Runtime Environments I

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* Course website: https://www.cs.columbia.edu/ rgu/courses/4115/spring2019

** These slides are borrowed from Prof. Edwards.

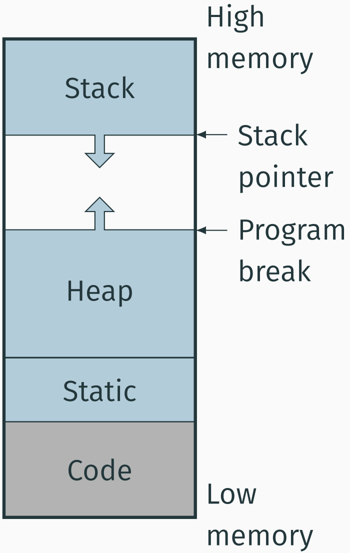
Storage Classes

Storage Classes and Memory Layout

Stack: objects created/destroyed in last-in, first-out order

Heap: objects created/destroyed in any order; automatic garbage collection optional

Static: objects allocated at compile time; persist throughout run



Static Objects

```
class Example {
  public static final int a = 3;

  public void hello() {
    System.out.println("Hello");
  }
}
```

Examples

Static class variable

String constant “Hello”

Information about the Example class

Advantages

Zero-cost memory management

Often faster access (address a constant)

No out-of-memory danger

Disadvantages

Size and number must be known beforehand

Wasteful

The Stack and Activation Records

Stack-Allocated Objects

Idea: some objects persist from when a procedure is called to when it returns.

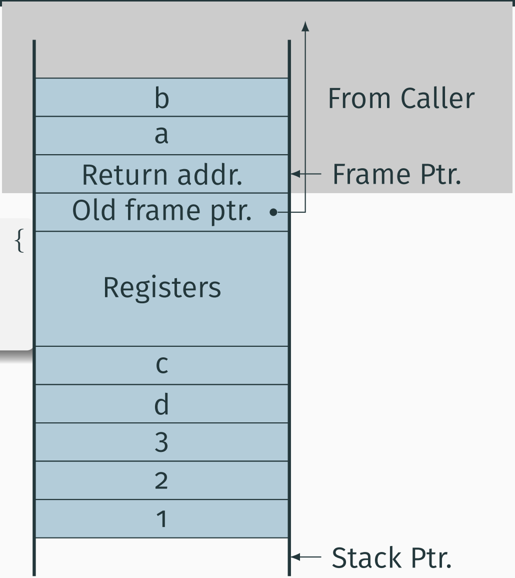
Naturally implemented with a stack: linear array of memory that grows and shrinks at only one boundary.

Natural for supporting recursion.

Each invocation of a procedure gets its own *frame* (*activation record*) where it stores its own local variables and bookkeeping information.

An Activation Record: The State Before Calling *bar*

```
int foo(int a, int b) {
  int c, d;
  bar(1, 2, 3);
}
```



Recursive Fibonacci

(Real C)

```
int fib(int n) {

  if (n<2)

    return 1;
  else
    return
        fib(n-1)
        +
        fib(n-2);

}
```

(Assembly-like C)

```
int fib(int n) {
    int tmp1, tmp2, tmp3;
    tmp1 = n < 2;
    if (!tmp1) goto L1;
    return 1;
L1: tmp1 = n - 1;
    tmp2 = fib(tmp1);
L2: tmp1 = n - 2;
    tmp3 = fib(tmp1);
L3: tmp1 = tmp2 + tmp3;
    return tmp1;
}
```

```
            fib(3)
           /      \
      fib(2)      fib(1)
     /      \
fib(1)      fib(0)
```

