# CS 241: Systems Programming
# Lecture 14. Structures

Fall 2023

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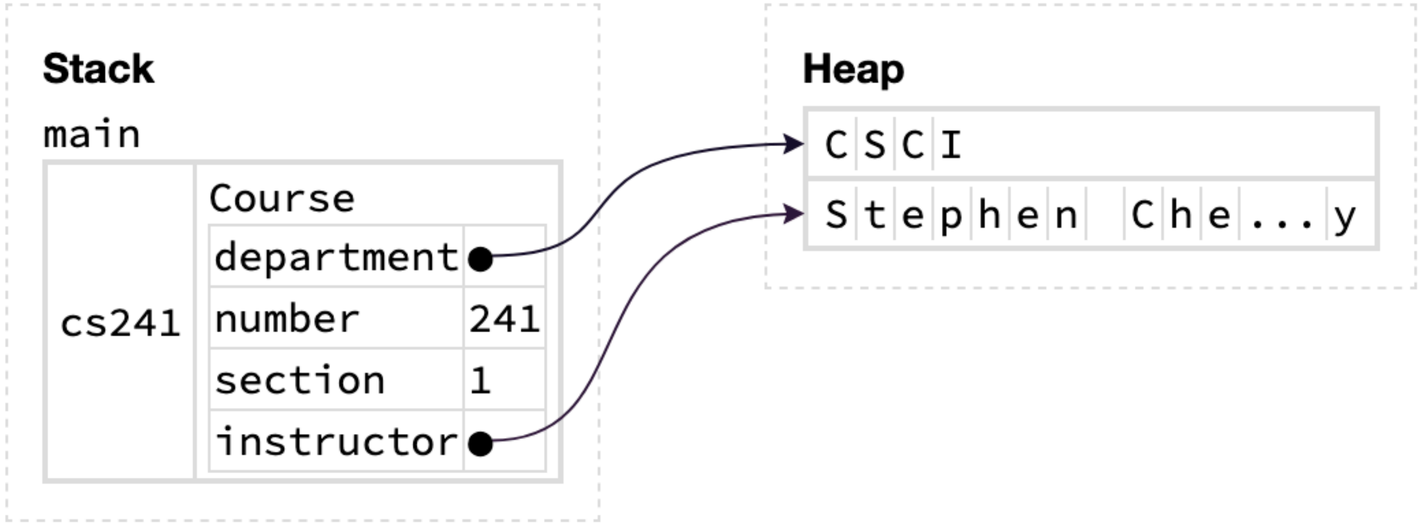
# struct

```
struct Course {
    department: String,
    number: i32,
    section: i32,
    instructor: String,
}

fn main() {
    let cs241 = Course {
        department: String::from("CSCI"),
        number: 241,
        section: 1,
        instructor: String::from("Stephen Checkoway"),
    };
}
```

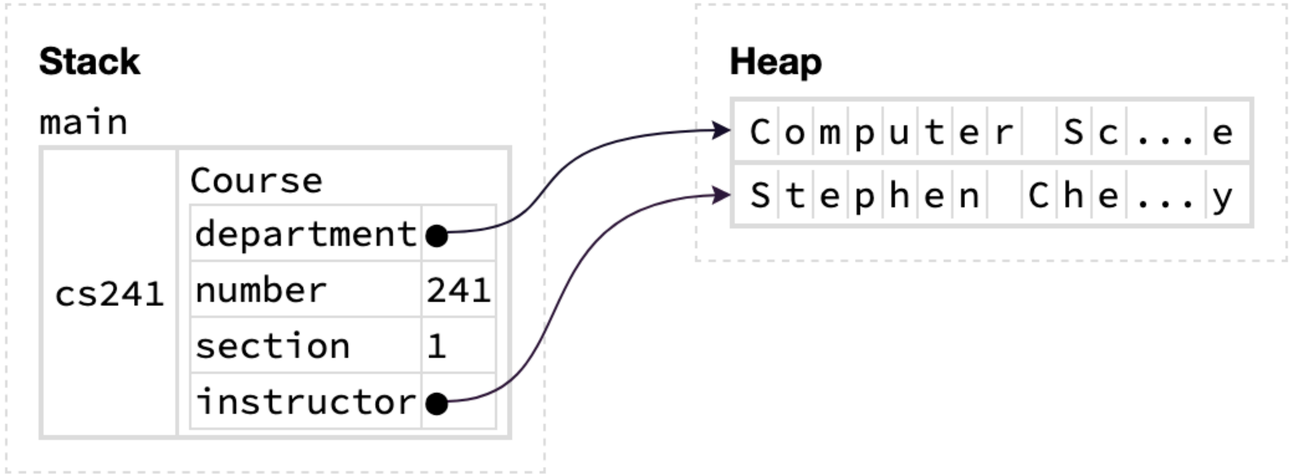


# Accessing members

```
struct Course {
    department: String,
    number: i32,
    section: i32,
    instructor: String,
}

fn main() {
    let cs241 = Course {
        department: String::from("CSCI"),
        number: 241,
        section: 1,
        instructor: String::from("Stephen Checkoway"),
    };
    println!("{} {}", cs241.department, cs241.number);
}
```

