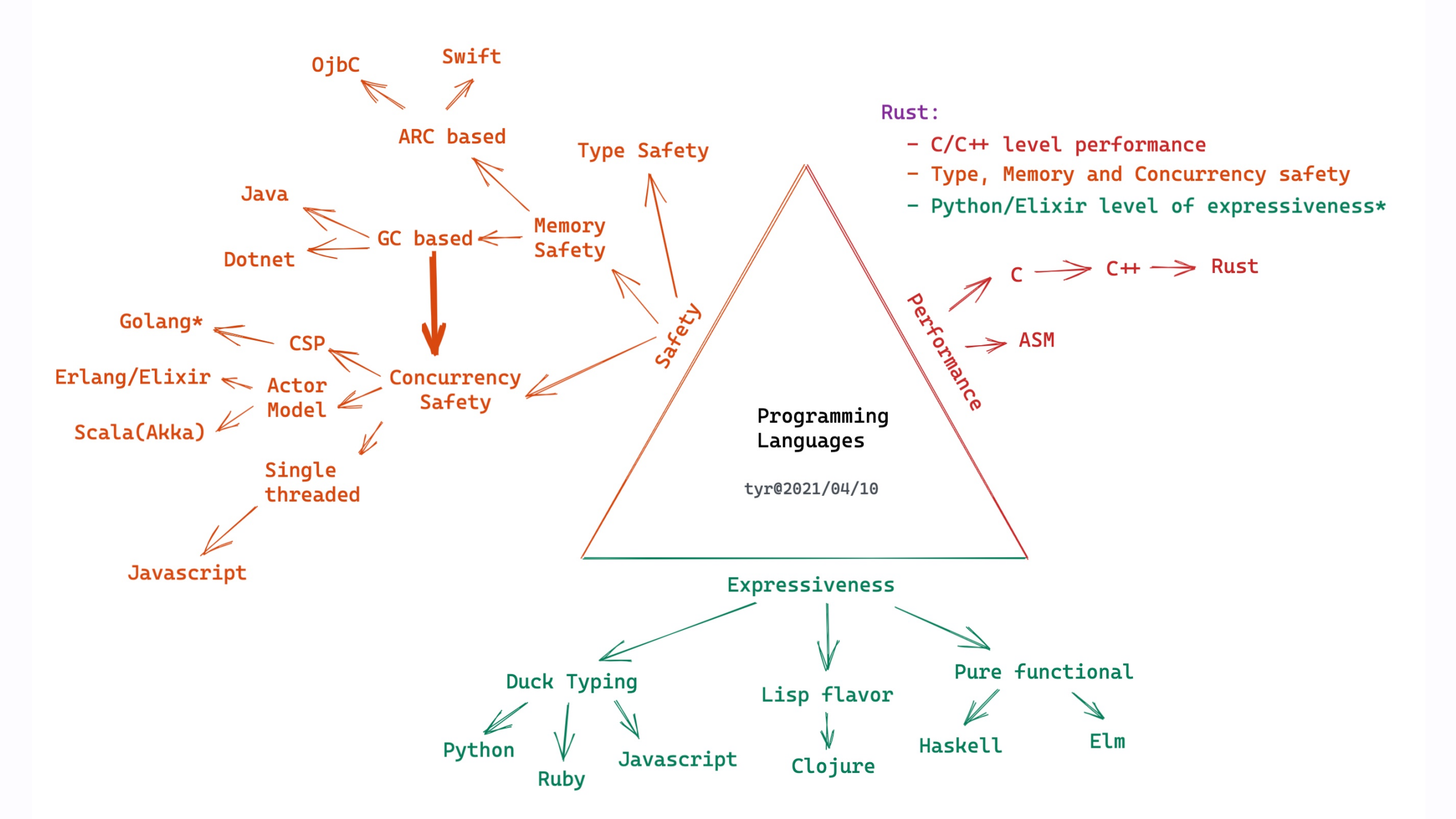
Rust Trainings All in One

- High-level intro about Rust
- Ownership, borrow check, and lifetime
- Typesystem and data structures
- Concurrency - primitives
- Concurrency - async/await
- Networking and security
- FFI with C/Elixir/Swift/Java
- WASM/WASI
- Rust for real-world problems