Executing fib(3)


```
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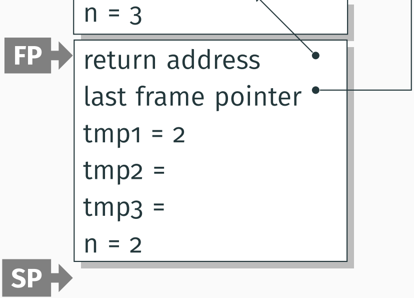

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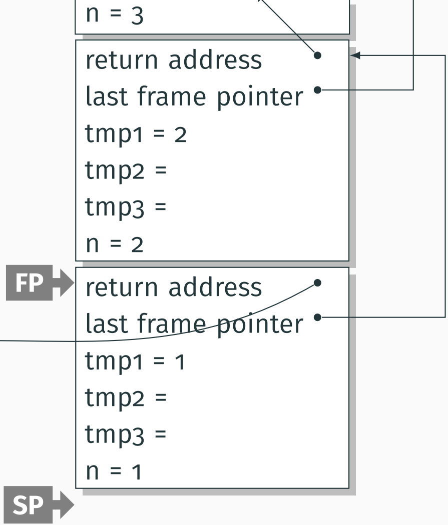

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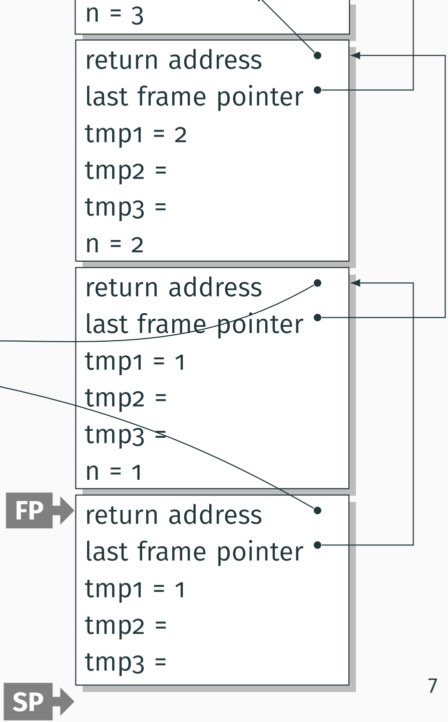

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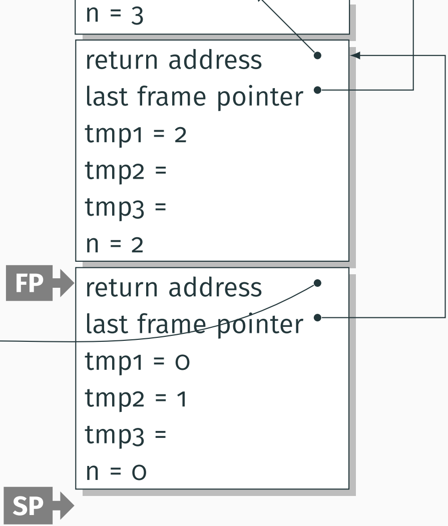

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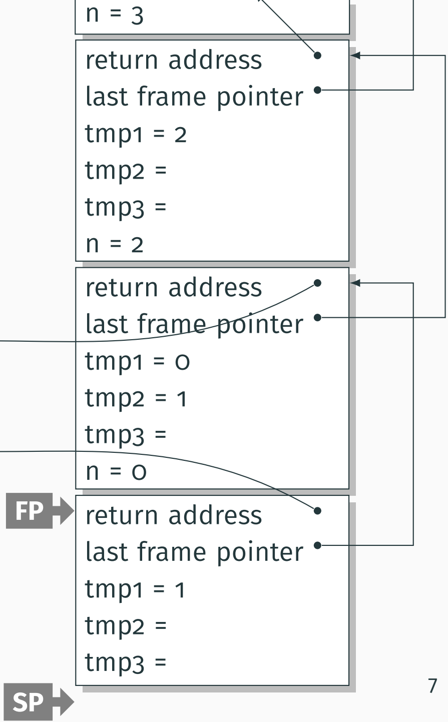

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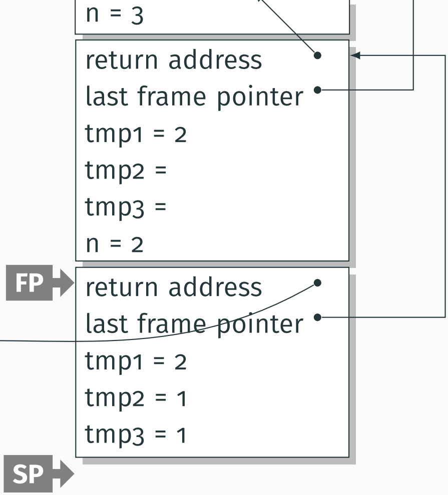

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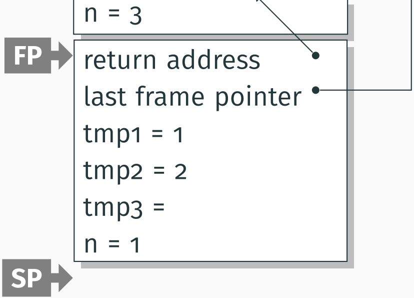

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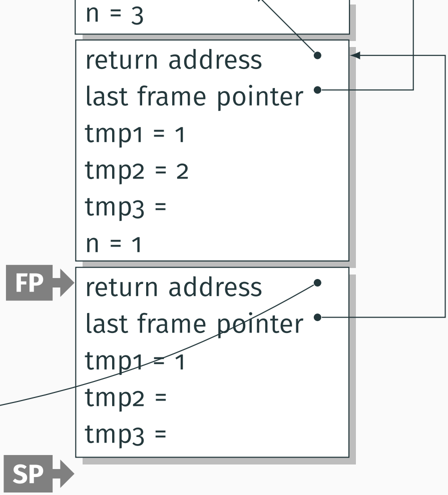

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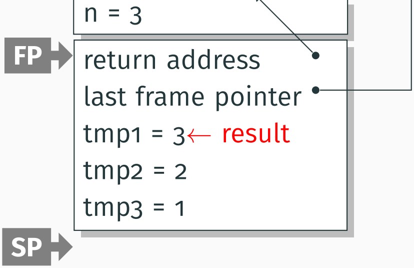
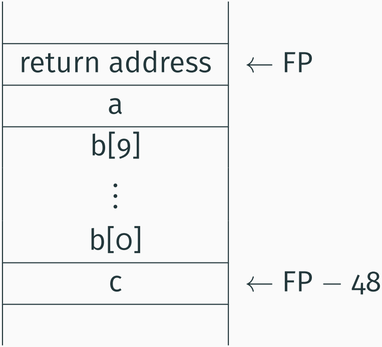


Allocating Fixed-Size Arrays

Local arrays with fixed size are easy to stack.

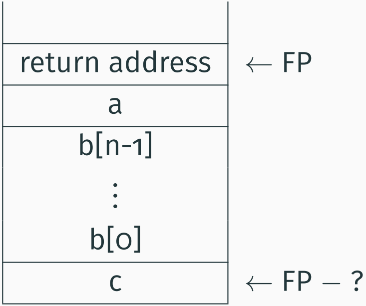
```
void foo()
{
  int a;
  int b[10];
  int c;
}
```



Allocating Variable-Sized Arrays

Variable-sized local arrays aren't as easy.

