Rust Fundamentals

Basics of Rust
Part III

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RustCourse
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Course. Not talk!

Follow along!

- Rust Playground
- Exercises

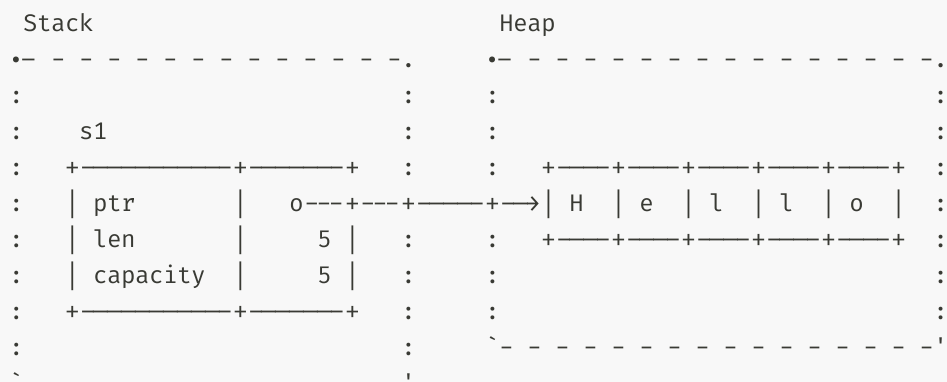
▶ Show hints

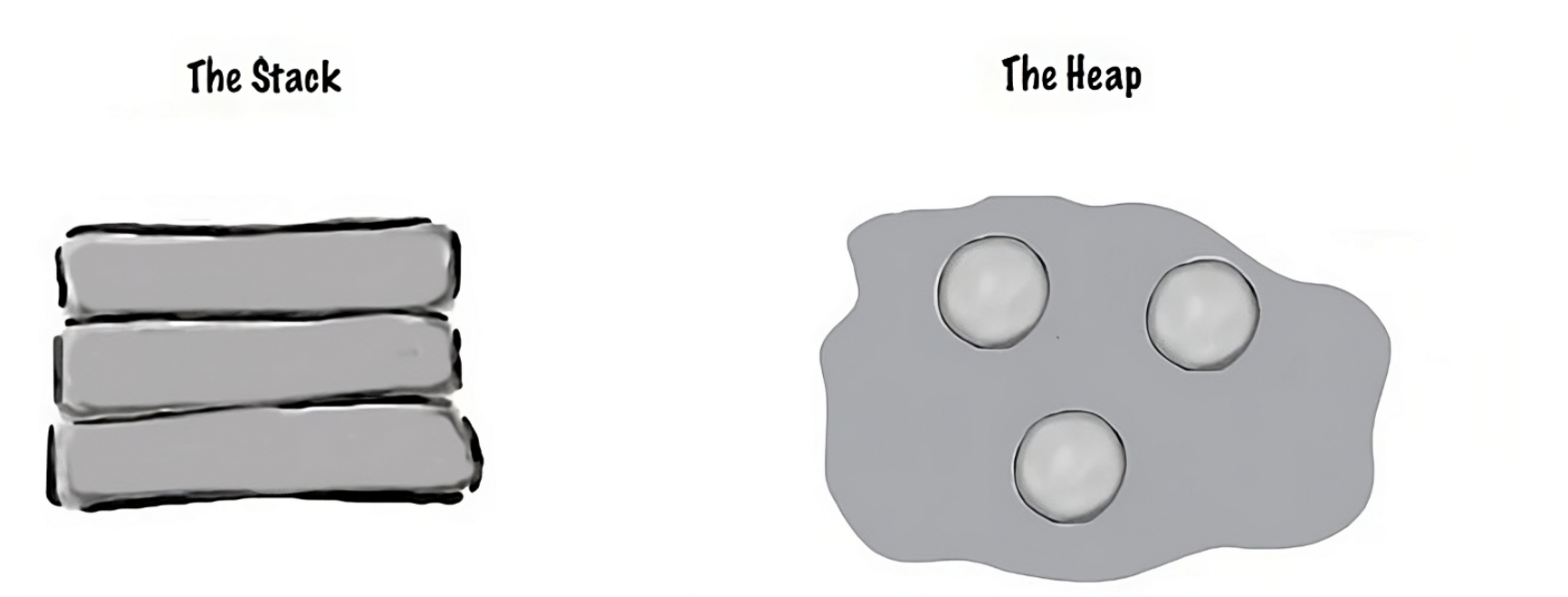
Memory Management

The Stack vs The Heap

- **Stack**: Continuous area of memory for local variables.
  - Values have **fixed sizes** known at compile time.
  - **Extremely fast**: just move a stack pointer.
  - Easy to manage: follows function calls.
- Heap: Storage of values outside of function calls.
  - Values have **dynamic sizes** determined at runtime.
  - **Slower** than the stack: some book-keeping needed.

```rust
fn main() {
    let s1 = String::from("Hello");
}
```





Head First Java by Kathy Sierra

Ownership

```rust
fn main() {
    {
        let x = 42;
