
```
error: the type ` [...]` does not fulfill the required lifetime  
    thread::spawn(move || {  
        ^~~~~~  
note: type must outlive the static lifetime
```

# Dangers of mutation

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

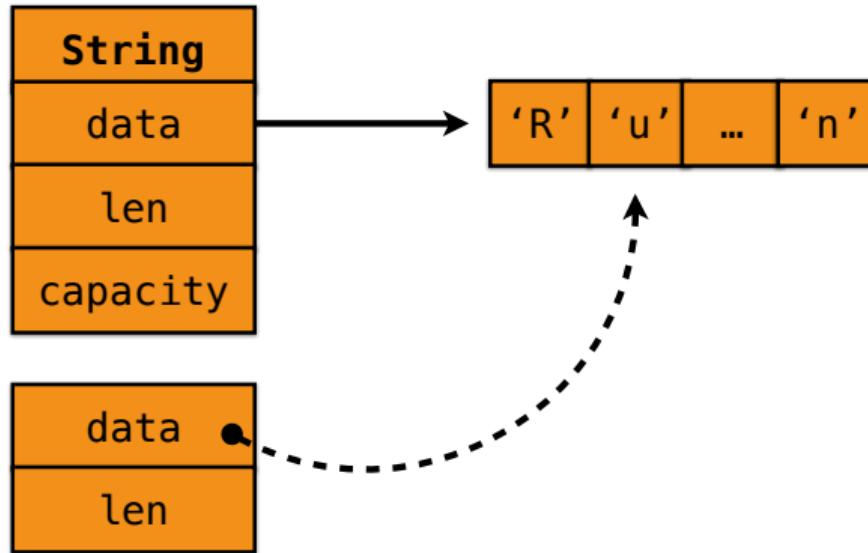
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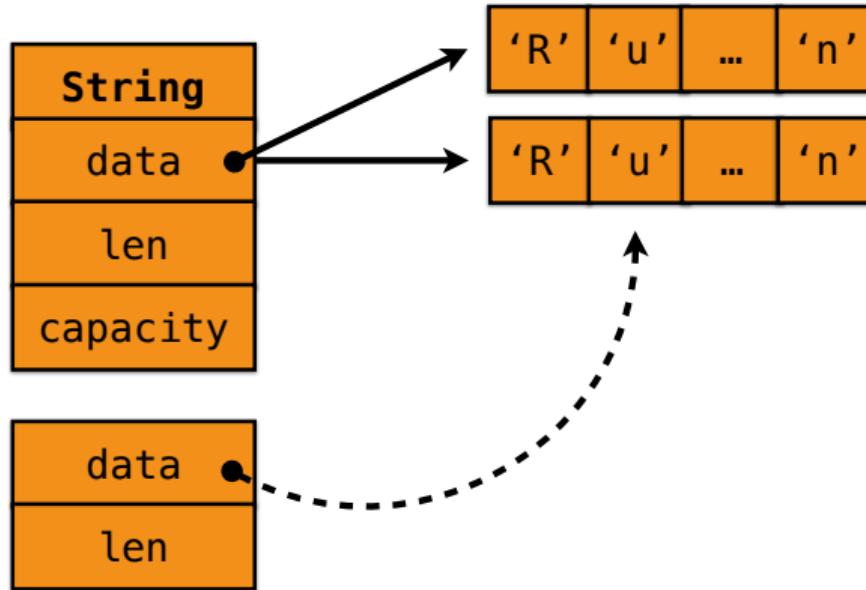
# Dangers of mutation

```
let mut buffer: String = format!("Rustacean");
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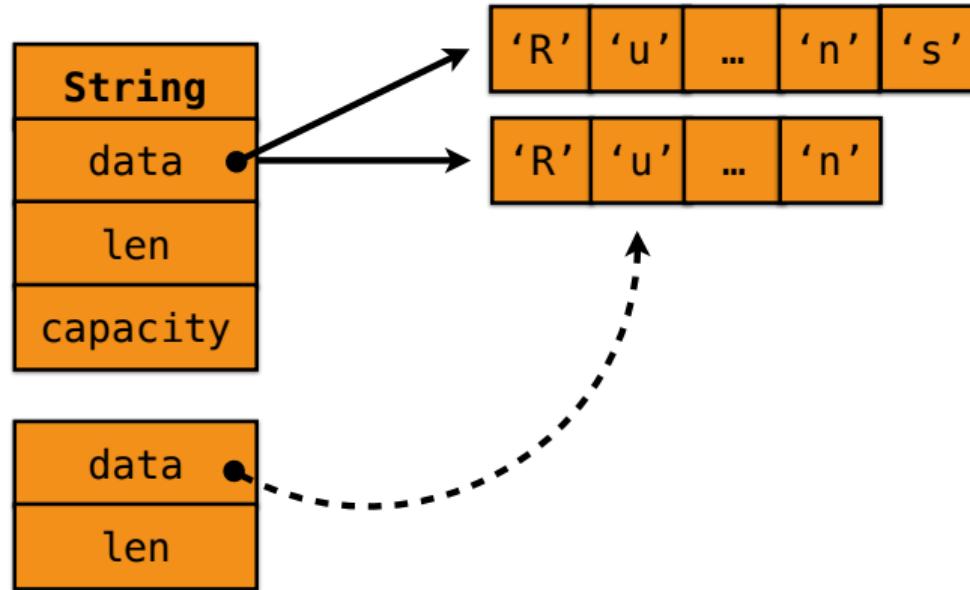
