Programming Software Systems

Introduction to Programming for the Computer Engineering Track

Tutorial 2

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Fall Semester 2020
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Static vs Dynamic

Static typing

C, C++, Java, Scala, C#, Eiffel, …

- ☹ Requires more efforts while writing a program: need to explicitly specify object types.
- ☺ **The program is (much) more safe**: many bugs are detected before running (in compile time).
- ☺ The program is more readable; it's easier to read, understand and maintain it.

```
int x;
...
x = 7; // OK
...
x = "string"; // error
```

The binding between the variable and its type is **hard**: x can take any value but the type of the value must be always the same.

Dynamic typing

Javascript, Python, Ruby, …

- ☺ It's much easier to write a program: no need to take care about object types.
- ☺ The program is more flexible: no need to introduce different objects for different purposes.
- ☹ The program often looks cryptic; it's required much more efforts to understand and maintain them.
- ☹ **Programs are unsafe and inefficient** .

The binding between the variable and its type is **soft**: x can hold any value of any type.

```
x = 7;          // OK
...
x = "string"; // OK!
...
y = x + 7;      // OK!
```

Static vs Dynamic: Pros & Cons

Why dynamic programs are less safe?

```
a * b
```

Static vs Dynamic: Pros & Cons

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```
a * b
```

A static language:
the compiler checks types of a and b and concludes (before programs starts) whether multiplication operator is valid for those types.

If types are inappropriate compiler reports a diagnostic message, and the bug can be fixed before launching the program.

Static vs Dynamic: Pros & Cons

Why dynamic programs are less safe?

```
a * b
```

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the compiler checks types of a and b and concludes (before programs starts) whether multiplication operator is valid for those types.

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A dynamic language:
the compiler knows nothing about types of a and b therefore it cannot judge whether this code is valid of not.

Typically, compiler trusts programmer and considers the code valid.

For some values of a and b the code could be really valid, but for other could be erroneous.

The bug can occur only while program is running and sometimes after long time after it is written...

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Why dynamic programs are less efficient?

```
a * b
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Static vs Dynamic: Pros & Cons

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A static language:
the compiler knows for sure that a and b both have integer type.
So, it generates the compact and fast code:

```
•   Load integers a & b to the stack
•   Perform integer multiplication
•   Remove operands from the stack
    and put the result to the stack
```

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- Load integers a & b to the stack
- Perform integer multiplication
- Remove operands from the stack and put the result to the stack

A dynamic language:
the compiler knows nothing about types of a and b therefore it should generate code for **all possible cases**:

```
if a, b are integers:
  Perform integer multiplication
else if a, b are strings:
  Perform string concatenation
else if a is string, b is integer:
  Create repetition like a+a+a
else if a is integer, b is string:
  Convert a to string
  Perform string concatenation
else ...
```

Types & Memory

- Each object is of some type - *obvious*
- Each object (value) occupies some amount of memory – *trivial*

=> What's the **size** of memory for (values of) various types?

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Different approaches are taken in programming languages

Java

All type sizes are defined in the language reference explicitly

(for example, type `int` occupies 32 bits)

C

- (A value of) `char` type occupies exactly one byte
- Other type sizes depend on underlying hardware (RAM/CPU)

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C

```
int si = sizeof (int);
int se = sizeof a+b;
```

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=> What's the **size** of memory for (values of) various types?

C

sizeof is a unary operator

```
int si = sizeof (int);
int se = sizeof a+b;
```

- sizeof returns the amount of memory <u>in bytes</u>
- sizeof applies to any expression or to any type
- sizeof is a compile time construct

Different approaches are taken in programming languages

Java

All type sizes are defined in the language reference <u>explicitly</u>
(for example, type int occupies 32 bits)

C

- (A value of) char type occupies exactly <u>one byte</u>
- Other type sizes <u>depend on underlying hardware</u> (RAM/CPU)

C Derived ("User-Defined") Types

Some tricks & flaws with C types and declarations

```
struct S {
   int a, b;
};
```

Usual declaration of a structure type…

We can use it like as follows: `struct S s;`

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struct S {
    int a, b;
} s1, s2;
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The structure type declaration **together** with variable declaration!

We can still use `S` in declarations: `struct S s3;`

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Unnamed structure type declaration **together** with variable declaration.

