



Concurrency in Rust

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What's Rust?

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

Concurrency?

Rust?

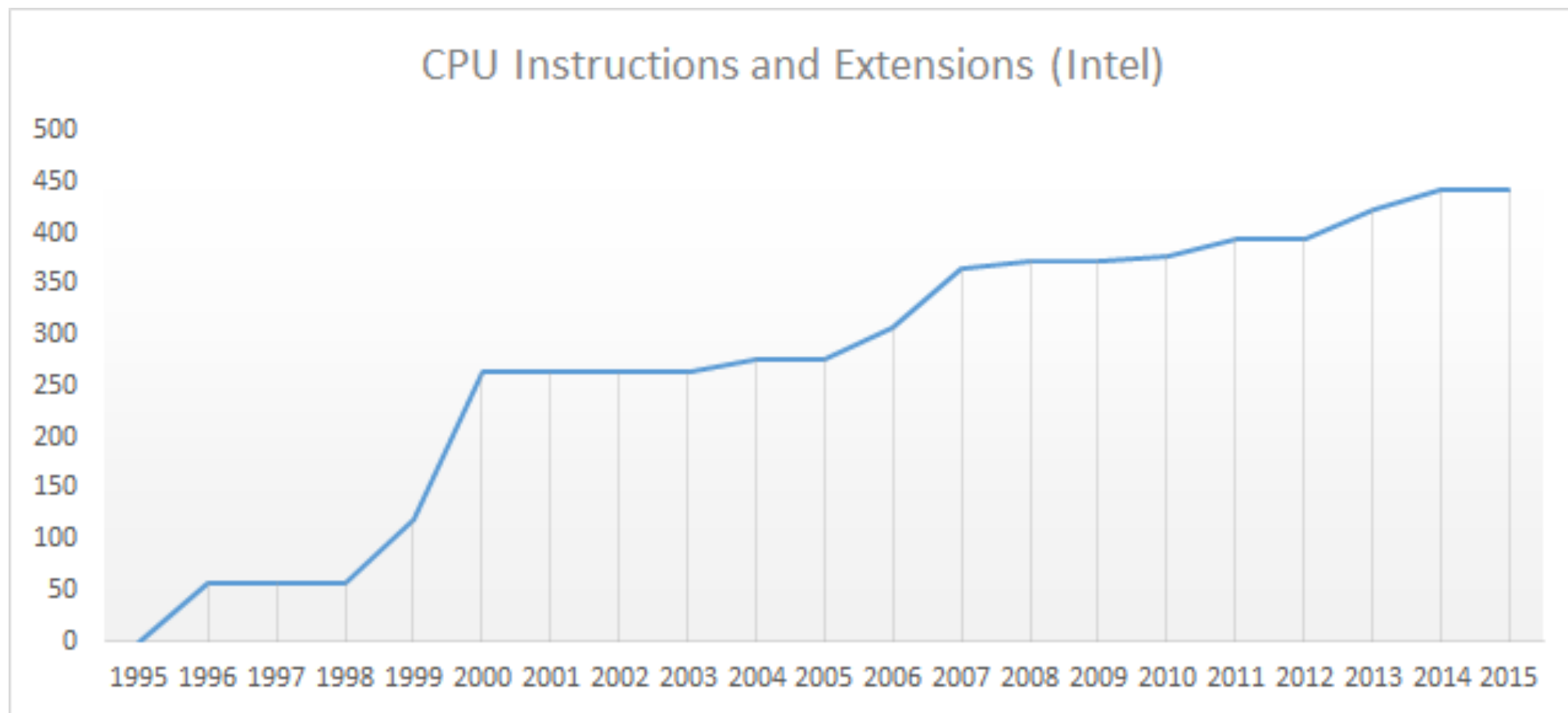
Libraries

Futures

What's concurrency?

In computer science, concurrency is a property of systems in which several computations are executing simultaneously, and potentially interacting with each other.

Why concurrency?



Getting our feet wet

```
// What does this print?  
int main() {  
    int pid = fork();  
    printf("%d\n", pid);  
}
```

Concurrency is hard!

- Data Races
 - Race Conditions
 - Deadlocks
 - Use after free
 - Double free
- Exploitable!
- 
- A diagram consisting of three blue arrows pointing from the word 'Exploitable!' on the right towards a list of concurrency issues on the left. The arrows point to 'Data Races', 'Use after free', and 'Double free'.

Concurrency?

Rust?