# Dangers of mutation

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



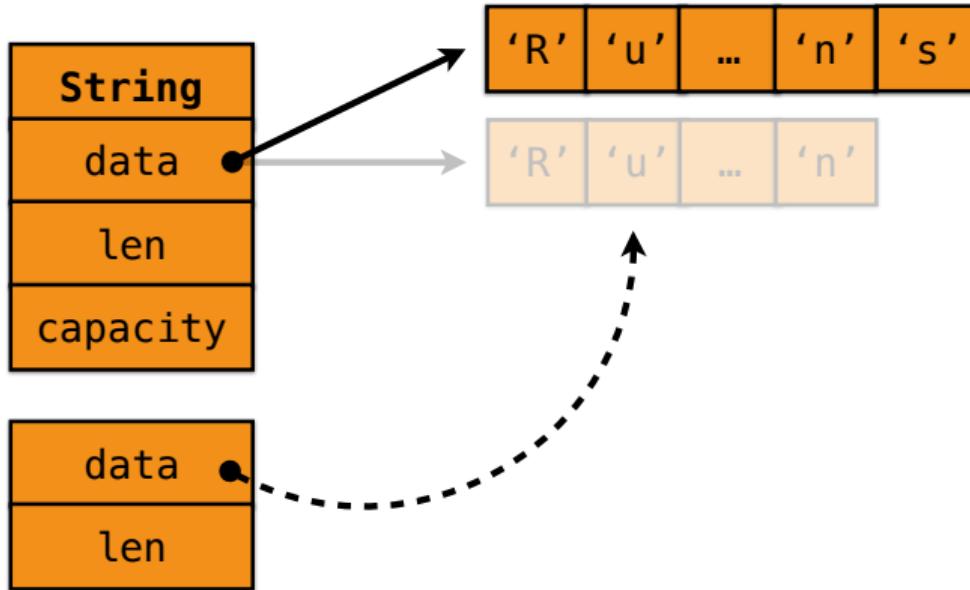
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let mut buffer: String = format!("Rustacean");
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```



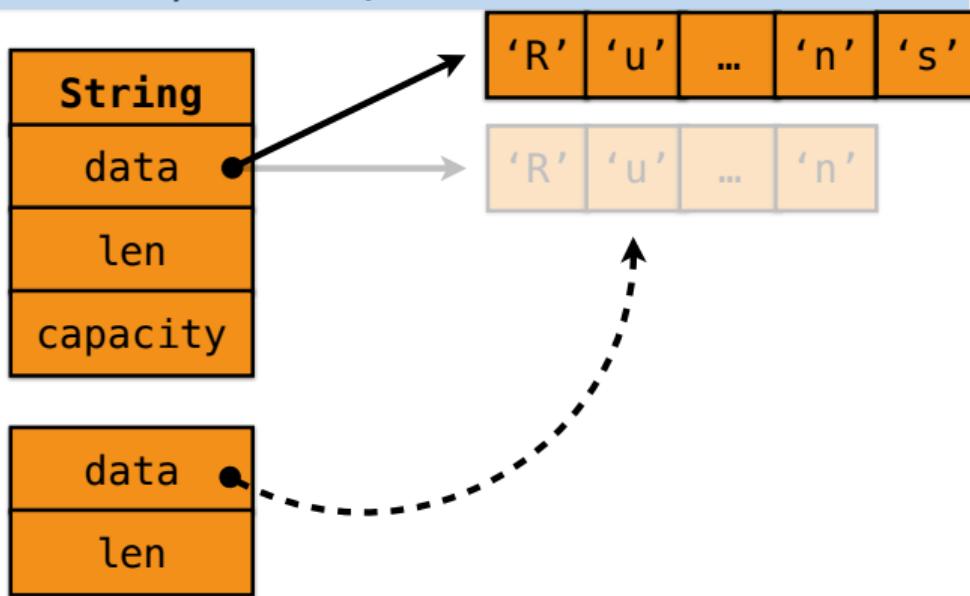
# Dangers of mutation

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



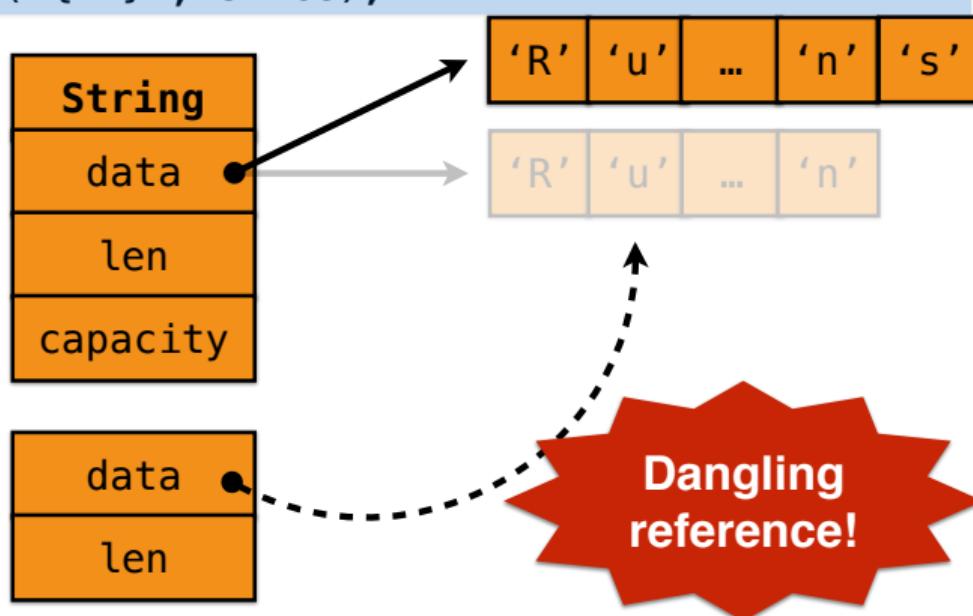
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```



# 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);  
}
```