# Modifying a member

```
struct Course {
    department: String,
    number: i32,
    section: i32,
    instructor: String,
}

fn main() {
    let mut cs241 = Course {
        department: String::from("CSCI"),
        number: 241,
        section: 1,
        instructor: String::from("Stephen Checkoway"),
    };

    cs241.department = String::from("Computer Science");
}
```




Old department String was dropped (and its contents deallocated)

# Field init shorthand

```
fn new_course(department: &str, number: i32) -> Course {
    Course {
        department: department.to_string(),
        number, // <- No need to write number: number
        section: 1,
        instructor: String::from("Staff"),
    }
}

fn main() {
    let cs241 = new_course("CSCI", 241);
    println!("{} {}", cs241.department, cs241.number);
}
```

You're designing a program for interacting with social media and you want to represent posts using a Post structure you're designing. Each Post needs an account name, contents, and a number of "likes." The account name and contents never change, but the number of likes can. Which structure definition best models this?

```
// A
struct Post {
    account: String,
    contents: String,
    likes: u64,
}
```

```
// B
struct Post {
    account: String,
    contents: String,
    likes: mut u64,
}
```

```
// C
struct Post {
    String account;
    String contents;
    u64 likes;
}
```

```
// D
struct Post {
    account: readonly String,
    contents: readonly String,
    likes: u64,
}
```

# Update syntax

```
fn main() {
    let cs241 = new_course("CSCI", 241);
    let cs241_2 = Course {
        instructor: String::from("Stephen Checkoway"),
        section: 2,
        ..cs241
    };
}
```

Moves all of the remaining fields from cs241 into cs241_2 and drops cs241

# Tuple structs

```
struct Point(i32, i32);

fn main() {
    let p = Point(4, 5);
    println!("{} {}", p.0, p.1);
}
```

Create an new instance by giving the name and field values

Refer to fields using .0, .1, .2, etc., just like tuples

# Printing structs

We cannot print an instance of a struct with println!("{cs241}")

error[E0277]: `Course` doesn't implement `std::fmt::Display`

Display is a **trait** (like an interface in Java) that we can implement for our own types

For arrays and Vecs and Results, we printed the debug representation with println!("{cs241:?}")

error[E0277]: `Course` doesn't implement `Debug`

# Deriving Debug

We can ask Rustc to produce an implementation of the Debug trait for us

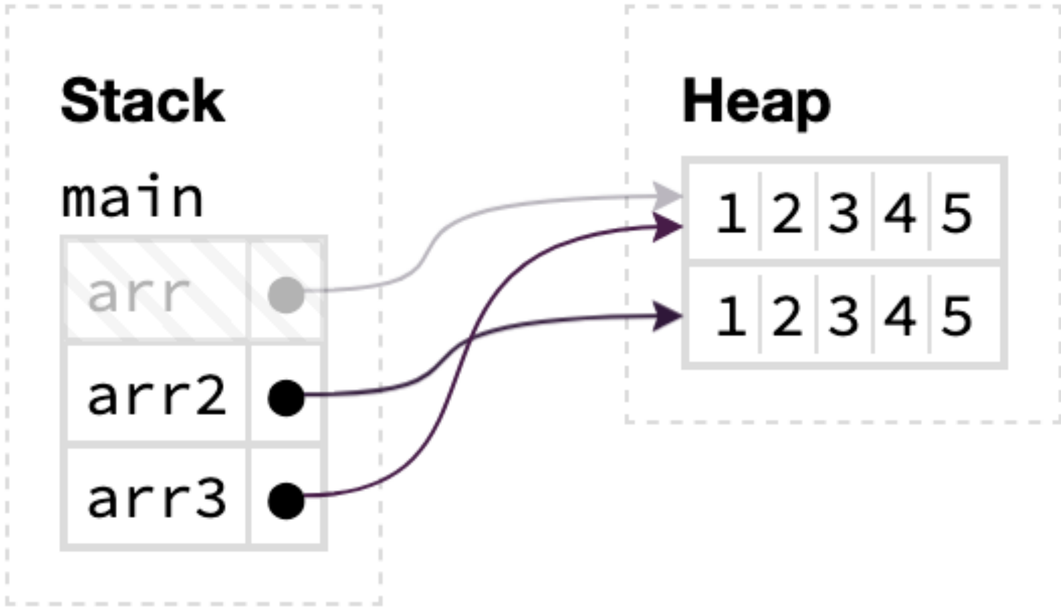
```
#[derive(Debug)]
struct Course { … }

fn main() {
    let cs241 = new_course("CSCI", 241);
    println!("{cs241:?}");
    println!("{cs241:#?}");
}

Output:
Course { department: "CSCI", number: 241, section: 1, instructor: "Staff" }
Course {
    department: "CSCI",
    number: 241,
    section: 1,
    instructor: "Staff",
}
```