Libraries

Futures

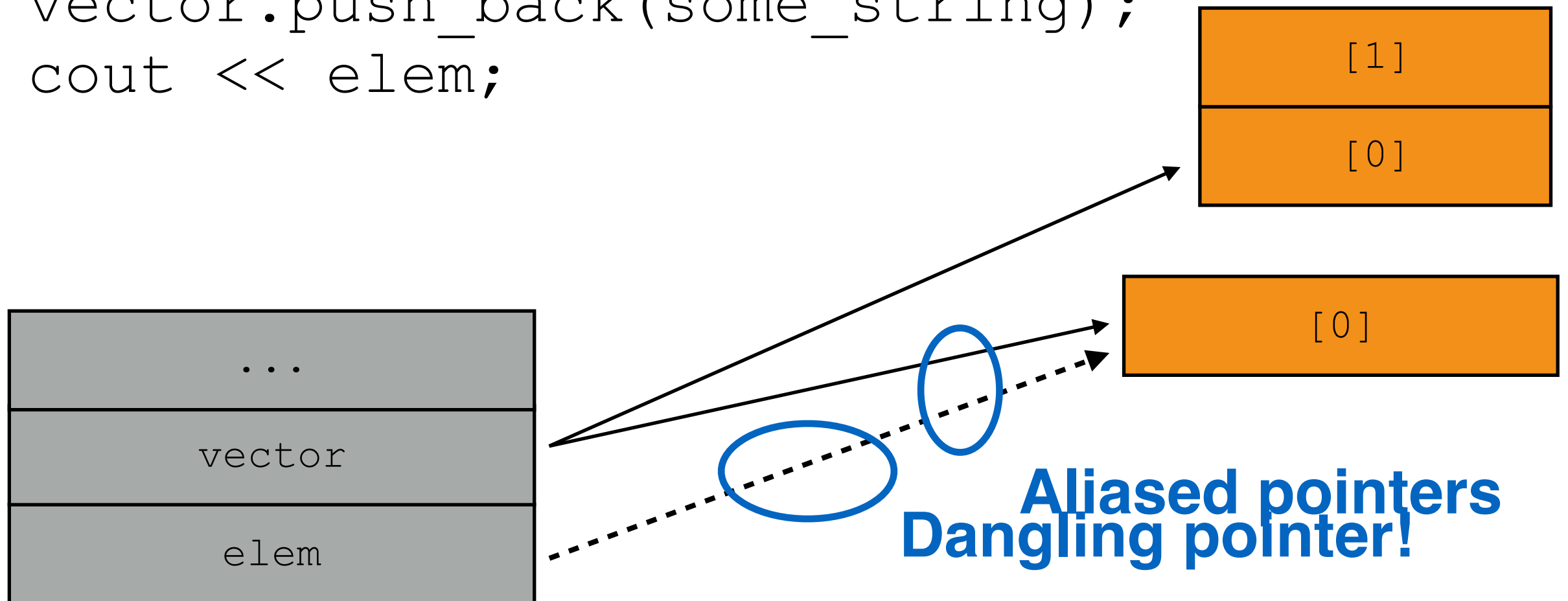
What's Rust?

Rust is a systems programming language that runs blazingly fast, **prevents segfaults**, and guarantees thread safety.