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# Dangers of mutation

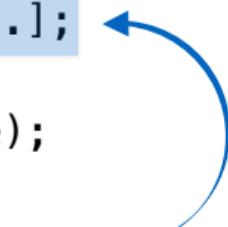
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    buffer.push_str("s");  
    println!("{}:?", slice);  
}
```

**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");  
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}
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        println!("{}:?", slice);  
    }  
    buffer.push_str("s");  
}
```

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

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

(Un)safe

---

Comparison

---

```
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 }
```

---

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

---

---

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

---

---

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

---

```
1 let vec: Vec<u32> = Vec::new(); Rust
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 }
```

---

```
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
```

---

```
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



---

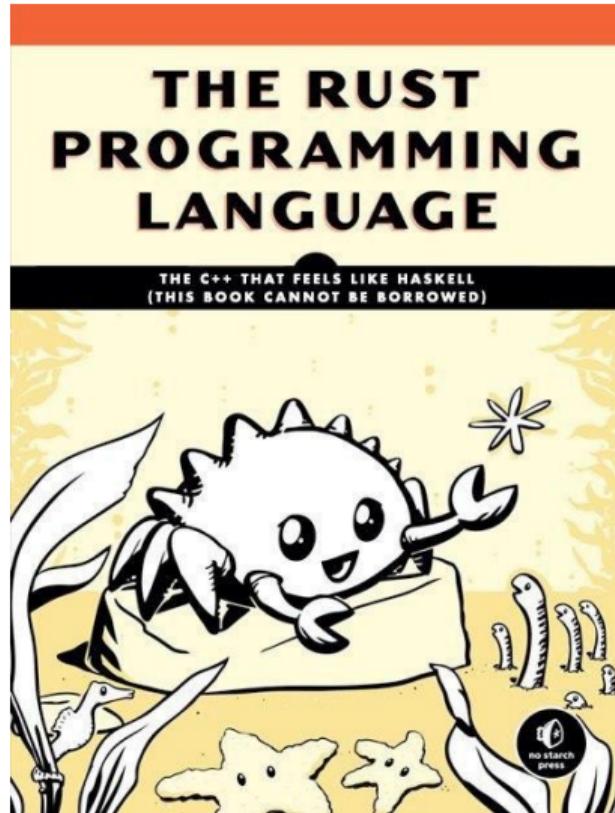
Rust

```
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) ->
2     f64 {
3         for c in blue_pill.chars() {
4             print!("{}" , c);
5         }
6         if is_hack {
7             loop { break 3.1337; }
8         } else if backdoor.len() > 3 {
9             42.0 - 42.0
10        } else {
11            3.14
12        }
13    }
```

## Syntax

---

Enums (Algebraic data type)

```
1 enum Pohek {  
2     XSS(XssType),  
3     SocialEngineering,  
4     Phishing,  
5     // ...  
6 }  
  
7  
8 enum XssType {  
9     Reflected,  
10    Stored,  
11    // ...  
12 }
```

```
1  
2 match pohek {  
3     Pohek::XSS(xss_type) =>  
4     {  
5         hack_by_xss(xss_type);  
6     },  
7     Pohek::SocialEngineering  
8     |  
9     Pohek::Phishing =>  
10    {  
11        pa3Becmu_JI0XA();  
12    }  
13    _ => {},  
14 }
```

---

```
1 fn find_vulnerability(program: &Program) ->
2     Option<Vulnerability> {...}
3
4 fn hack_program(program: &mut Program) {
5     match find_vulnerability(&program) {
6         Some(vuln) => {
7             exploit(vuln);
8         }
9     }
10 }
```

---

- `std::optional`
- `std::variant`
- `std::any`
- `std::pair`