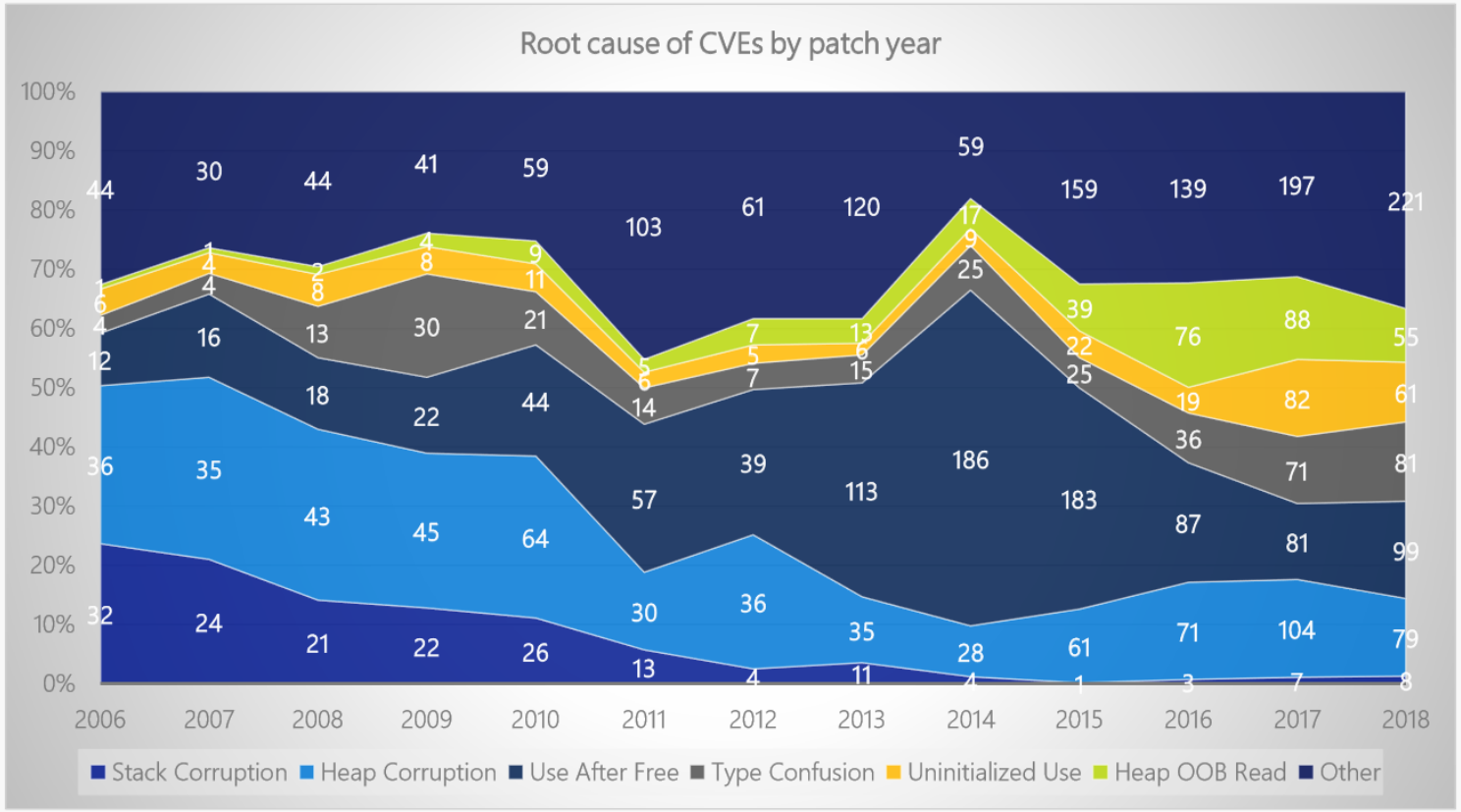
High-level Intro About Rust

Why Rust?


