Programming Paradigms Lecture 4: Names, Scopes, and Bindings

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Winter 2019/2020

Names in PLs

Abstraction in two dimensions

- **From hardware**
  - Variable names abstract away how exactly values are stored
- **From implemented functionality**
  - Function names abstract from the implemented behavior

Binding

- **Association between entities and their names, e.g.,**
  - A variable bound to a memory object
  - A function bound to the code implementing the function
- **Different languages have different rules**
  - E.g., static vs. dynamic binding

Scope

- **Scope of a binding**: Textual region where binding is active
- **Scope**: Maximal region where no bindings change

Example (Python):

```
x = 1
def f():
    x = 2
    y = x
```

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Outer scope

Scope of function

Overview

- Object lifetime and storage management
- Scopes
- Aliasing and overloading
- Binding of referencing environments

Object Lifetime

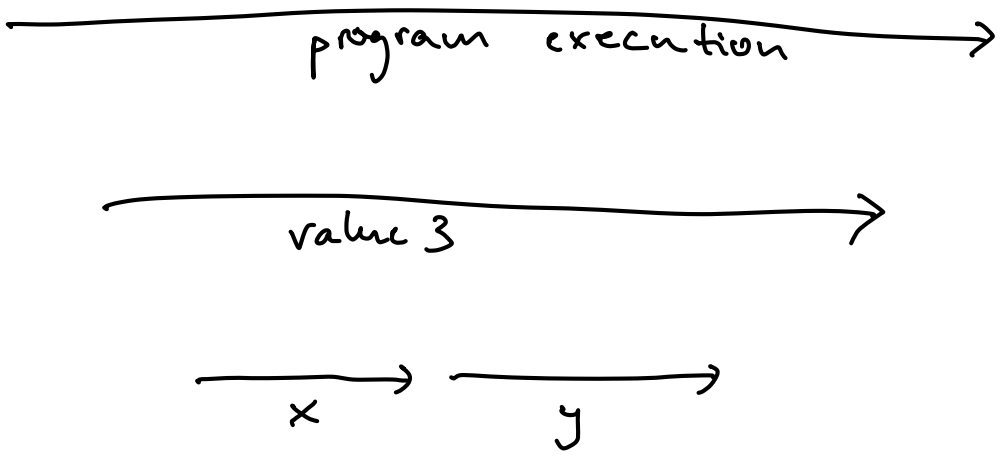
Every memory object has a lifetime

- Global variables: Entire program execution
- Local variables: Function execution

Object lifetime vs. binding lifetime

- A single object may be bound to multiple names
- Bindings may be concurrent

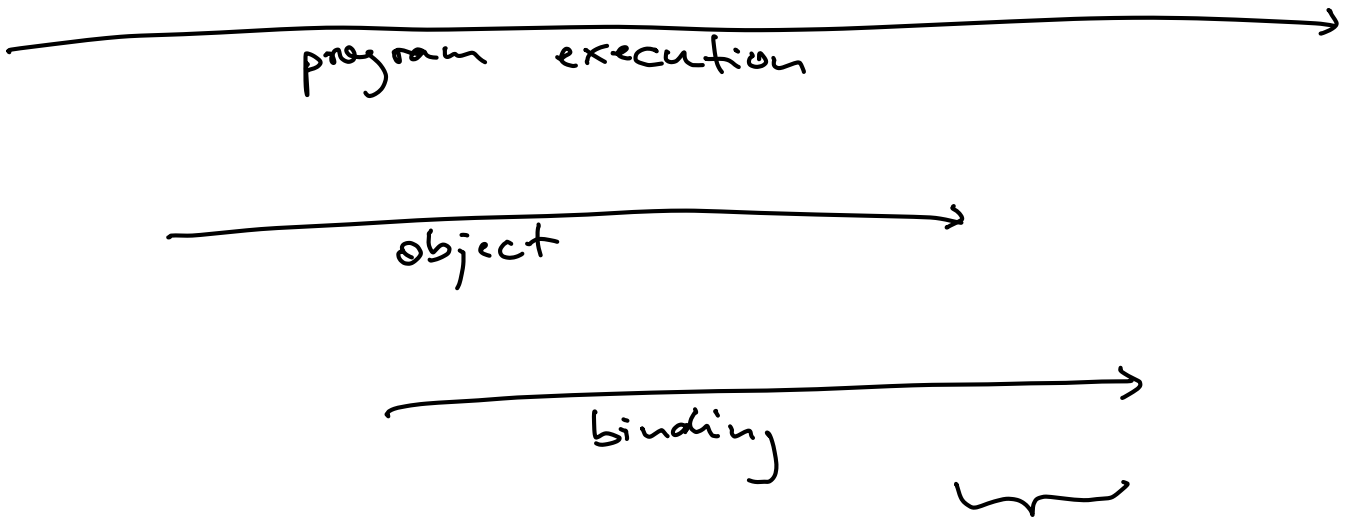
Example 1




```
fun f() {
    x = 3
    return x
}

y = f()
```

Example 2:



usually a bug ("dangling reference")