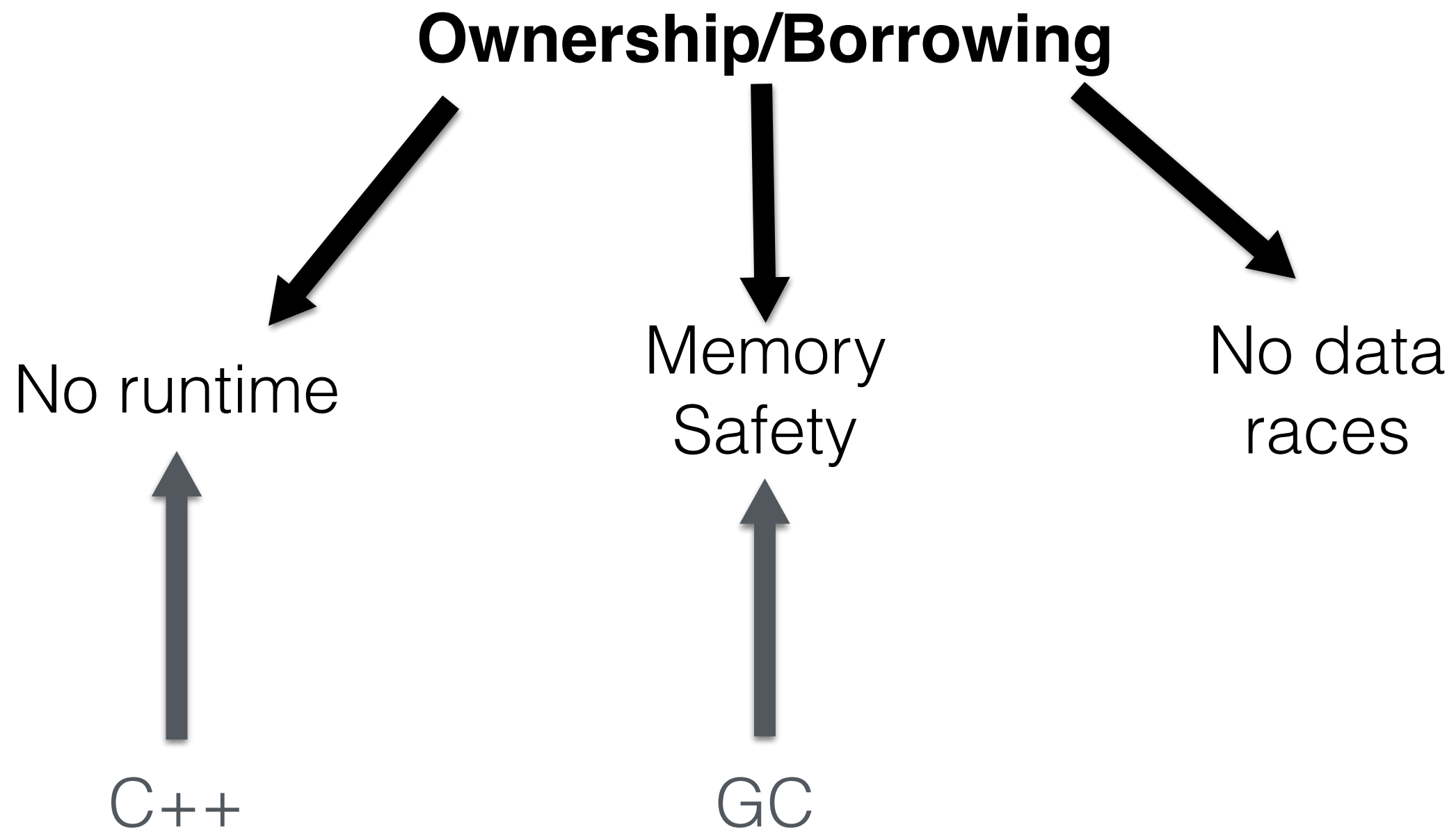
What's **safety**?

```
void example() {  
    vector<string> vector;  
    // ...  
    auto& elem = vector[0];  
    vector.push_back(some_string);  
    cout << elem;  
}
```