OjbC
Swift
ARC based
Java
Dotnet
GC based
Memory Safety
Type Safety
Golang*
CSP
Erlang/Elixir
Actor Model
Scala(Akka)
Concurrency Safety
Single threaded
Javascript
Safety
Programming Languages
tyr@2021/04/10
Performance
C
C++
Rust
ASM
Rust:
- C/C++ level performance
- Type, Memory and Concurrency safety
- Python/Elixir level of expressiveness*
Expressiveness
Duck Typing
Python
Ruby
Javascript
Lisp flavor
Clojure
Pure functional
Haskell
Elm

Why safety is important?

Drilling down into root causes



Stack corruptions are essentially dead

Use after free spiked in 2013-2015 due to web browser UAF, but was mitigated by Mem GC

Heap out-of-bounds read, type confusion, & uninitialized use have generally increased

Spatial safety remains the most common vulnerability category (heap out-of-bounds read/write)

Top root causes since 2016:

- #1: heap out-of-bounds
- #2: use after free
- #3: type confusion
- #4: uninitialized use

Note: CVEs may have multiple root causes, so they can be counted in multiple categories

(**Source:** **Memory Safety Issues Are Still the Leading Source of Security Vulnerabilities**)

Why safety is hard?

- memory safety is not easy (you need to understand the corner cases)
- conccurency safety is really hard (without certain tradeoffs)
- Often you have to bear the extra layer of abstractions
  - normally it means performance hit

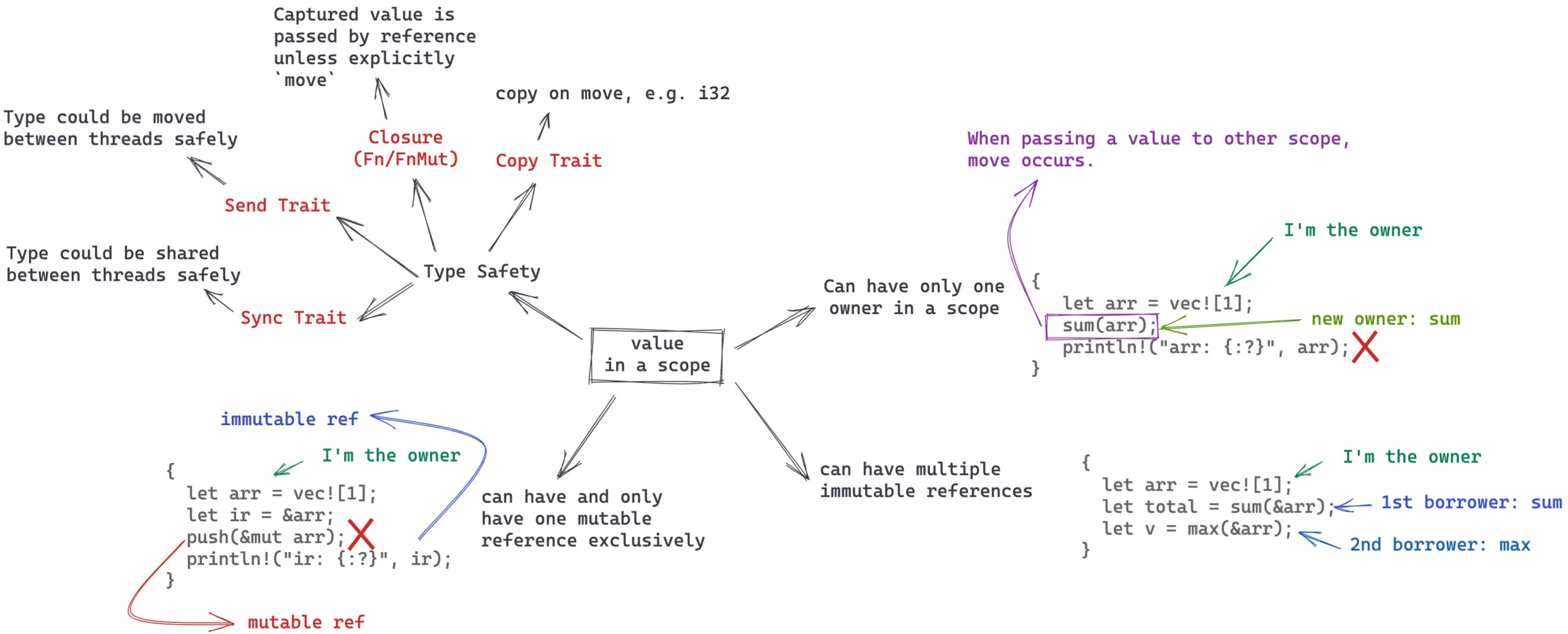
Memory safety

- Manually - C/C++: painful and error-prone
- Smart Pointers - C++/ObjC/Swift: be aware of cyclical references
- GC - Java/DotNet/Erlang: mubch bigger memory consumption, and STW
- Ownership - Rust: learning curve