        println!("x: {x}");
    } // variable `x` is dropped, data is freed.

    println!("x: {x}");
}
```

Move Semantics

```
fn main() {
    let s1: String = String::from("Hello!");
    let s2: String = s1;

    println!("s2: {s2}");
    //println!("s1: {s1}");
}
```

- The assignment of `s1` to `s2` transfers ownership.
- There is always *exactly* one variable binding which owns a value.

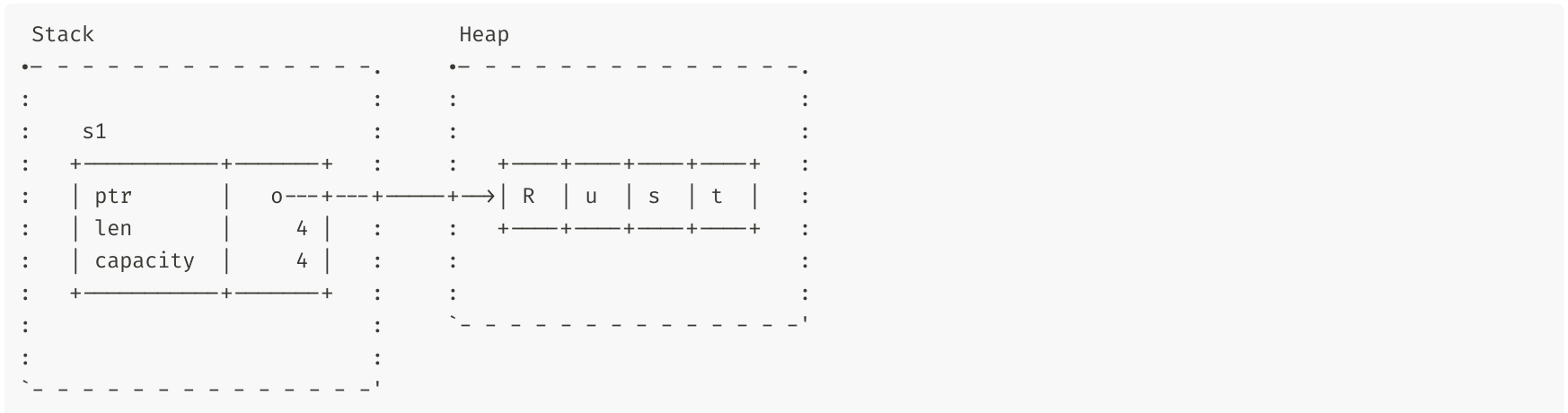
```
error[E0382]: borrow of moved value: `s1`
 ⟶ src/main.rs:6:19
  |
2 |     let s1: String = String::from("Hello!");
  |         -- move occurs because `s1` has type `String`, which does not implement the `Copy` trait
3 |     let s2: String = s1;
  |                      -- value moved here
...
6 |     println!("s1: {s1}");
  |                   ^^^^ value borrowed here after move
  |
...
  |
3 |     let s2: String = s1.clone();
  |                      ++++++++
```

