Storage allocation

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Programming Language Concepts

Lecture 8, 01 February 2024

Variables, functions and storage

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- Scope and lifetime of variables

Scope

- Consider the following program block

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{
  int x = 2;
  int y = 4;
  {
    int y = 3;
    x = x+2; y = x+y;
    print(x,y);
  }
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Updated y value is not propagated outside
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Outer y value and updated x value
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- Scope of `howManyAs` is limited to the class `A`

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- Activation record — collection of all data related to a function invocation
- Includes space for local variables, parameters, intermediate results, and some pointers
- Also called a stack frame — the reason will be clear later

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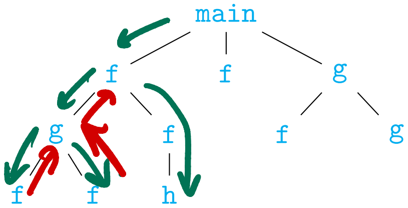

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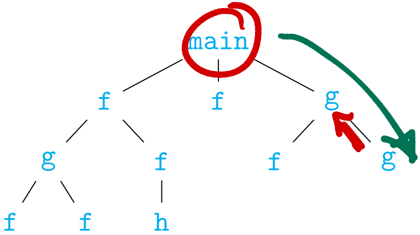

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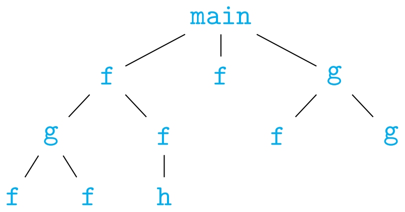

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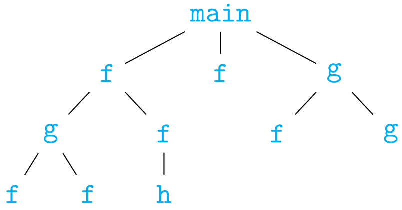
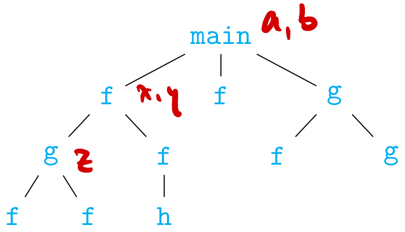


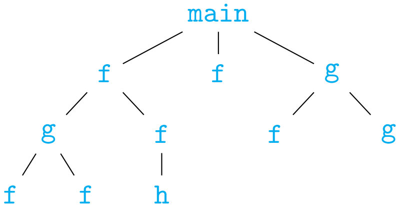
- The set of active function calls at any point of time lies on the path from the root to the right most leaf
- If `f` calls `g`, then `g` is completed before `f`
- Store the activation records on a stack

Activation records on stack



- Assume that `main` has local variables `a` and `b`, `f` has `x` and `y`, and `g` has `z`

Activation records on stack



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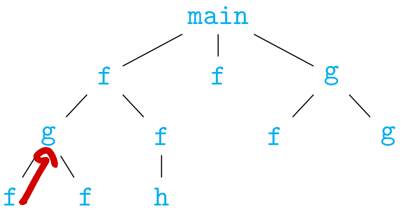

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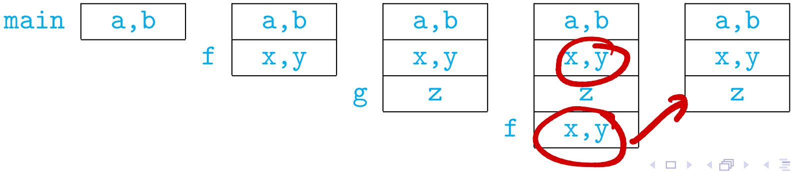
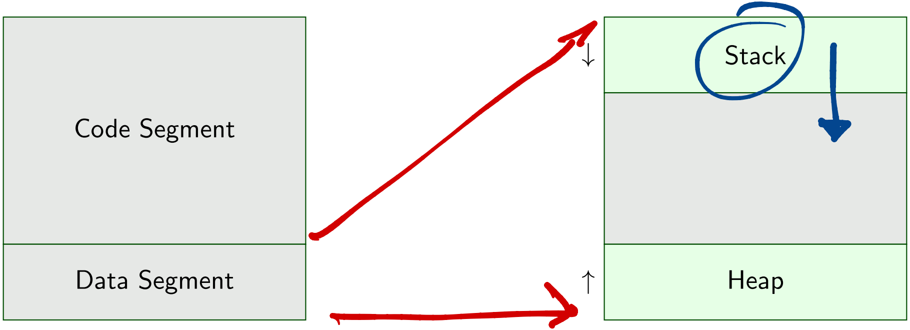
- The stack evolves as follows:



General layout of a program in memory



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- Various pointers — Control link, access link, return address

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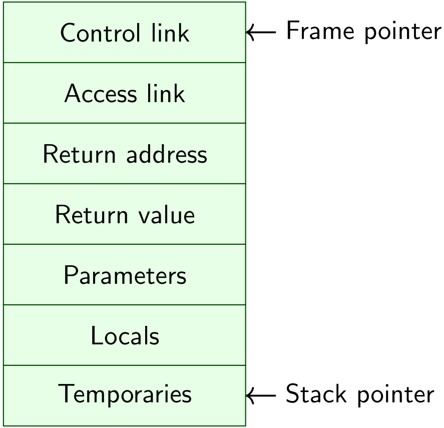
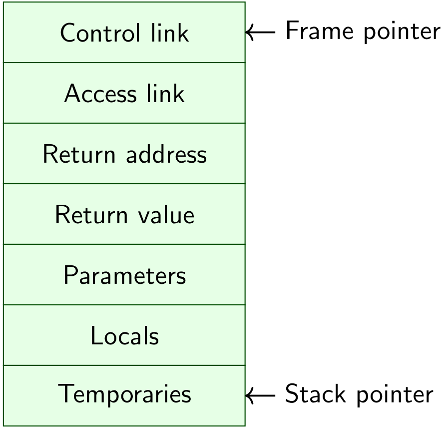
- Stores parameters, local variables, temporary variables used in running the function
- Various pointers — Control link, access link, return address
- System-wide pointers
  - Program counter — address of the next instruction to execute
  - Stack pointer — points to the top of the system stack
  - Frame pointer — points to the start of the topmost frame on stack
  - Data in topmost frame accessed via offsets from the frame pointer or stack pointer — offsets can computed at compile time

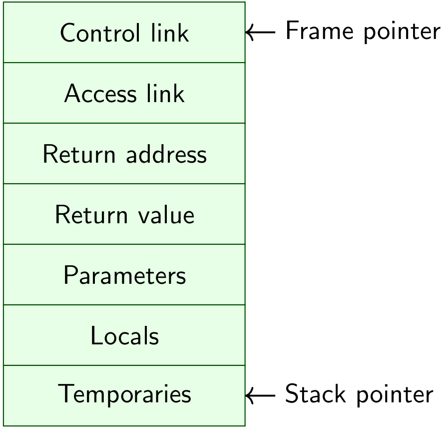
relative addressing

Activation record . . .





- Control link points to activation record of caller



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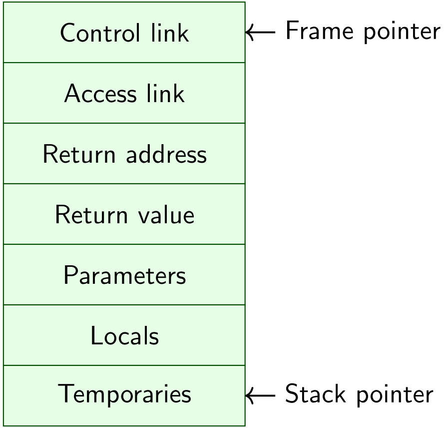

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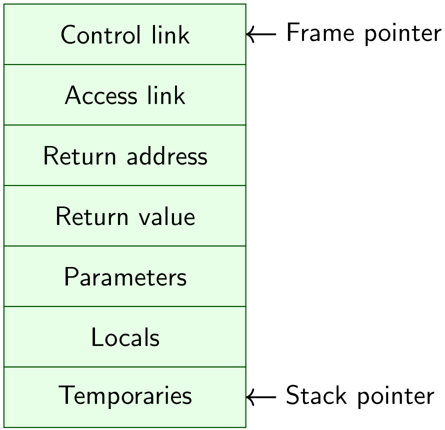