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```
struct {
    int a, b;
} s1, s2;
```

Unnamed structure type declaration **together** with variable declaration.

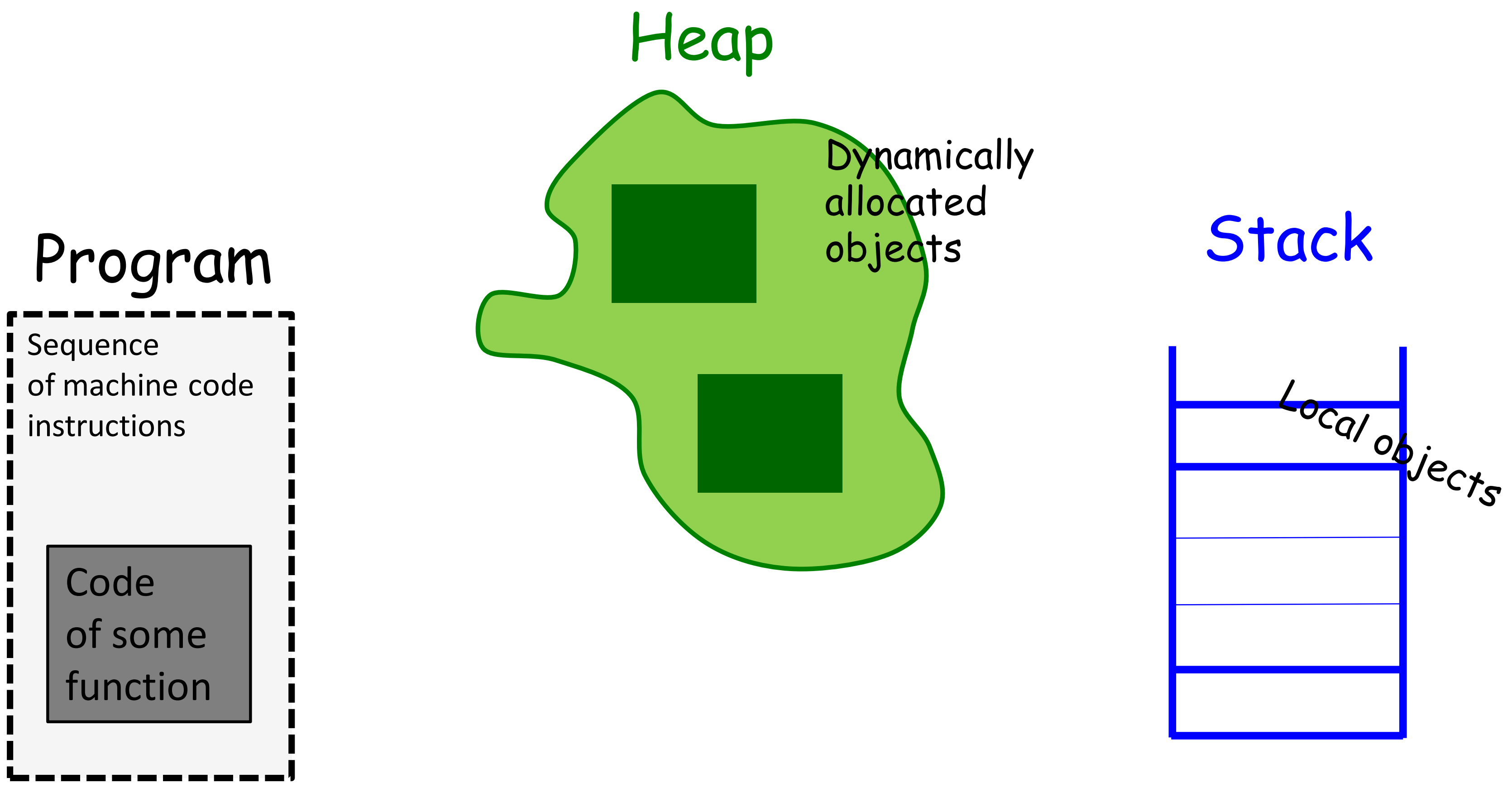
```
typedef struct {
    int a, b;
} S;
```

Here, we introduce a **synonym** to the unnamed structure type.

Later, we can use the synonym:

`S s1, s2;`

Pointers & The C Memory Model