Mutation



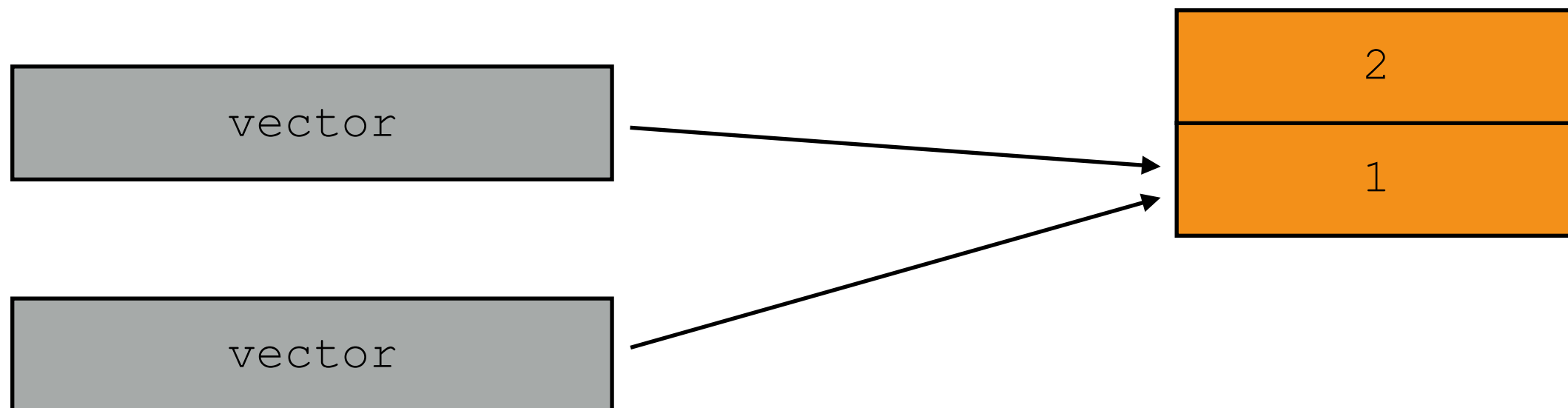
Rust's Solution



Ownership

```
fn main() {  
    let mut v = Vec::new();  
    v.push(1);  
    v.push(2);  
    take(v);  
    // ...  
}
```

```
fn take(v: Vec<i32>) {  
    // ...  
}
```



Ownership

```
fn main() {  
    let mut v = Vec::new();  
    v.push(1);  
    v.push(2);  
    take(v);  
    // ...  
}  
  
fn take(v: Vec<i32>) {  
    // ...  
}
```

Ownership

```
fn main() {  
    let mut v = Vec::new();  
    v.push(1);  
    v.push(2);  
    take(v);  
    v.push(3);  
}  
  
fn take(v: Vec<i32>) {  
    // ...  
}
```

Ownership

```
fn main() {  
    let mut v = Vec::new();  
    v.push(1);  
    v.push(2);  
    take(v);  
    v.push(3);  
}  
  
fn take(v: Vec<i32>) {  
    // ...  
}
```

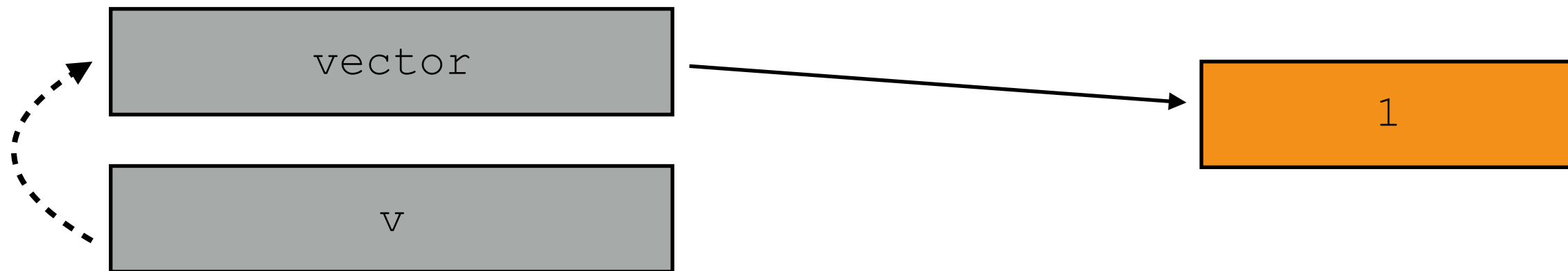
error: use of moved value `v`



Borrowing

```
fn main() {  
    let mut v = Vec::new();  
    push(&mut v);  
    read(&v);  
    // ...  
}
```

```
fn read(v: &mut Vec<u32>) {  
    // push(1);  
}
```

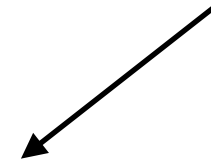


Safety in Rust

- Rust *statically* prevents aliasing + mutation
- Ownership prevents double-free
- Borrowing prevents use-after-free
- Overall, no segfaults!

Data races

Aliasing!



- A data race happens when there are two concurrent memory accesses to the same location in a program where:
 - at least one is unsynchronized
 - at least one is a write



Mutation!

Concurrency?

Rust?