```
error C2664: 'void
std::vector<block,std::allocator<_Ty>>::p
ush_back(const block &)': cannot convert
argument 1 from 'std::
_Vector_iterator<std::_Vector_val<std::
_Simple_types<block>>>' to 'block &&'
```



## Syntax

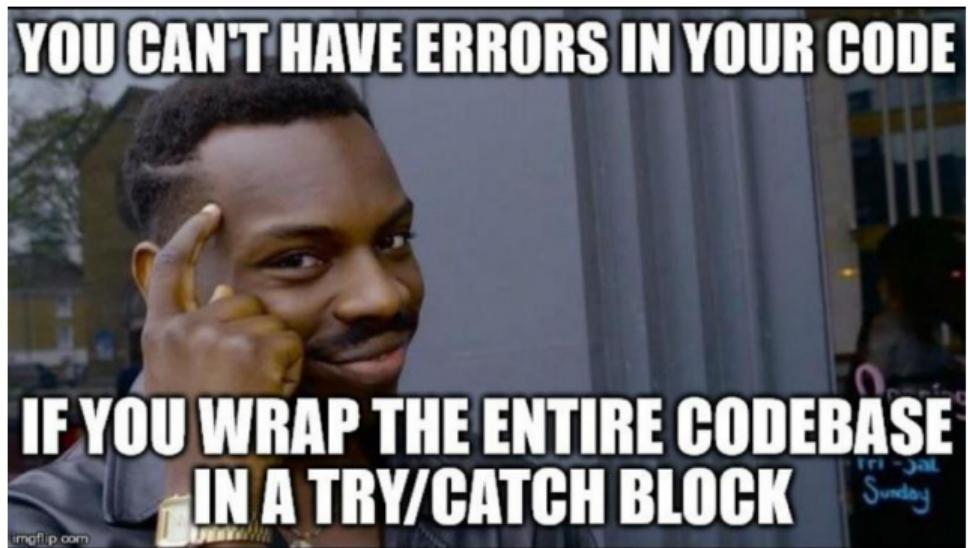
---

### Error handling

- Return code (C, Go)



- Return code (C, Go)
- Exceptions (C++, Python)

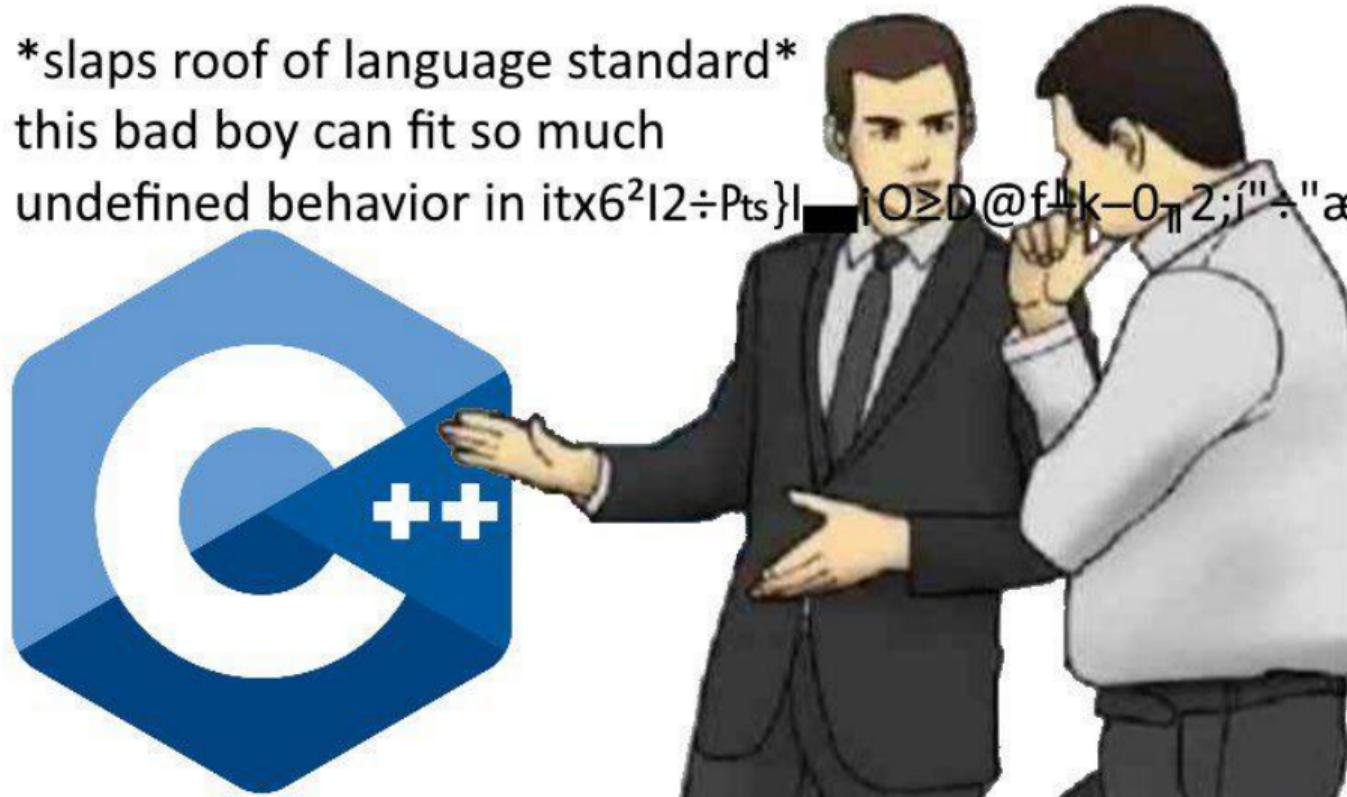


- Return code (C, Go)
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- Return code (C, Go)
- Exceptions (C++, Python)
- Global variable (custom)
- Design by Contract (SPARK)
- Error (success) indicator  
(Haskell)

\*slaps roof of language standard\*  
this bad boy can fit so much  
undefined behavior in itx6<sup>2</sup>I2÷Pts}{I—iO>D@f—k—0\_||2;j"—"æ



---

```
1 fn main() {  
2     let v = vec![1, 2, 3];  
3  
4     v[99];  
5 }
```

---

Panic

---

1 thread 'main' panicked at 'index out of bounds: the len is 3  
  ↳ but the index is 99',  
  ↳ /checkout/src/liballoc/vec.rs:1555:10

2 note: Run with `RUST\_BACKTRACE=1` for a backtrace.

---

---

Output

---

```
1 ...
2 2: std::panicking::default_hook::{closure}
3     at /checkout/src/libstd/sys_common/backtrace.rs:60
4     at /checkout/src/libstd/panicking.rs:381
5 ...
6 11: panic::main
7     at src/main.rs:4
8 12: __rust_maybe_catch_panic
9     at /checkout/src/libpanic_unwind/lib.rs:99
10 13: std::rt::lang_start
11     at /checkout/src/libstd/panicking.rs:459
12     at /checkout/src/libstd/panic.rs:361
13     at /checkout/src/libstd/rt.rs:61
14 14: main
15 ...
```

---

```
1 enum Result<T, E> {
2     Ok(T),
3     Err(E),
4 }
```

---

Result

---

```
1 pub fn hack_program(program: &Program) -> Result<Shell>
2   ↪   {...}
3
4   match hack_program(&program) {
5     Ok(shell) => connect(shell),
6     Err(error) => {
7       // Do something with error
8     }
}
```

---

```
1 fn hack_world(world: World) -> Result<Power, u32> {
2     hack_program(&program)?;
3
4     for program in &world.programs() {
5         hack_program(program).map(install_spy).map(get_money)?;
6     }
7 }
```

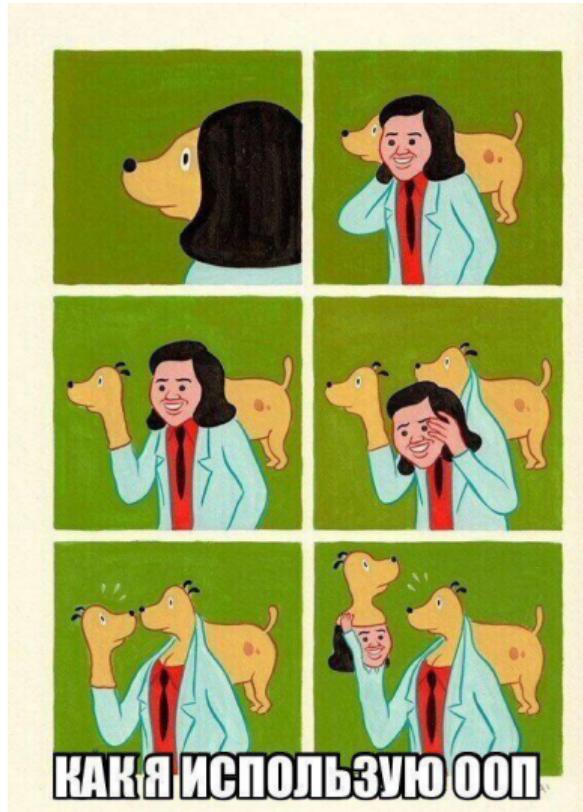
# Syntax

---

## Structs



Проблемы при использовании ООП



---