Program cannot modify this memory (self-modified programs are not allowed)

The discipline of using heap is defined by program **dynamic semantics**, i.e., at runtime (while program execution)

The discipline of using stack is defined by the (static) **program structure**

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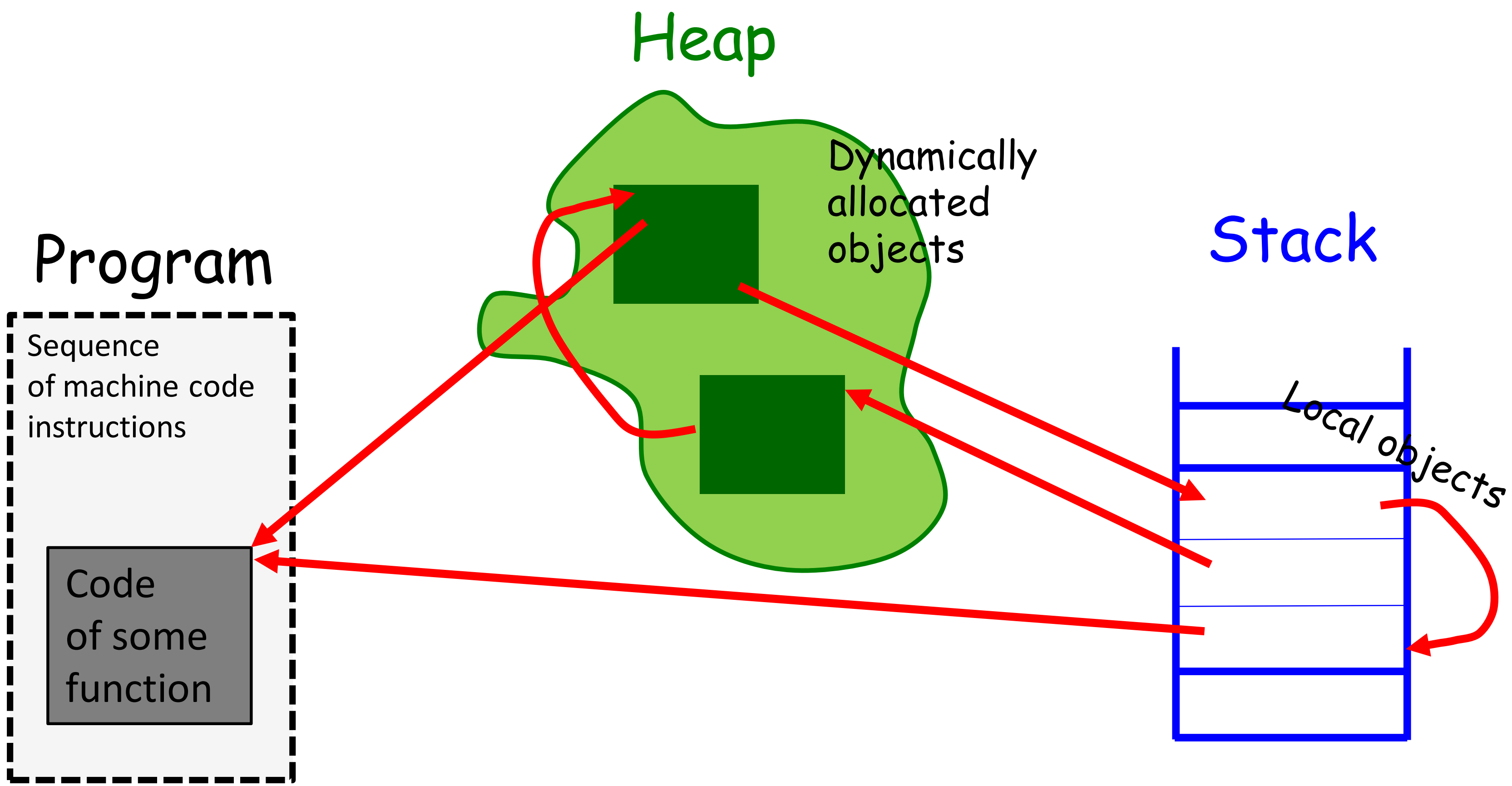

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Problems with C pointers

Example: pointers & scopes