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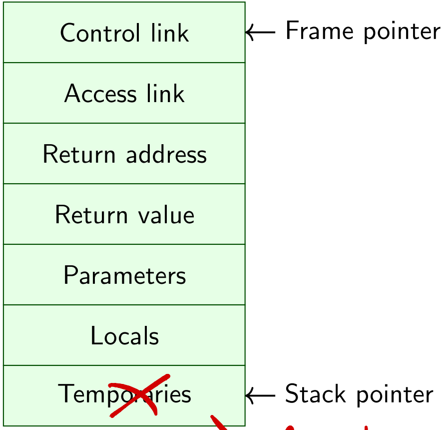
Activation record ...



Compiler creates to avoid recomputing

- Control link points to activation record of caller
- Access link is for non-local variable access
- Return address is the address of first instruction to execute after the function call returns
- Return value stores the return value, which should be picked up by the caller
- Temporaries are locations to store intermediate values in

Access links

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func f {
    int x = 0;
    int fib(int n) {
        if n <= 1 then return n;
        else {
            x += 1;
            return fib(n-1) + fib(n-2);
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    }
    print(fib(4));
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- But `fib(3)` is called by `fib(4)`, so control link cannot be used to access `x`

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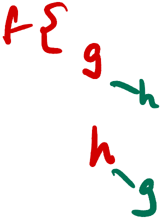

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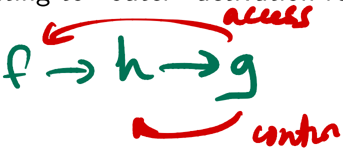
- Need a new kind of link — access link pointing to “outer” activation record