```
1 struct Hacker {
2     nickname: String,
3     scope: Scope,
4     cves: Vec<u32>,
5 }
6
7 enum Scope {
8     Fuzzing,
9     Developing,
10    Exploiting,
11    Reversing,
12 }
```

```
1 impl Hacker {  
2     fn new(nickname: String, scope: Scope) -> Hacker {  
3         Hacker {  
4             nickname: nickname,  
5             scope: scope,  
6             cves: Vec::new(),  
7         }  
8     }  
9 }
```

---

```
1 impl Hacker {  
2     fn new(nickname: String, scope: Scope) -> Self {  
3         Hacker {  
4             nickname, scope,  
5             cves: Vec::new(),  
6         }  
7     }  
8 }
```

---

---

```
1 impl Hacker {  
2     fn add_cve(&mut self, cve: u32) {  
3         self.cves.push(cve);  
4     }  
5     fn cves(&self) -> &Vec<u32> {  
6         &self.cves  
7     }  
8 }
```

---

## Syntax

---

Other

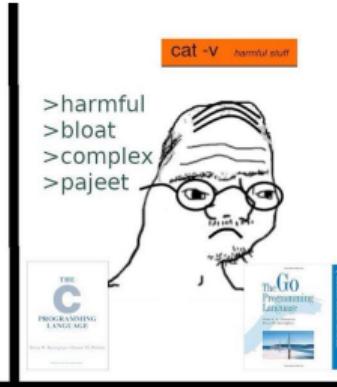
- Generics



- Generics
- Traits
  - as interfaces
  - for code reuse
  - for operator overloading
- Trait objects

## Traits Polymorphism Generics Concepts

	<code>innatezu</code>	set: added constructor for set with a size hint
■	b16set	set: added constructor for set with a size hint
■	b32set	set: added constructor for set with a size hint
■	b64set	set: added constructor for set with a size hint
■	f32set	set: added constructor for set with a size hint
■	f64set	set: added constructor for set with a size hint
■	i32set	set: added constructor for set with a size hint
■	i64set	set: added constructor for set with a size hint
■	internalset	set: added constructor for set with a size hint
■	iset	set: added constructor for set with a size hint
■	s32set	set: added constructor for set with a size hint
■	s64set	set: added constructor for set with a size hint
■	u32set	set: added constructor for set with a size hint
■	u64set	set: added constructor for set with a size hint
■	unset	set: added constructor for set with a size hint
■	uset	set: added constructor for set with a size hint



>simple  
>beautiful  
>minimal



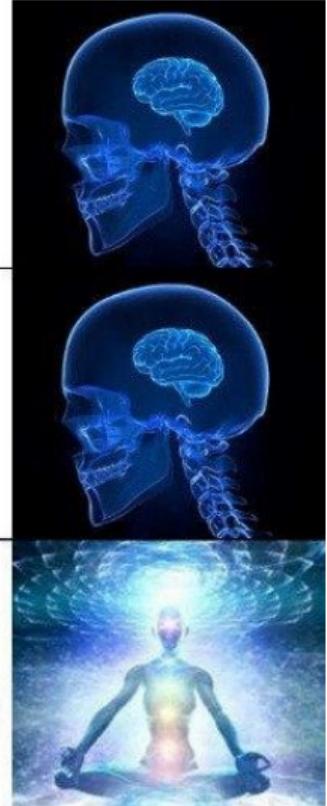
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- Common collections
- Smart pointers

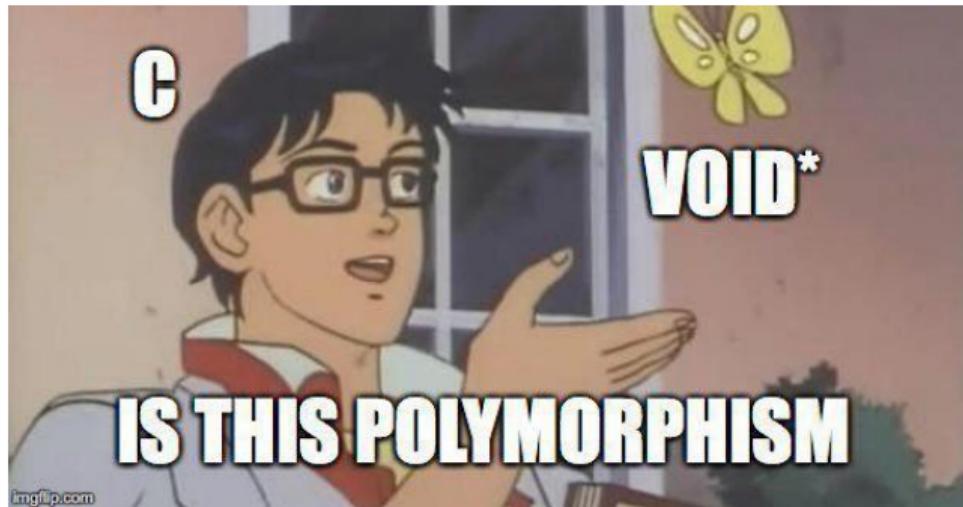
## SMART POINTERS

## RAW POINTERS

## RAW POINTERS TO SMART POINTERS



- Generics
- Traits
  - as interfaces
  - for code reuse
  - for operator overloading
- Trait objects
- Closures ( $|x| \ 2 \ * \ x$ )
- Common collections
- Smart pointers
- Polymorphism, encapsulation
- ...



# Ecosystem

---

A faint, light-gray background network graph consisting of numerous small, semi-transparent gray dots connected by thin white lines, forming a complex web-like structure.

**Ecosystem**

---

**Community**

- Rust Working Groups
  - Networking services
  - WebAssembly
  - CLI Apps
  - Embedded Devices
  - Lang and compiler working groups (WG-NLL, WG-UCG, WG-Traits and etc)



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- Blogs (Official, Read Rust, Core Developers, many others)



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**Ecosystem**

---

**Cargo**

Best package manager!

- Create structure of project
- Check and update dependencies
- Check, build and compile project
- Search and install packages
- Compile and run examples
- Generate docs
- Compile and run tests (in docs too)
- Compile and run benchmarks
- etc



# Ecosystem

---

Additional tools

## Cargo plugins

- cargo-asm
- cargo-call-stack
- cargo-clippy
- cargo-fmt
- cargo-fuzz
- cargo-geiger
- cargo-graph
- cargo-install-update
- cargo-llvm-ir
- cargo-profdata
- cargo-size
- many others!

---

Sanitize code

---