```
int* p;

void f() {
    int A[10];
    p = A+2;
}

void main() {
    f();
    *p = 777;
}
```

p is the **global object**; it's created on the program's start and exist until its end

A is the **local object**; it's created on the f's start and exists **until exit from** f

What the hell will happen here?!

Problems with C pointers

Execution Stack

```
int* p;
void f() {          2
    int A[10];
    p = A+2;        3
}
void main() {       1
    f();
    *p = 777;       4
}
```

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}
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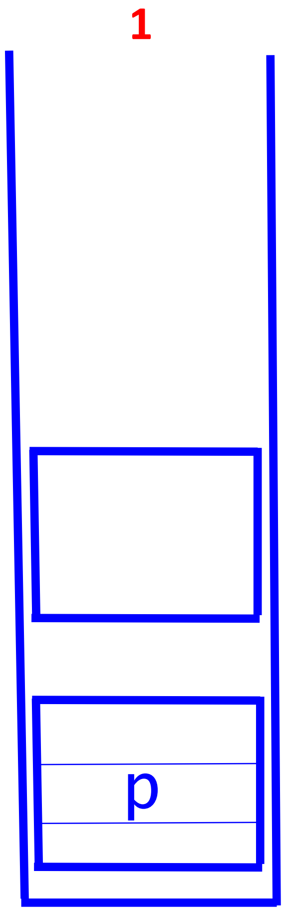
}
```

2
3
1
4

Execution Stack



Stackframe for global variables

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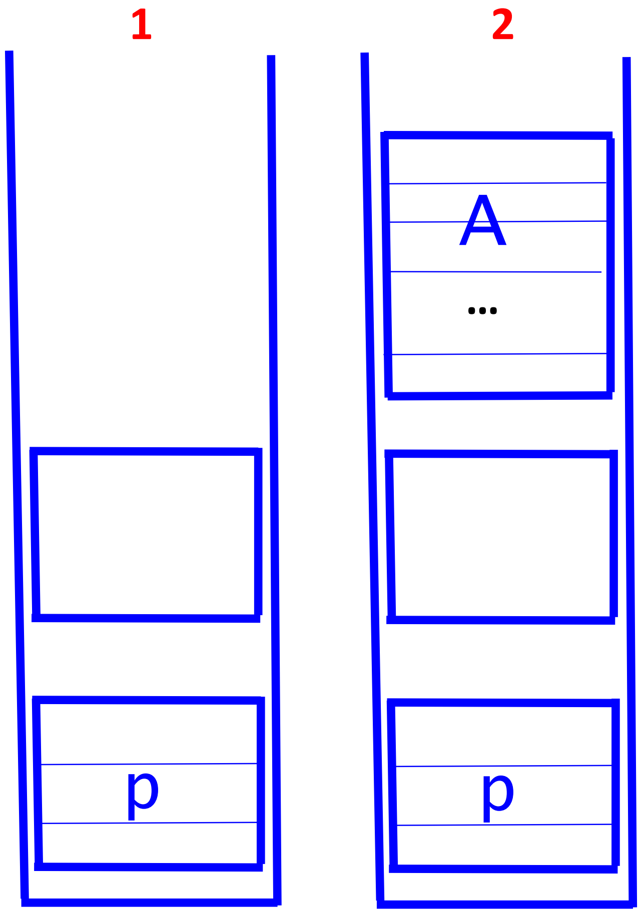
Execution Stack



Stackframe for the call to f

Stackframe for the call to main

Stackframe for global variables

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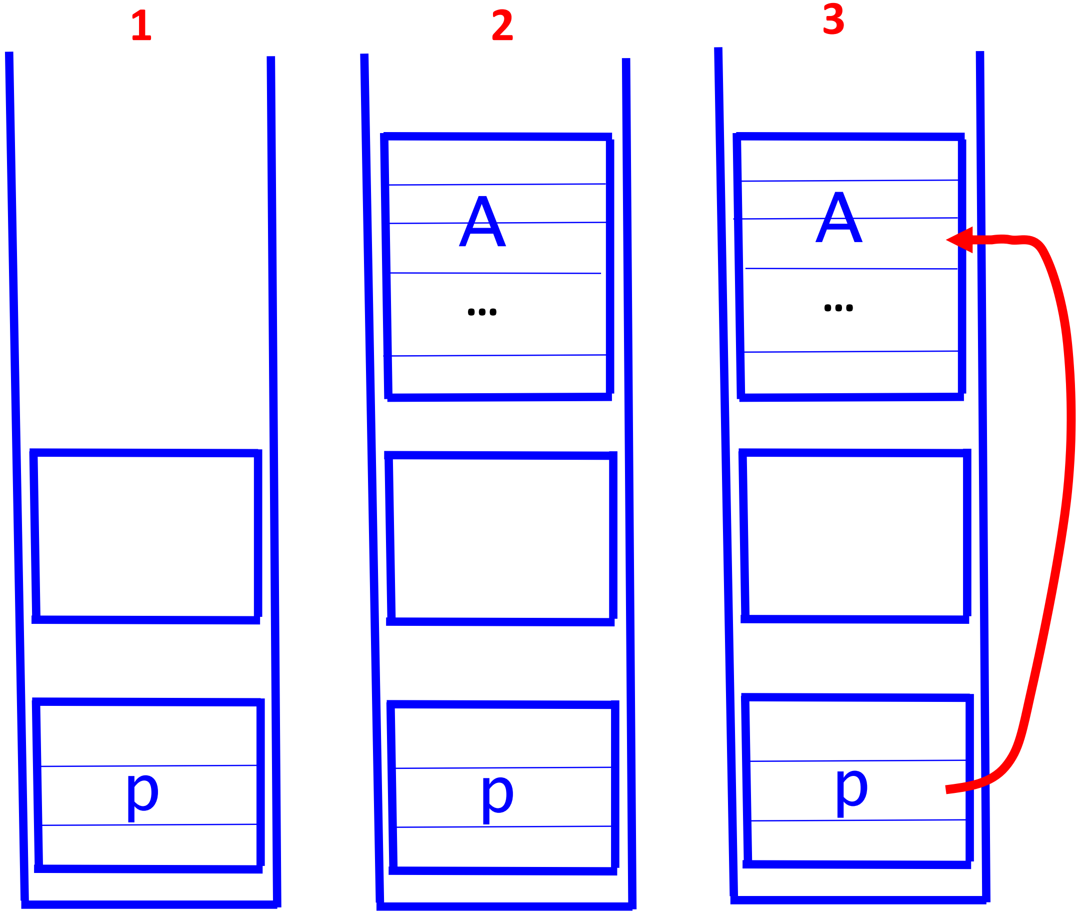