Dynamic allocation

```
class A {
    int x, y, z;
    A(x,y,z) {
        this.x = x; ...
    }
    public int f(int n) {
        int arr[n]; ...
    }
}
main {
    A aObj(2,5,7);
    aObj.f(100); ...
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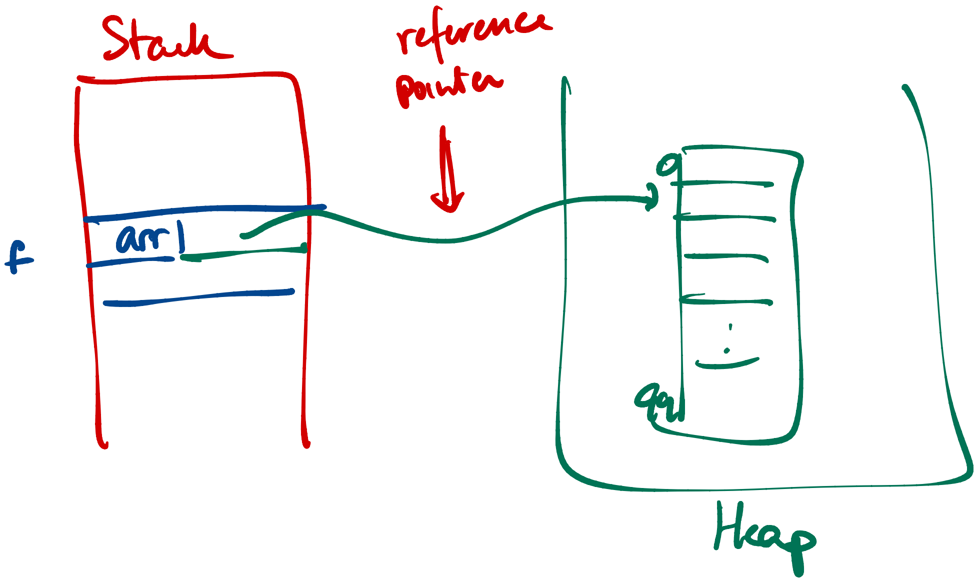
Stack
reference
pointer
f
arr1
0
99
Heap

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- The AR for `f` has a pointer to an array stored on heap

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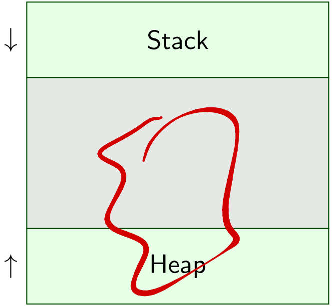

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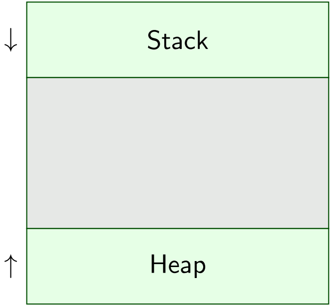
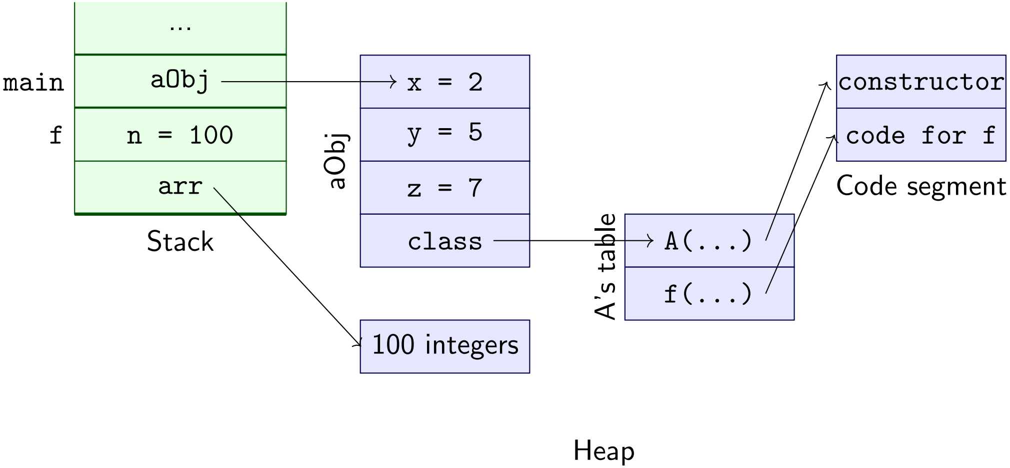
- Consist of chunks of allocated and unallocated memory




...
main
aObj
f
n = 100
arr
Stack
aObj
x = 2
y = 5
z = 7
class
100 integers
A's table
A(...)
f(...)
constructor
code for f
Code segment
Heap

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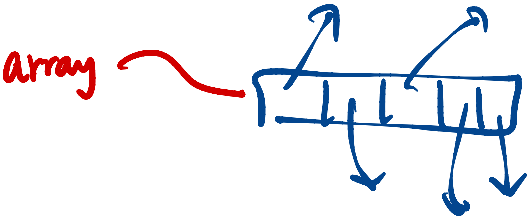

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- Consider an array of `Shape`, each element being an instance of a subclass
- Elements of the array are pointers to objects
- The object data has a pointer to the precise subclass it is an instance of!
- Calling `perimeter` on each element of the array runs the code pointed to by the appropriate subclass table

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- This is called garbage – waste of memory

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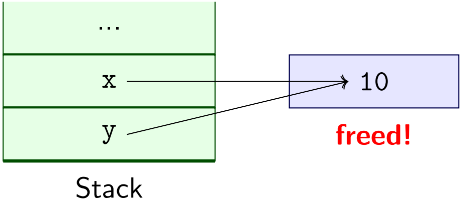
- Can cause the problem of dangling pointers – pointers to deallocated variables

```
int *x = malloc(sizeof(int));
*x = 10;
y = x;
free(x);
```



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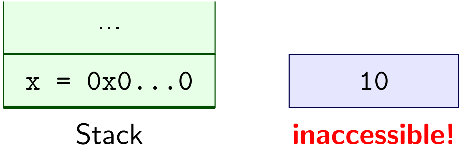
```
int *x = malloc(sizeof(int));
*x = 10;
x = NULL;
```



x = y for references
- copies address