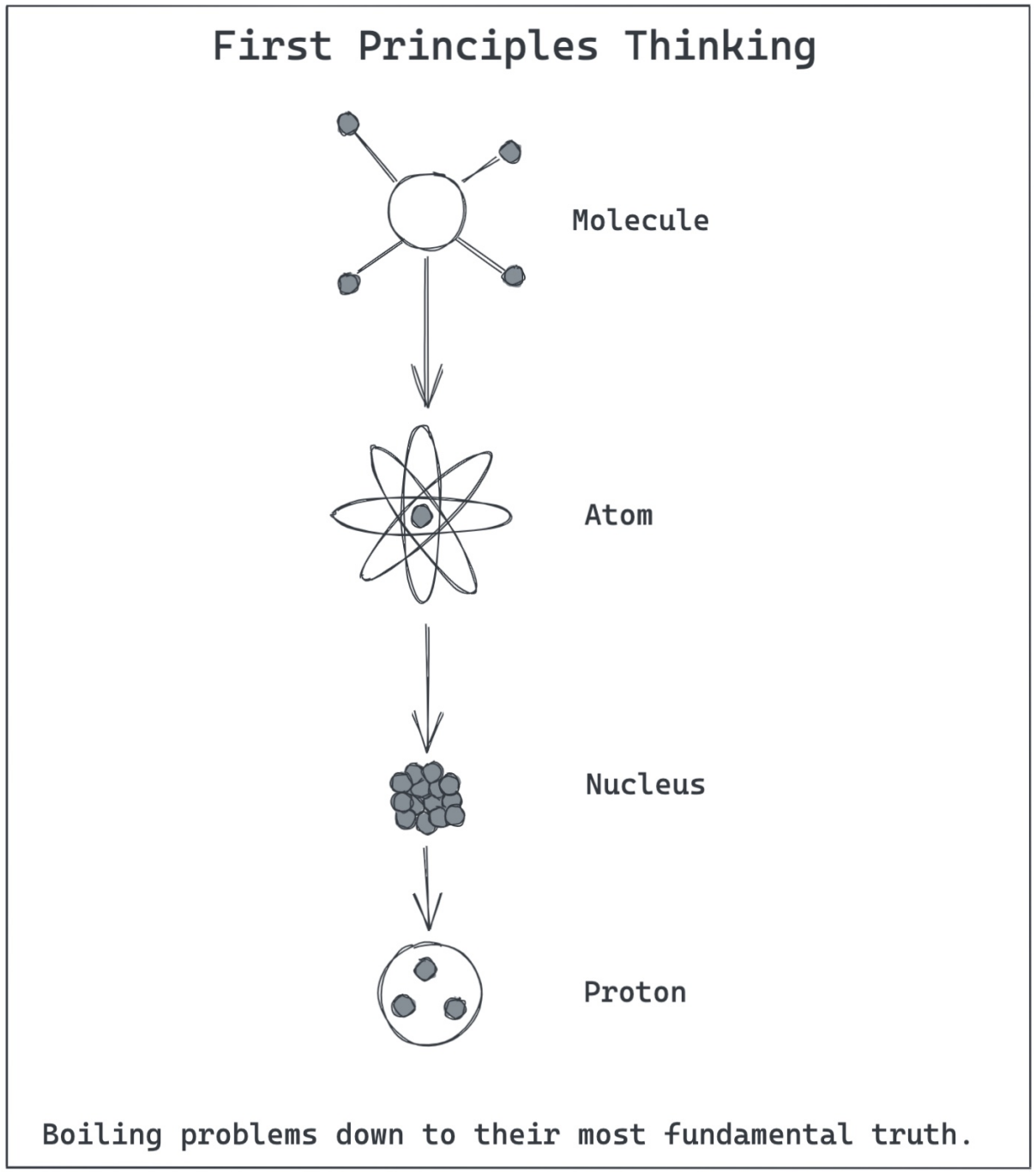
Concurrency safety

- single-threaded - Javascript: cannot leverage multicore
- GIL - Python/Ruby: multithreading is notorious inefficient
- Actor model - Erlang/Akka: at the cost of memory copy
- CSP - Golang: at the cost of memory copy
- Ownership + Type System - Rust: very elegant and no extra cost!