Moved Strings in Rust

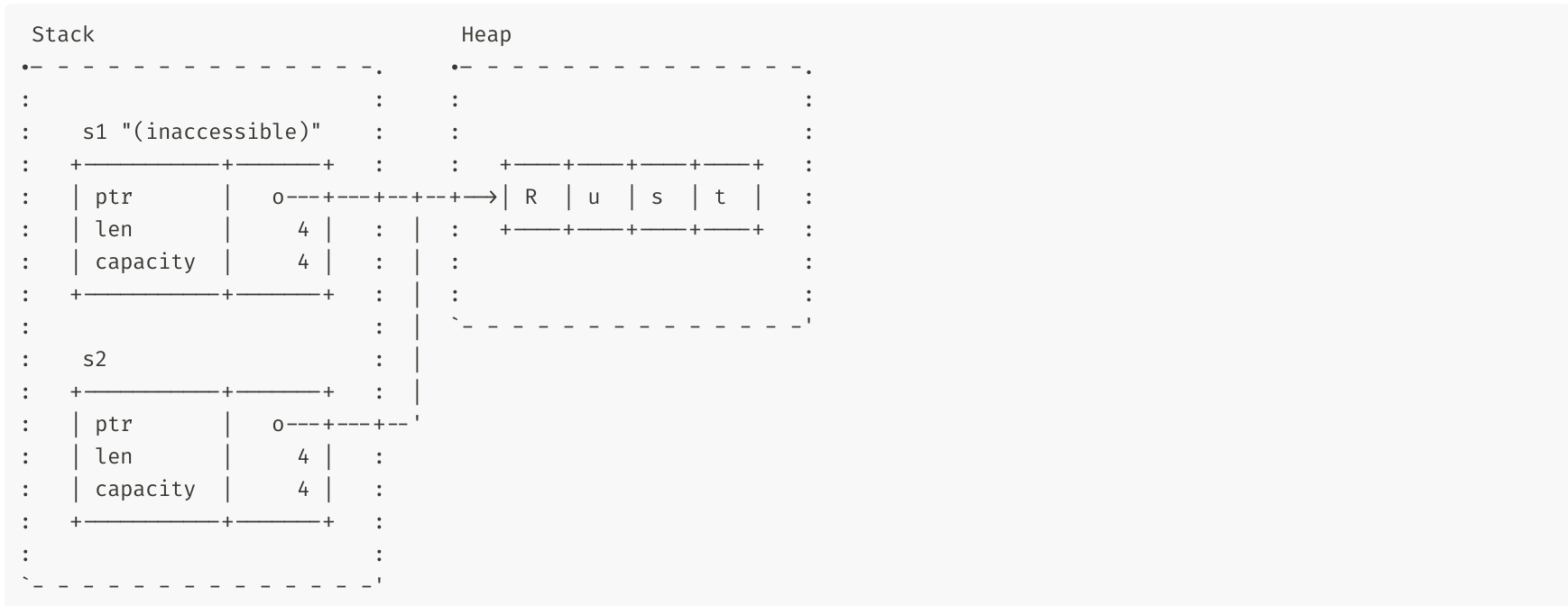
```
fn main() {
    let s1: String = String::from("Rust");
    let s2: String = s1;
}
```

- The heap data from `s1` is reused for `s2`.
- When `s1` goes out of scope, nothing happens (it has been moved from).