Libraries

Futures

Rust Concurrency Libs

- Language only provides ownership/borrowing
- Libraries implement common abstractions
- Flexible to cover wide range of paradigms

std::thread

```
let loc = thread::spawn(|| {  
    "world"  
});  
println!("Hello, {}!",  
        loc.join().unwrap());
```

std::sync::mpsc

```
let (tx, rx) = mpsc::channel();  
let tx2 = tx.clone();  
thread::spawn(move || tx.send(5));  
thread::spawn(move || tx2.send(4));  
  
// Prints 4 and 5 in an unspecified order  
println!("{}", rx.recv());  
println!("{}", rx.recv());
```

std::sync::Arc

```
let shared_numbers = Arc::new(vec![1, 2, 3]);  
let child_numbers = shared_numbers.clone();  
thread::spawn(move || {  
    assert_eq!(child_numbers, [1, 2, 3]);  
});  
assert_eq!(shared_numbers, [1, 2, 3]);
```

std::sync::atomic::*

```
let number = AtomicUsize::new(10);  
let prev = number.fetch_add(1, SeqCst);  
assert_eq!(prev, 10);  
let prev = number.swap(2, SeqCst);  
assert_eq!(prev, 11);  
assert_eq!(number.load(SeqCst), 2);
```


std::sync::Mutex

```
let lock = Mutex::new(vec![1, 2, 3]);  
{  
    let mut vector = lock.lock();  
    vector.push(3);  
}  
// no more access to `vector`,  
// lock is unlocked
```

crossbeam

- Epoch-based memory reclamation
- Easy translation of algorithms that require GC
- Work stealing deque
- MPMC queues

rayon

```
fn sum_of_squares(input: &i32) -> i32 {  
    input.iter()  
        .map(|&i| i * i)  
        .sum()  
}
```

rayon

```
use rayon::prelude::*;

fn sum_of_squares(input: &[i32]) -> i32 {
    input.par_iter()
        .map(|&i| i * i)
        .sum()
}
```

100% Safe

- Everything you just saw is foolproof
- No segfaults
- No data races
- No double frees...

Concurrency?

Rust?

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Async I/O in Rust (last year)

- *mio*, a “cross platform epoll” event loop library
- Servers were hand-written state machines
- Composition was quite difficult



 [facebook](#) / [wangle](#)

What's a future?

- Database query
- RPC request
- Timeouts
- CPU intensive work
- Socket readiness

What's a future in Rust?

```
trait Future {  
    type Item;  
    type Error;  
  
    fn poll(&mut self) -> Poll<Item, Error>;  
    // ...  
}
```

Composing futures

```
// Run one future, then another  
f.and_then(|v| new_future(v))
```

```
// Wait for one of two futures  
a.select(b)
```

```
// Wait for both futures  
a.join(b)
```

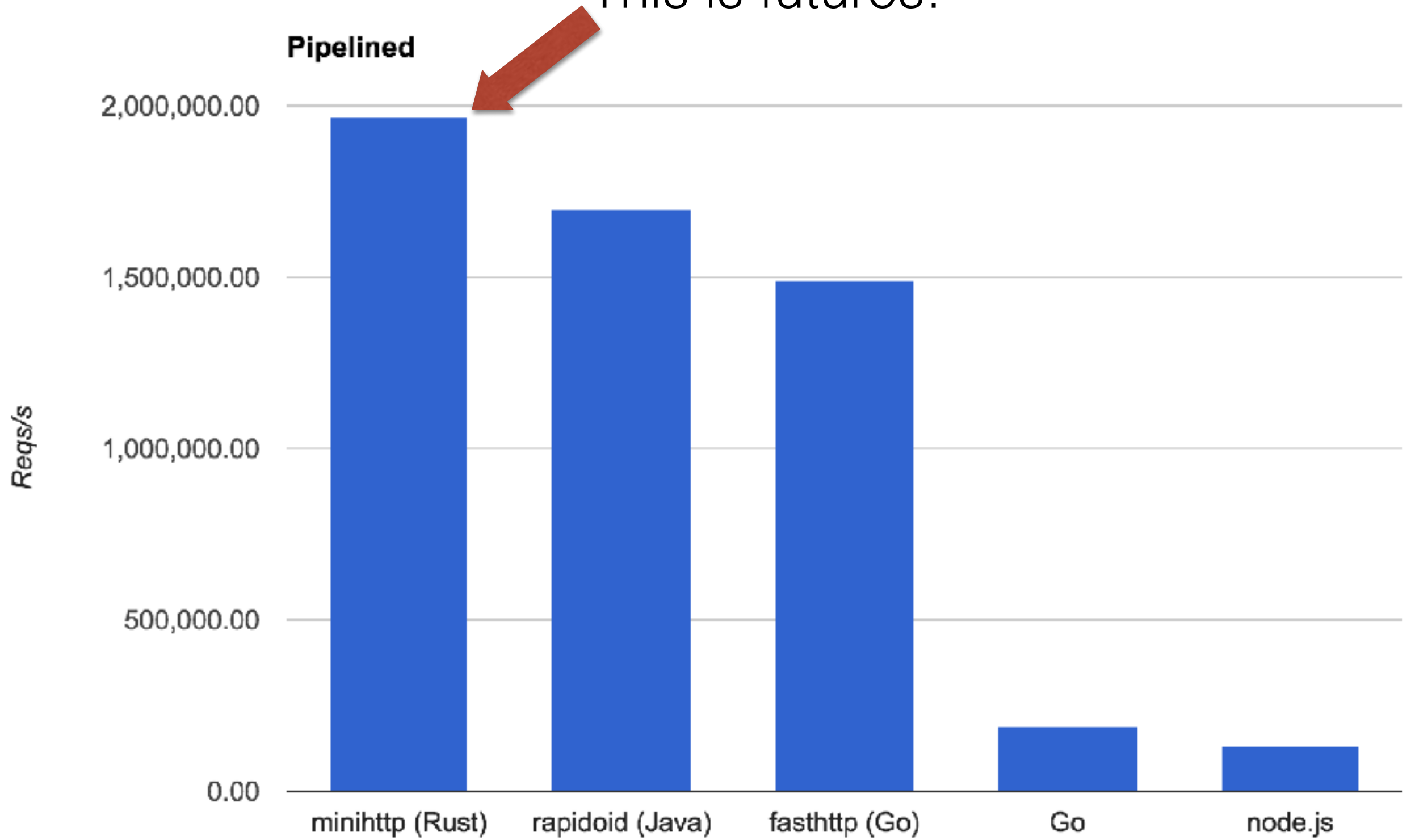
Async I/O in Rust (today)