```
1 $ RUSTFLAGS="-Z sanitizer=address" cargo test
2 $ RUSTFLAGS="-Z sanitizer=leak" cargo test
3 $ RUSTFLAGS="-Z sanitizer=memory" cargo test
4 $ RUSTFLAGS="-Z sanitizer=thread" cargo test
```

---

- Rust documentation
- Crates.io – all packages
- Docs.rs – all documentation
- Rust book



# Ecosystem

---

Rustup

---

```
$ curl https://sh.rustup.rs -sSf | sh
```

---

---

### Toolchain format

---

<channel>[-<date>][-<host>]

<channel> = stable|beta|nightly|<version>

<date> = YYYY-MM-DD

<host> = <target-triple>

---

---

### Install nightly toolchain

---

\$ rustup toolchain install nightly

---

---

### Cross compile

---

```
$ rustup target add mips64el-unknown-linux-gnuabi64
$ cargo build --target=mips64el-unknown-linux-gnuabi64
```

---

- aarch64-apple-ios
- aarch64-fuchsia
- arm-unknown-linux-gnueabihf
- armv5te-unknown-linux-musleabi
- asmjs-unknown-emscripten
- i686-pc-windows-msvc
- powerpc-unknown-linux-gnu
- riscv32imac-unknown-none-elf
- sparcv9-sun-solaris
- wasm32-unknown-emscripten
- x86\_64-unknown-redox
- ...

# Ecosystem

---

Rust in production

Hundreds of companies around the world are using Rust in production today for fast, low-resource, cross-platform solutions

- Mozilla
- Cloudflare
- Microsoft
- Facebook
- Ready at Dawn Studios
- CoreOS, Inc.
- The GNOME Project
- Coursera
- Unity
- Google
- npm, Inc.
- Amazon
- Red hat
- Frostbite Engine
- Parity
- Canonical
- System 76
- Wire
- Samsung
- Dropbox
- Twitter
- Electronic Arts
- Discord
- Atlassian
- Baidu
- Reddit
- many others

## Experience and Pitfalls

---

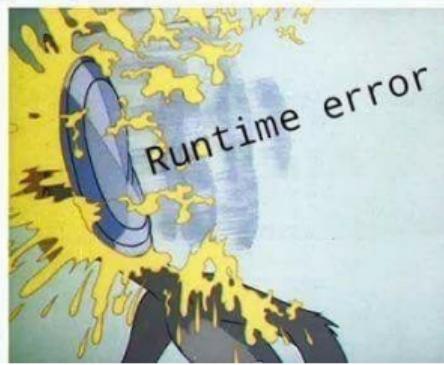
## Experience and Pitfalls

---

Compile time errors



# Compile time errors



## Experience and Pitfalls

---

Compilation times

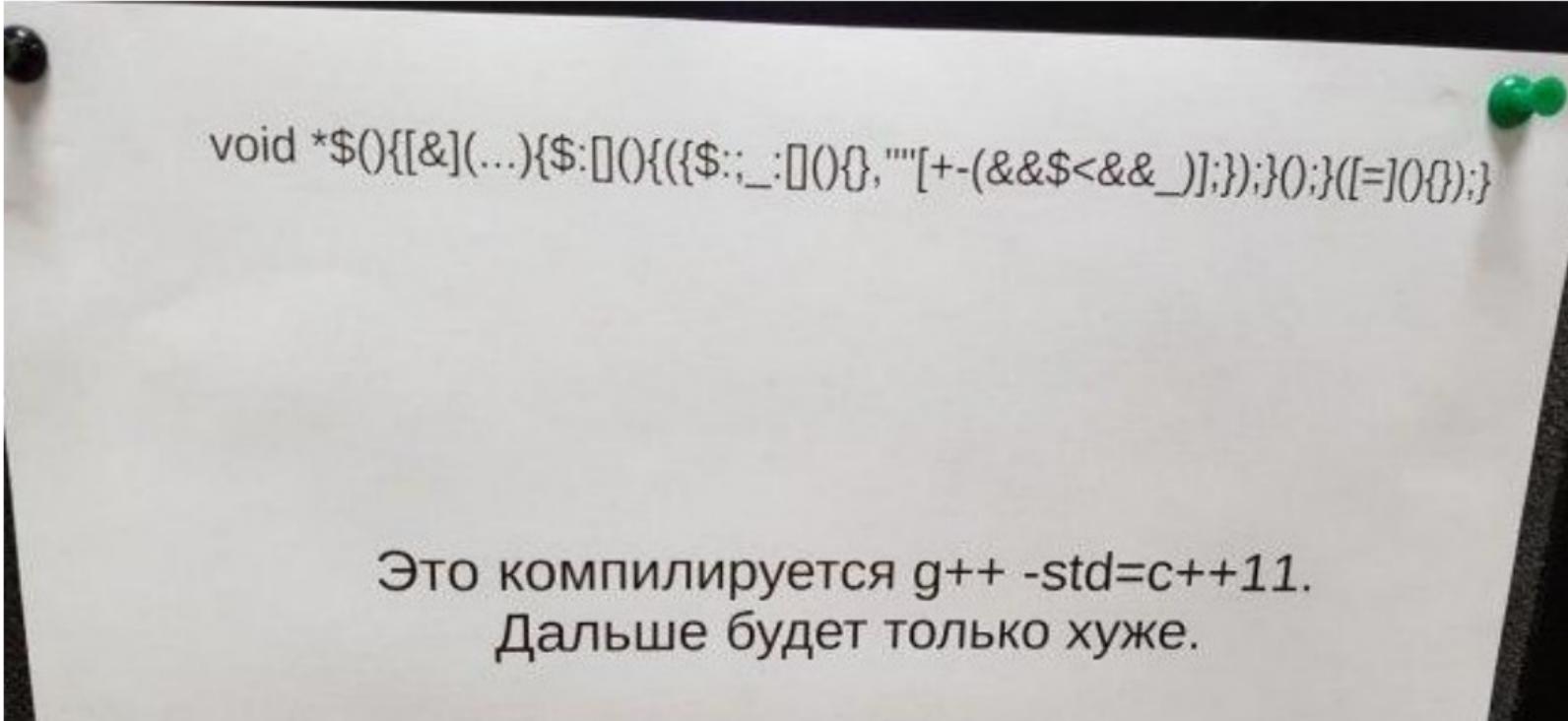


## Experience and Pitfalls

---

Complex syntax