```
void foo(int n)
{
  int a;
  int b[n];
  int c;
}
```

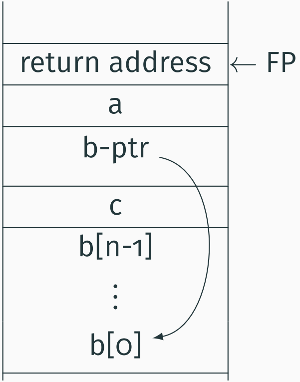


Doesn't work: generated code expects a fixed offset for c. Even worse for multi-dimensional arrays.

Allocating Variable-Sized Arrays

As always:
add a level of indirection

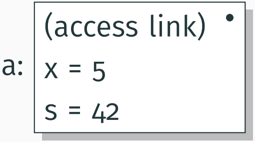
```
void foo(int n)
{
  int a;
  int b[n];
  int c;
}
```



Variables remain constant offset from frame pointer.

Implementing Nested Functions with Access Links

```
let a x s =
  let b y =
    let c z = z + s in
    let d w = c (w+1) in
    d (y+1) in (* b *)
  let e q = b (q+1) in
e (x+1) (* a *)
```



What does “a 5 42” give?

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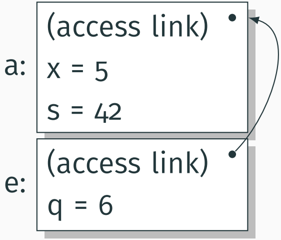

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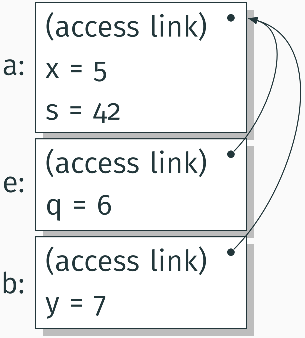

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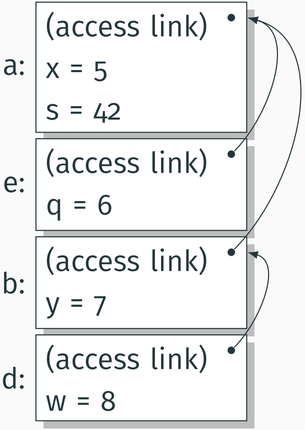

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