How Rust achieve memory safety and conccurency safety?


Captured value is passed by reference unless explicitly `move`
Type could be moved between threads safely
Closure (Fn/FnMut)
copy on move, e.g. i32
Copy Trait
Send Trait
Type could be shared between threads safely
Type Safety
Sync Trait
value in a scope
Can have only one owner in a scope
When passing a value to other scope, move occurs.
I'm the owner
{
let arr = vec![1];
sum(arr);
println!("arr: {:?}", arr);
}
new owner: sum
immutable ref
I'm the owner
{
let arr = vec![1];
let ir = &arr;
push(&mut arr);
println!("ir: {:?}", ir);
}
mutable ref
can have and only have one mutable reference exclusively
can have multiple immutable references
{
I'm the owner
let arr = vec![1];
let total = sum(&arr);
1st borrower: sum
let v = max(&arr);
2nd borrower: max
}

```rust
fn main() {
    let mut arr: Vec<i32> = vec![1, 2, 3];    move occurs because `arr` has type `Vec<i32>`, which does not implement the `Copy` trait
    arr.push(4);

    let result: Result<(), Error> = process(arr);    unused variable: `result`
    let _v: Option<i32> = arr.pop(); // failed since arr is moved    borrow of moved value: `arr`

    // you can have multiple immutable references
    let mut arr1: Vec<i32> = vec![1, 2, 3];
    let ir1: &Vec<i32> = &arr1;
    let ir2: &Vec<i32> = &arr1;

    println!("ir1: {:?} ir2: {:?}", ir1, ir2);

    // but you can't have both mutable and immutable references
    let mr1: &mut Vec<i32> = &mut arr1;    first mutable borrow occurs here
    let mr2: &mut Vec<i32> = &mut arr1;    cannot borrow `arr1` as mutable more than once at a time

    println!("mr1: {:?} mr2: {:?}", mr1, mr2);    first borrow later used here

    // by default, closure borrows the data
    let mut arr2: Vec<i32> = vec![1, 2, 3];
    thread::spawn(|| {    closure may outlive the current function, but it borrows `arr2`, which is owned by the current function
        arr2.push(4);    `arr2` is borrowed here
    });

    // we shall move the data explicitly
    let mut arr3: Vec<i32> = vec![1, 2, 3];
    thread::spawn(move || arr3.push(4));
}

fn thread_safety() {
    // but certain types cannot be moved to other thread safely
    let mut rc1: Rc<Vec<i32>> = Rc::new(vec![1, 2, 3]);
    thread::spawn(move || {    `Rc<Vec<i32>>` cannot be sent between threads safely
        rc1.push(4);
    });
}
```



Recap

- One and only one owner
- Multiple immutable references
- mutable reference is mutual exclsive
- **use type safety for thread safety**

With these simple rules, Rust achieved safety with

zero cost abstraction

Zero Cost Abstraction

Rust way of searching for solutions

Let's go to basics about types

- can be used any number of times
  - Other languages: this is how we works
  - Rust: Copy / Clone
- can't be used more than once
  - Other lanugages: ??
  - Rust: move semantics
- must be used at least once
  - Other lanugages: linter will detect that, hopefully
  - `unused_variables`, `unused_assignments`, `unused_must_use`
- must be used exactly once

References

- The pain of real linear types in Rust
- Substructural type system

About memory safety

- C/C++

Ownership, borrow check, and lifetime

Typesystem and data structures

Concurrency - primitives

Concurrency - async/await

Networking and security

FFI with C/Elixir/Swift/Java

WASM/WASI

Rust for real-world problems

May the Rust be with you