```
1  _____ Rust _____  
2  impl<'a, 'gcx, 'tcx> InferCtxt<'a, 'gcx, 'tcx> {  
3      pub fn replace_bound_vars_with_placeholders<T>(&self,  
4          binder: &ty::Binder<T>  
5      ) -> (T, PlaceholderMap<'tcx>) where T: TypeFoldable<'tcx>  
6      {  
7          let next_universe = self.create_next_universe();  
8  
8          let fld_r = |br| {  
9              self.tcx.mk_region(ty::RePlaceholder(ty::PlaceholderRegion {  
10                  universe: next_universe,  
11                  name: br,  
12                  }))  
13          };  
14          ...  
15      }  
16  }
```



```
void *$0{[&](...){$:_(){({$:_(){},""+[+-(&&$<&&_)];)();}(){[=]();};}
```

Это компилируется g++ -std=c++11.  
Дальше будет только хуже.

## Experience and Pitfalls

---

Barriers to entry

Typically scope:

- Object-oriented programming
- Garbage collected programming language
- Dynamic programming language

Rust scope:

- No object-oriented programming
- No garbage collector
- No dynamic typing

## Experience and Pitfalls

---

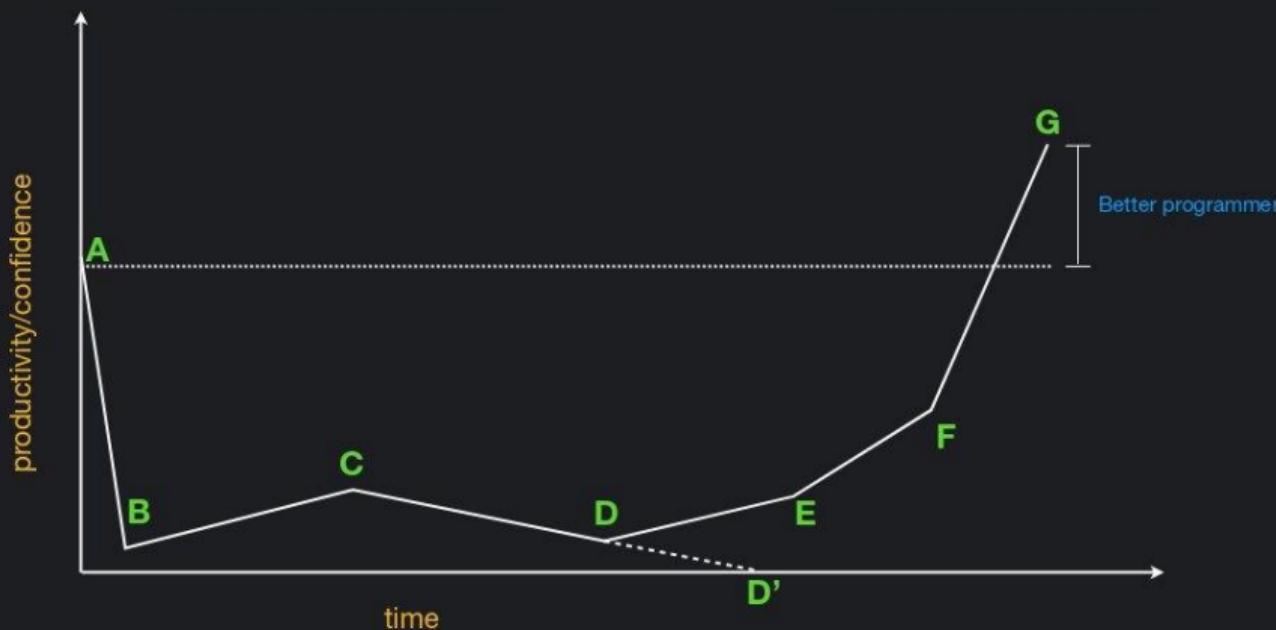
Ecosystem immaturity



## Experience and Pitfalls

---

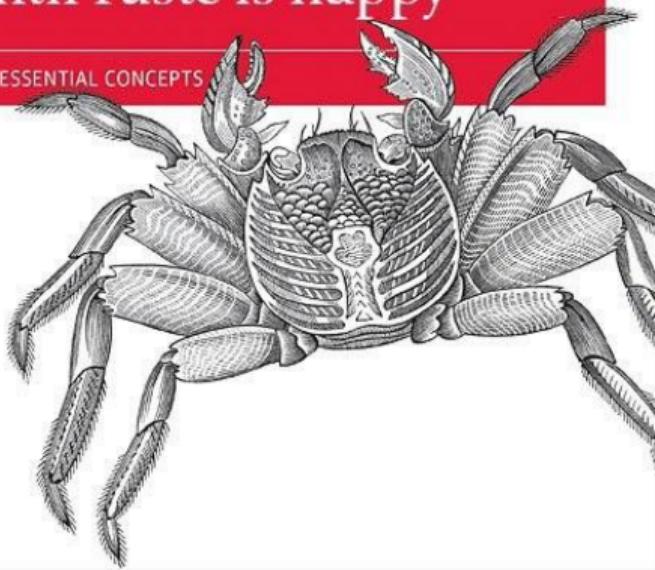
Learning curve



- A I know X, How hard Rust can be?
- B Borrow checker: Will my code ever compile? This is hard
- C Borrow checker thing is not that bad. I still cannot write non-trivial code
- D Even more errors while writing non-trivial code. Who decided to use Rust?
- D' I give up. Rust is too hard. Will use Go instead
- E Now I see how things fit. Compiler is indeed my friend.
- F Discover the wonders e.g Rayon. Refactoring is a pleasure.
- G Write much better code in first shot. Increase in productivity

# Adding and Removing & and \* at random until rustc is happy

50 ESSENTIAL CONCEPTS





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## Experience and Pitfalls

---

Format of errors or compiler driven development

# Format of errors or compiler driven development



---

C++

---

1 Too big, too unclear

---

---

Rust

---