- *futures*, a foundational abstraction for Async I/O
- Tokio, a runtime built on *mio* and *futures*
- Futures are **at all layers** of the stack

Zero-cost futures

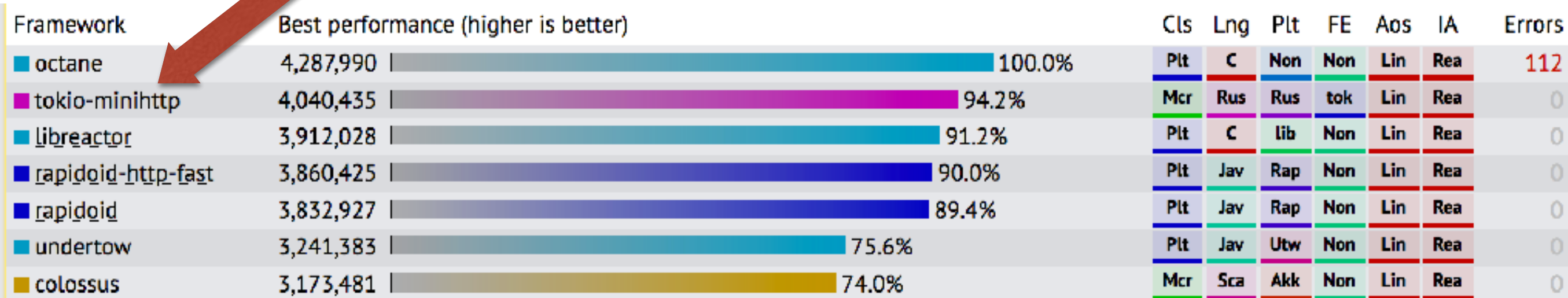
- No allocations in combinators
- No synchronization in combinators
- Library is `#![no_std]` compatible
- One dynamic dispatch per event
- One allocation per connection

This is futures!



Don't just take my word

Tokio

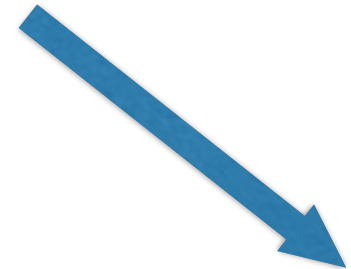


trait Future

- Allows for most specialized implementation
- Enables inter-combinator optimizations
- Permits dynamic dispatch when required

trait Future

Zero-cost closures



```
fn and_then<F, B>(self, f: F) -> AndThen<Self, B, F>
where F: FnOnce(Item) -> B,
      B: IntoFuture<Error=Self::Error>,
      Self: Sized,
```



Ergonomic conversion

Cancellation

- Cancel a future by dropping it
- Ownership implies one handle to a future
- Deterministic destruction so we know what drops



Questions?