# Making copies via clone

The Clone trait has a .clone() method that makes a deep copy of objects

```
fn main() {
    let arr = vec![1, 2, 3, 4, 5];
    let arr2 = arr.clone();
    let arr3 = arr;
}
```

Most types implement Clone



# Deriving Clone

```
#[derive(Debug, Clone)]
struct Course {
    department: String,
    number: i32,
    section: i32,
    instructor: String,
}
```

All of the members' types must implement Clone in order to derive Clone

# Methods

Methods are functions defined for a type that take an instance of the type as the first argument

- Similar to methods in object-oriented languages like Java and Python

The first parameter is always named self and it is explicit (unlike Java and C++'s implicit this parameter)

We've used a bunch of examples of methods already including

- .len() for slices
- .push() for Strings and Vecs
- .push_str() for Strings
- .chars() to get an iterator over characters in a String
- .iter() to get an iterator over a collection (like a Vec)

# Three types of methods

There are three types of methods which are distinguished by the self parameter

- `fn foo(&self) {}` self is a shared reference to the instance
- `fn foo(&mut self) {}` self is a mutable reference to the instance
- `fn foo(self) {}` foo takes ownership of the instance

# Methods taking shared refs

```
impl Course {
    fn name(&self) -> String {
        format!("{} {}", self.department, self.number)
    }

    fn full_name(&self) -> String {
        format!("{} {}-{}", self.department, self.number, self.section)
    }
}

fn main() {
    let cs241 = new_course("CSCI", 241);
    println!("{}", cs241.name());
}
```

# Methods taking mutable refs

```
impl Course {
    fn set_instructor(&mut self, instructor: &str) {
        self.instructor = instructor.to_string();
    }
}

fn main() {
    let mut cs241 = new_course("CSCI", 241);
    cs241.set_instructor("Stephen Checkoway");
    println!("{}", cs241.instructor);
}
```

# Methods taking ownership

Two main use cases

- The type can be copied (like i32, usize, bool)
- The method is returning some lower-level implementation

i32 (and other integer types) have a bunch of methods that take self

- `fn abs(self) -> i32`
- `fn pow(self, exp: u32) -> i32`

Many types have .into_foo() methods that return implementation details

- String has `fn into_bytes(self) -> Vec<u8>`

Getters and setters are methods for getting or setting the value of a field. Imagine we have the following struct with getters and setters for the url field. Which of the three possible self parameters should we use for the url() and set_url() methods?

```
struct Foo {
    url: String,
}

impl Foo {
    fn url(SELF) -> &str { &self.url }
    fn set_url(SELF, url: String) { self.url = url; }
}
```

| | url() | set_url() |
|---|---|---|
| A | `&self` | `&mut self` |
| B | `self` | `mut self` |
| C | `self` | `&self` |
| D | `&mut self` | `&mut self` |
| E | `&self` | `&self` |

# Method calls are syntactic sugar

```
cs241.set_instructor("Stephen Checkoway");
println!("{}", cs241.name);
```

is the same as

```
Course::set_instructor(&mut cs241, "Stephen Checkoway");
println!("{}", Course::name(&cs241));
```

# Associated functions

Functions defined inside impl blocks are called associated functions

Methods are one type of associated functions

We can also have associated functions that don’t take an instance as an argument

- These are typically constructor functions
- Most types have a new() associated function that returns a new instance of the type

Inside the impl block we can refer to the type as Self

# Constructor

```
impl Course {
    fn new(department: &str, number: i32) -> Self {
        Self {
            department: department.to_string(),
            number,
            section: 1,
            instructor: String::from("Staff"),
        }
    }
}

fn main() {
    let cs241 = Course::new("CSCI", 241);
    println!("{}", cs241.name());
}
```

# Examples from the standard library

- String::new() — Creates a new, empty String
- Vec::new() — Creates a new, empty Vec
- Vec::with_capacity(100) — Creates a new, empty Vec with capacity 100
- HashMap::new() — Creates a new, empty HashMap
- BufReader::new(inner) — Creates a new BufReader around some underlying type that implements the Read trait