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}
void main() {
    f();
    *p = 777;
}
```

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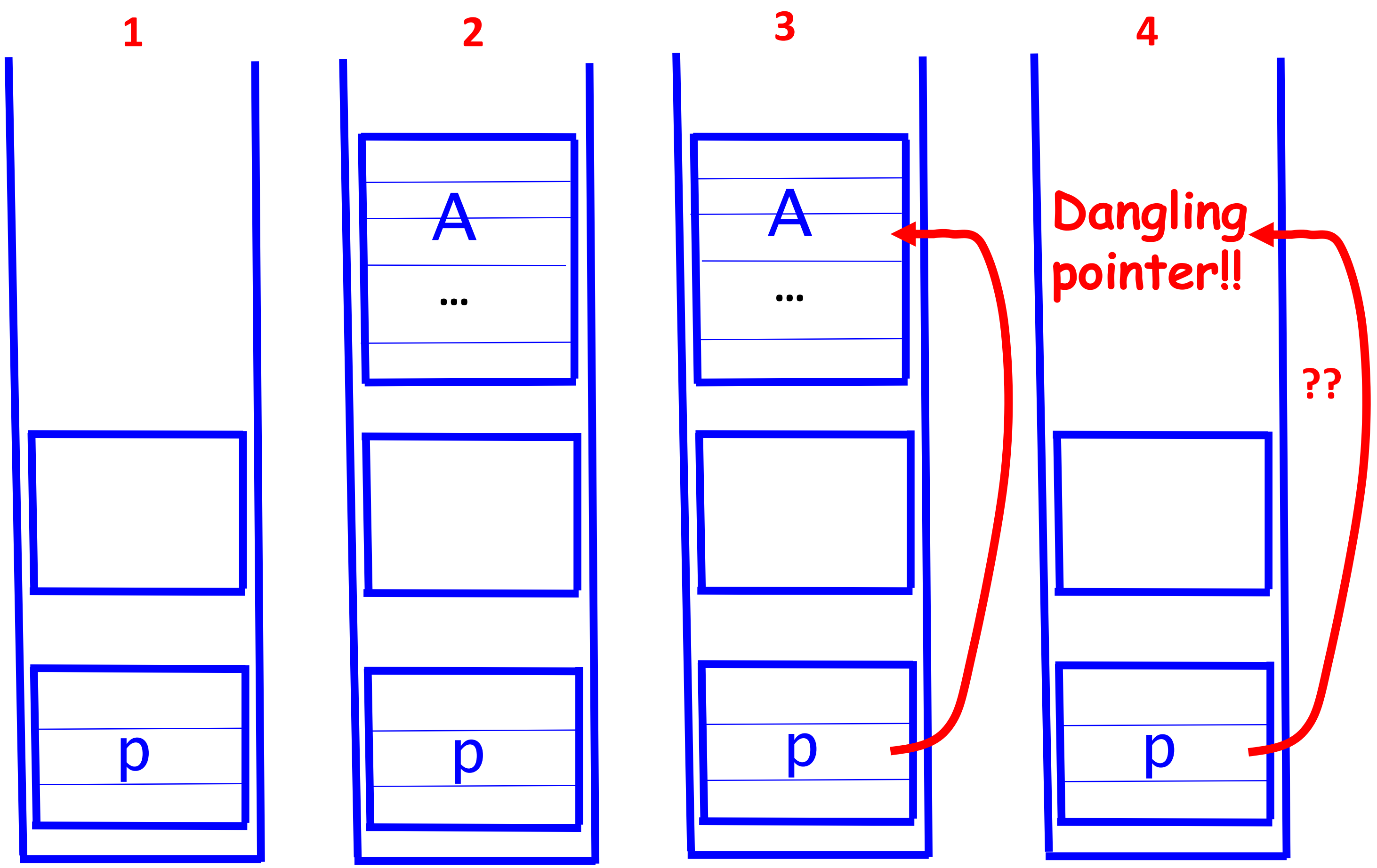

Stackframe for the call to f

Stackframe for the call to main

Stackframe for global variables

Problems with C pointers

Example: dynamic objects, pointers & scopes