↳ use-after-free attack in C

Storage Allocation

Three kinds of memory objects

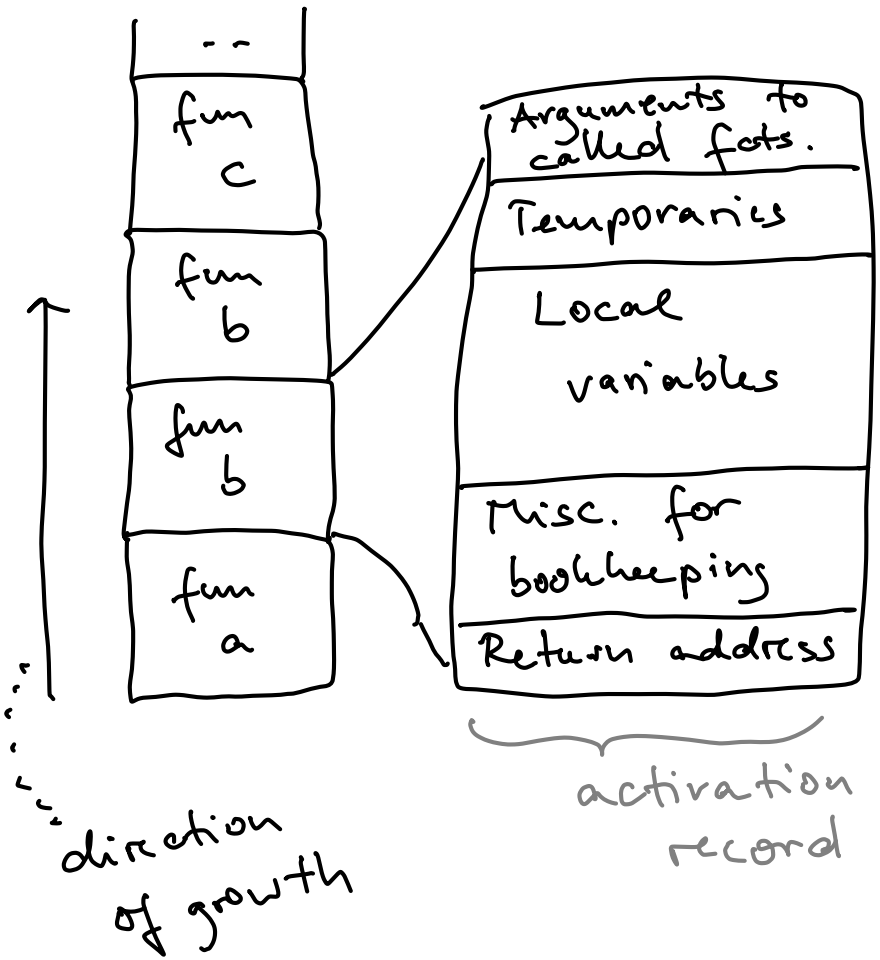
- Static
  - Absolute address retained throughout execution
- Stack
  - Usually within subroutines
  - Allocation/deallocation on call/return
- Heap
  - Allocation and deallocation at arbitrary times

Statically Allocated Memory

Depending on the PL, used, e.g., for

- Global variables
- Constant literals
- Symbol tables
- Program code itself
- Compile-time constants
  - Even if local to function

Stack-based Allocation




```
fun c() {
    ...
}
fun b(...) {
    if ...
        b()
    else
        c()
}
fun a() {
    b()
}
// main
a()
```

Heap-based Allocation

- **For dynamically allocated data structures and objects whose size is statically unknown**
  - E.g., objects in Java
- **Some PLs: Managed memory**
  - Unreachable objects: Implicitly deallocated
    - Unreachable = No active binding
  - Less control but fewer bugs
    - E.g., no use-after-free

Quiz: Memory Allocation

Where are the following data objects stored (Java)?

- The integer 23
- The string `"John"`
- The `Person` object
- The reference variable `p`

```
class Person {
    int pid;
    String name;

    // constructor
}

public class Driver {
    public static void main(String[] args) {
        int id = 23;
        String pName = "John";
        Person p = null;
        p = new Person(id, pName);
    }
}
```

https://ilias3.uni-stuttgart.de/vote/0ZT9

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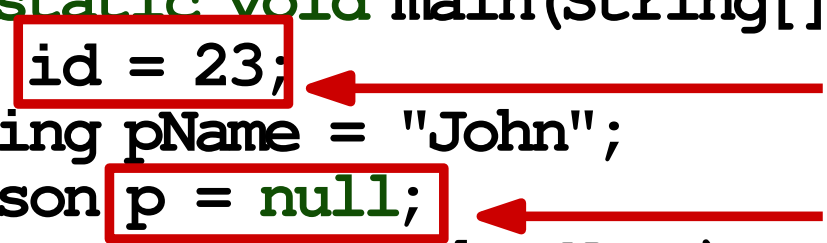

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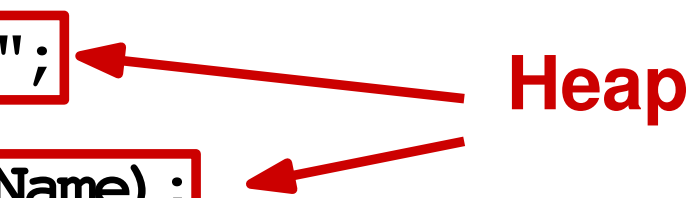

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