```
1 error: expected type, found `&'static`  
2 --> test_err.rs:3:9  
3 |  
4 3 |     Ref('static str),  
5 |             ^^^^^^  
6  
7 error: aborting due to previous error
```

---

---

C++

---

```
1 In file included from /usr/include/c++/8.2.1/cassert:44,
2                     from test_err.cpp:3:
3 test_err.cpp: In function 'int main()':
4 test_err.cpp:17:5: error: invalid use of void expression
5     assert(std::holds_alternative<std::string>(y)); //
6         succeeds
7 ^~~~~~
```

---

Rust

```
1 error: expected one of `.` , `;` , `?` , or an operator, found
  → `}`  
2 --> test_err.rs:6:1
  |
 3 |
 4 5 |     let y = S("xyz".to_string())
 5 |                         - expected one of `.` ,
 6 |                         → `;` , `?` , or an operator here
 6 | }  
7 | ^ unexpected token  
8
 9 error: aborting due to previous error
```

## Experience and Pitfalls

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Zero-cost abstractions

- Traits (static and dynamic dispatching)
- Zero sized types
- Closures
- Markers
- Higher-kinded types
- Compile-time function execution
- ...

- Python: `sum(range(1000))` – 1000 iterations and 1000 additions
- Rust: `(0..1000).sum()` – 499500



## Experience and Pitfalls

---

Undefined behaviour

---

C

```
1 memset(c, 0, sizeof(Net_Crypto));  
2 free(c);
```

---

## Summary

---

- Fearlessness

Still have logical problems or wrong architecture, but

- no race conditions,
- no leaking resources,
- no dangling pointers,
- no unhandled exceptions,
- no NULL dereferences,
- no out of bounds,
- ...

With Rust I can focus on the real problems.

- Fearlessness
- Universality

Rust is reasonably good at pretty much everything.

- Embedded systems
- WebAssembly frontend code
- Quick and dirty utility
- Sophisticated tool
- 3D engine or game
- Business server-side app
- Mobile app
- OS and drivers
- ...

- Fearlessness
- Universality
- Combines strengths of “best tools for the given job”
- The performance, power and control of C/C++
- Memory safety of JVM/scripting languages
- Expressive type system like OCaml/Haskell/Scala
- Automatic memory management like a GC
- Dependency management and code sharing like Node
- Error messages like Elm
- Built-in message passing like Go
- ...

- Fearlessness
- Universality
- Combines strengths of “best tools for the given job”
- Ownership system

*Bad programmers worry about the code. Good programmers worry about data structures and their relationships.*

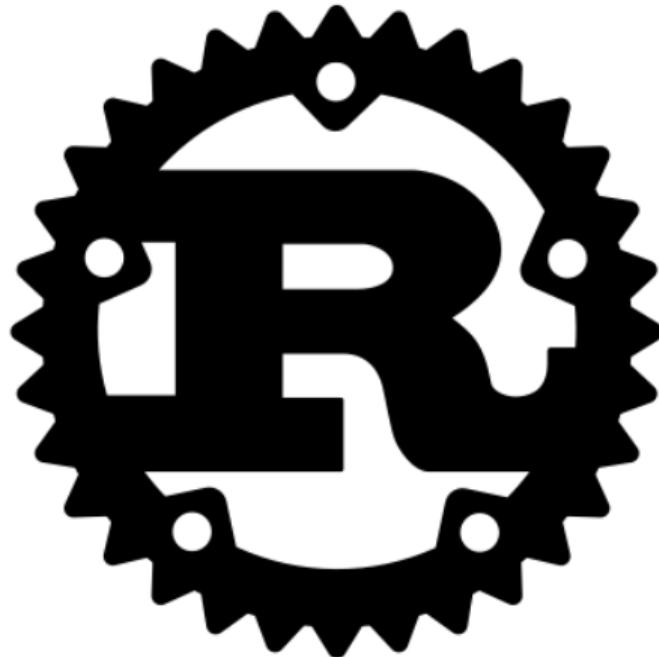
Rust will force you to be a good programmer, you like it or not.

- Fearlessness
- Universality
- Combines strengths of “best tools for the given job”
- Ownership system
- Community and collaboration

Rust community is just the best.

- Fearlessness
  - Universality
  - Combines strengths of “best tools for the given job”
  - Ownership system
  - Community and collaboration
  - **Tooling**
- rustup
  - cargo
  - xargo
  - rls
  - racer
  - rustfmt
  - ...

- Fearlessness
- Universality
- Combines strengths of “best tools for the given job”
- Ownership system
- Community and collaboration
- Tooling
- Keeps getting better



Questions?