```
void f() {
    int* p = (int*)malloc(10);
}

void main() {
    f();
    ...
}
```

p is the **local object**; it lives only within the f function

The unnamed object created by malloc() is **dynamic object**; it doesn't follow the scoping rules!

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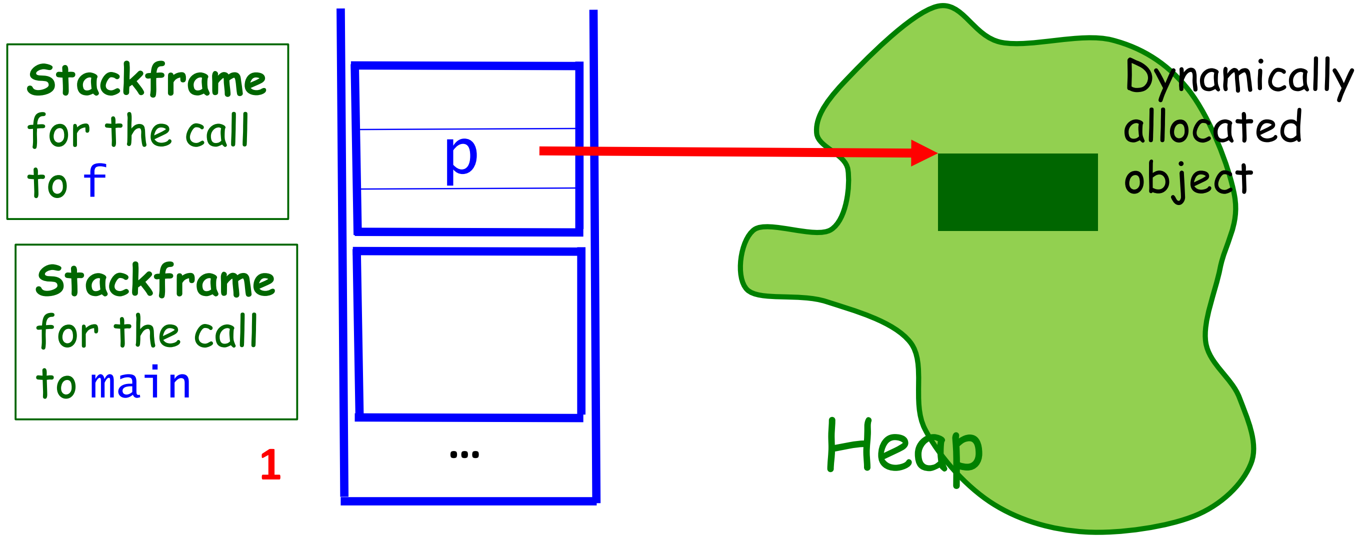

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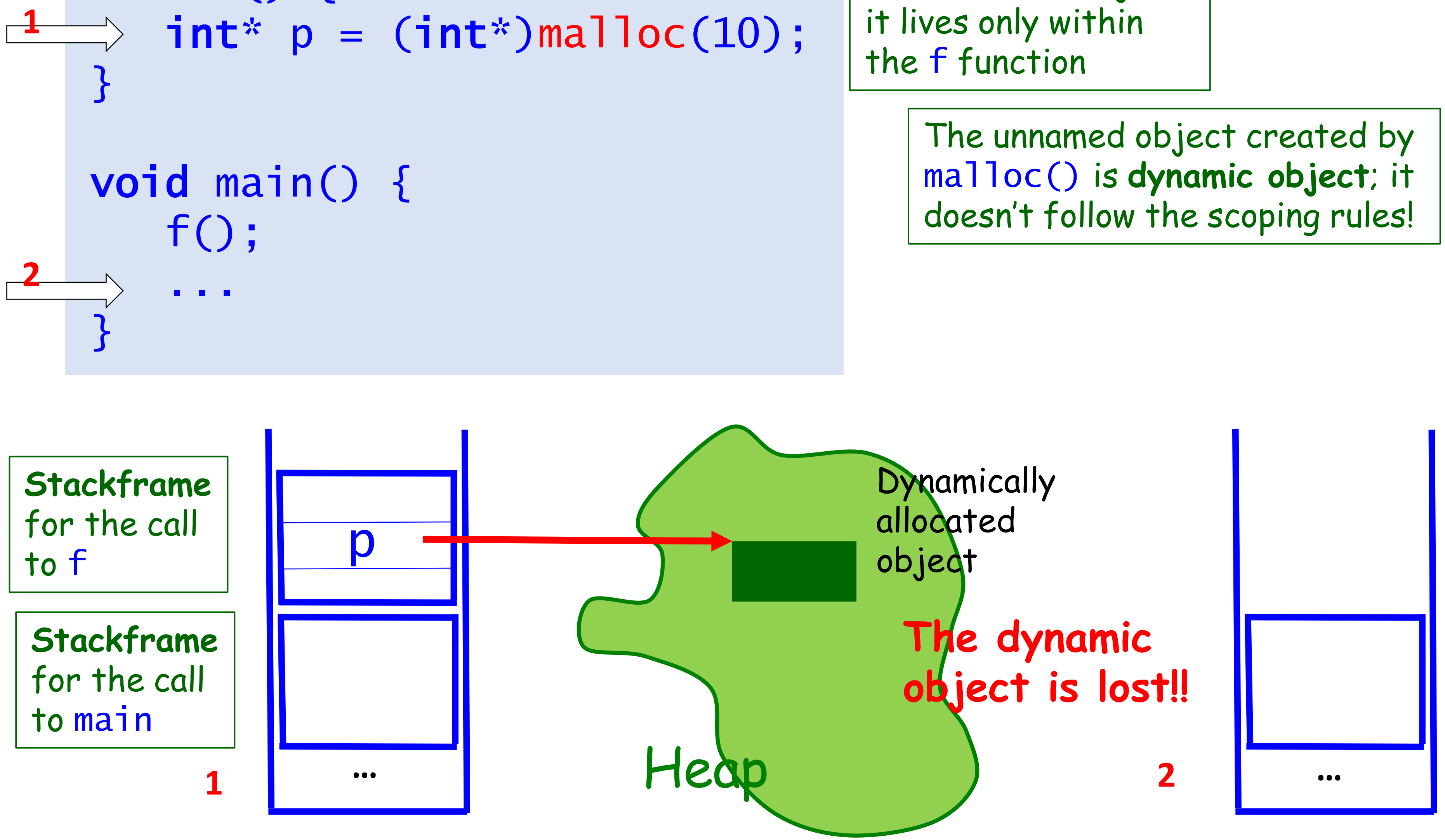


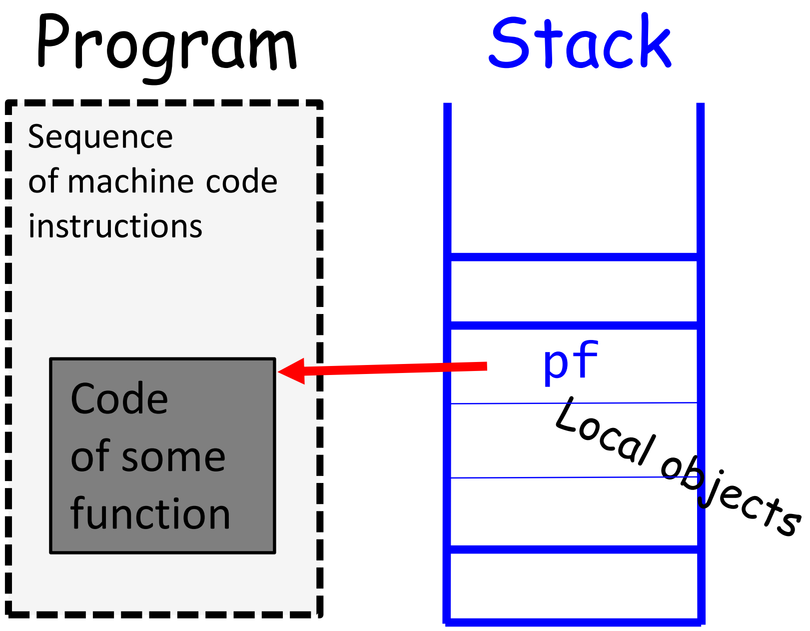
Pointers to Functions

```
void f(int p)
{
    ...
}
...