Before move to `s2`:



After move to `s2`:



Moves in Function Calls

```
fn say_hello(name: String) {
    println!("Hello {name}")
} // The heap memory allocated for `name` will be freed here


fn main() {
    let name = String::from("Alice");
    say_hello(name); // Ownership transferred to say_hello
    // say_hello(name); // You can't use `name` here anymore because it was moved
}
```

```rust
fn say_hello(name: &String) {
    println!("Hello, {}", name);
}

fn main() {
    let name = String::from("Alice");
    say_hello(&name); // Borrowing `name`, ownership remains with `main`
    // You can still use `name` here
}
```

```rust
fn say_hello(name: String) {
    println!("Hello {}", name);
}

fn main() {
    let name = String::from("Alice");
    let cloned_name = name.clone();
    say_hello(cloned_name);
    // You can still use `name` here because you cloned it.
```

Copying and Cloning

Move semantics are the default, but certain types are copied by default.

```
fn main() {
    let x = 42;
    let y = x;

    println!("x: {x}");
    println!("y: {y}");
}
```

These types implement the `Copy` trait.

- Primitive numeric types
- Tuples (if all their elements implement Copy)
- Fixed-size arrays (if their elements implement Copy)
- Some built-in types
- User-Defined types

```
#[derive(Debug)]
struct Point(i32, i32);

fn main() {
    let p1 = Point(3, 4);
    let p2 = p1;

    println!("p1: {p1:?}");
    println!("p2: {p2:?}");
}
```

```
error[E0382]: borrow of moved value: `p1`
 ⟶ src/main.rs:8:19
  |
5 |     let p1 = Point(3, 4);
  |         -- move occurs because `p1` has type `Point`, which does not implement the `Copy` trait
6 |     let p2 = p1;
  |              -- value moved here
7 |
8 |     println!("p1: {p1:?}");
  |                    ^^^^^^ value borrowed here after move
  |
```

```
#[derive(Copy, Clone, Debug)]
struct Point(i32, i32);

fn main() {
    let p1 = Point(3, 4);
    let p2 = p1;

    println!("p1: {p1:?}");
    println!("p2: {p2:?}");
}
```

Shared and Unique Borrows

Rust puts constraints on the ways you can borrow values:

- You can have one or more `&T` values at any given time, *or*
- You can have exactly one `&mut T` value.

Lifetimes

A borrowed value has a *lifetime*:

- The lifetime can be implicit: `` `add(p1: &Point, p2: &Point) → Point` ``.
- Lifetimes can also be explicit: `` `&'a Point` ``, `` `&'document str` ``.

Lifetimes in Function Calls

```
#[derive(Debug)]
struct Point(i32, i32);

fn left_most<'a>(p1: &'a Point, p2: &'a Point) -> &'a Point {
    if p1.0 < p2.0 { p1 } else { p2 }
}

fn main() {
    let p1: Point = Point(10, 10);
    let p2: Point = Point(20, 20);
    let p_ref: &Point = left_most(&p1, &p2);
    println!("left-most point: {:?}", p_ref);
}
```

```rust
#[derive(Debug)]
struct Point(i32, i32);

fn left_most<'a>(p1: &'a Point, p2: &'a Point) -> &'a Point {
    if p1.0 < p2.0 { p1 } else { p2 }
}

fn main() {
    let p1: Point = Point(10, 10);
    let p2: Point = Point(20, 20);
    let p_ref: &Point = left_most(&p1, &p2);
    println!("left-most point: {:?}", p_ref);
}
```

Lifetimes in Data Structures

```
#[derive(Debug)]
struct Highlight<'doc>(&'doc str);

fn main() {
    let text = String::from("The quick brown fox jumps over the lazy dog.");
    let fox = Highlight(&text[4..19]);
    let dog = Highlight(&text[35..43]);
    println!("{fox:?}");
    println!("{dog:?}");
}
```

```rust
#[derive(Debug)]
struct Highlight<'doc>(&'doc str);

fn main() {
    let text = String::from("The quick brown fox jumps over the lazy dog.");
    let fox = Highlight(&text[4..19]);
    let dog = Highlight(&text[35..43]);
    println!("{fox:?}");
    println!("{dog:?}");
}
```

Exercises

- `move_semantics1`
- `move_semantics2`
- `move_semantics3`
- `lifetimes1`
- `lifetimes2`
- `lifetimes3`

Credits 🌟

- Mo's (mo8it) Comprehensive Rust 🦀
- rustlings 🦀