...
void main()
{
    f(1);  // call to f

}
```

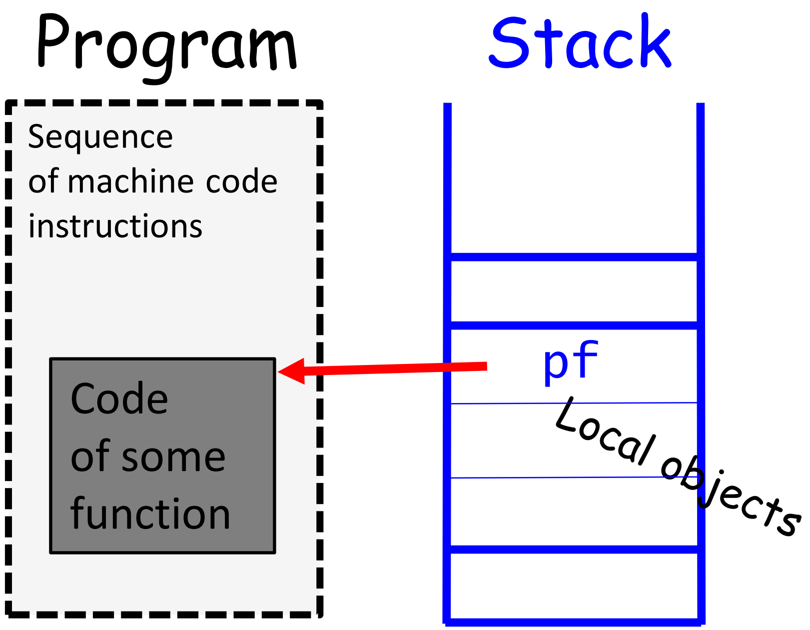
Pointers to Functions




```
void f(int p)
{
    ...
}
...
void (*pf)(int) = &f;
...
void main()
{
    f(1);  // call to f

}
```

Pointers to Functions




```
void f(int p)
{
    ...
}
...
void (*pf)(int) = &f;
...
void main()
{
    f(1);  // call to f
    pf(1); // call to f!
}
```

Automatic & static objects

```
void f() {
    int x = 0;
    ...
    x += 1;
    printf("%d", x);
}

void main() {
    for(int i=1; i<=100; i++)
        f();
}
```

x is the **local object**
- it “belongs” to the f function;
- it is **available** only from within the f function;
- it is created and gets initialized ***each time*** the f function is invoked

The loop prints the same value 1 on each iteration.

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The loop prints the same value 1 on each iteration.

The x variable is often called as **automatic local variable.**

```
...
auto int x = 0;
...
```

Automatic & static objects

```
void f() {
    static int x = 0;
    ...
    x += 1;
    printf("%d", x);
}

void main() {
    for(int i=1; i<=100; i++)
        f();
}
```

x is still the **local object**
- it "belongs" to the f function;
- it is **available** only from within the f function;
- it is created and gets initialized **only once**: before the very first call to the function it belongs to.

The loop prints values 1,2,3,… on each iteration.

Automatic & static objects

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The x variable is often called as **static local variable.**

Algol-60:
Own variables

Automatic & static objects

Example: Fibonacci numbers

Fib(0) = 0
Fib(1) = 1
Fib(n) = Fib(n-2) + Fib(n-1)

Automatic & static objects

Example: Fibonacci numbers

Fib(0) = 0
Fib(1) = 1
Fib(n) = Fib(n-2) + Fib(n-1)

```
long long Fib(int N)
{
    if ( N == 0 || N == 1 ) return N;
    return Fib(N-2) + Fib(N-1);
}
```

Automatic & static objects

Example: Fibonacci numbers

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{
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```

```
long long Fib() {
    static long long first = 0;
    static long long second = 1;
    long long out = first + second;
    first = second;
    second = out;
    return out;
}
```

Automatic & static objects

Example: Fibonacci numbers

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```

The stateless function

The function with its own state, OR

<u>Finite automat</u>

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}
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