ANSI C Programming Language

- A small, general-purpose, initially *systems programming language*
  - Used for writing the UNIX OS and tools for many computers
  - Now also very popular for general-purpose computing
- A “low-level” language

  datatypes and control structures are close to those on most machines
- Notable features

  pointer (address) arithmetic and operators

  all functions are call-by-value

  simple, 2-level scope structure

  no I/O or memory management facilities (provided by library routines)

  “flexible” type structure
- History

  BCPL → B → C → K&R C → ANSI C
  ~1960 ~1970 ~1972 ~1978 ~1988

C vs Modula-3

feature	C	Modula-3
safe	**no**	yes
efficient	yes	yes
garbage collection	**no**	yes
static typechecking	mostly	yes
enforced interfaces	**no**	yes
concurrency	**no**	yes
Huh?		
widely available	yes	**no**
everyone knows it	yes	**no**
software tools	yes	**some**
good for a summer job	yes	**no**

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C Program Structure

- ***Programs***

  are composed of one or more ***files***

  each file contains ***global variables*** and ***functions***

```
int a, b;       /* global variables */

int main(int argc, char *argv[]) {
   hello();
   return 0;
}

void hello(void) {
   printf("hello world\n");
}
```

- ***Execution***

  begins by calling **`main`**

  ends when **`main`** returns (or some function calls the library function **`exit`**)

Function Definitions

- General form of an ANSI C function ***definition***

  [*type*] *name* (*argument-declarations*) { *body* }

  ```
  int twice (int x, double y) {
     ...
  }
  ```

  - If no return value, type of function should be **`void`**.

- **`return`** statements specify function return values

  ```
  int twice(int x, double y) {
     return 2*x + y;
  }
  ```

- Unlike in Pascal, functions are never defined within functions

Declarations & Definitions

- ***Declaration***: specifies (announces) the ***properties*** of an identifier

  ```
  extern int sp;
  extern int stack[];
  ```

  specify that "**`sp`** is an **`int`**" and "**`stack`** is an array of **`ints`**"

  `extern` indicates they are ***defined*** elsewhere

  - outside this routine, or even outside this file

- ***Definition***: declares the identifier ***and*** causes ***storage*** to be allocated

  ```
  int sp;
  int ptr = 1;;
  int stack[100];
  ```

  declares **`sp`**, **`ptr`** and **`stack,`** allocates storage, **`ptr`** is initialized to 1

- Why does a language have declarations for variables?

- Can a variable have multiple declarations?

Scope

- How do functions defined in different files communicate?

  - by calling one another (parameter passing and return values

  - through global (externally declared) variables

- External variables

  Externally declared versus `extern`?

  Can we have multiple declarations of an externally defined variable within a file?

  What if an external declaration is not initialized? Is it treated as defined?

- So which functions and data may a function reference?

  - determined by the ***scope*** of identifiers

Global Variables & Scope

- The ***scope*** of an identifier says where the identifier can be used
- Functions can use global variables ***declared*** outside and above them

file **`a.c`**:

```
int stack[100];
main() {
    ...
}
```

`stack` is visible

```
int sp;
void push(int x) {
...
}
```

`stack, sp` are visible

- Global variables and functions in other files are made avaiilable with`extern`

file **`b.c`**:

```
extern int stack[];
void dump(void) { ... }
```

`stack` defined in **`a.c`** is visible here

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Scope, cont’d

- Formal parameter and local declarations “hide” outer-level declarations

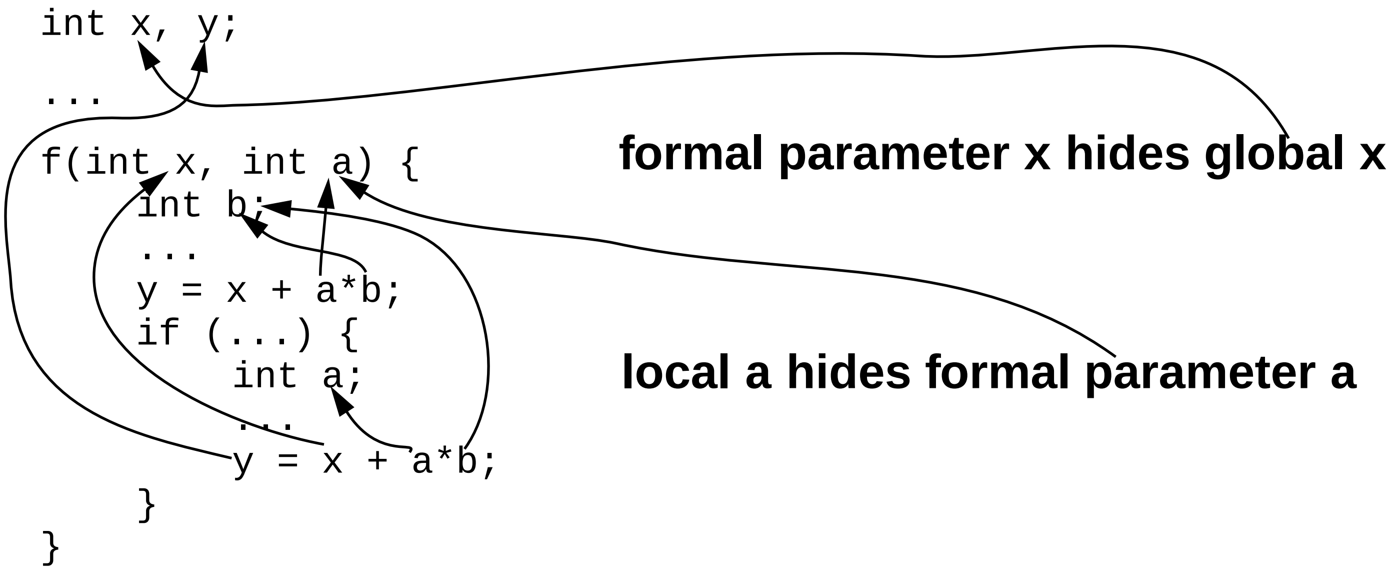
```
int x, y;

...

f(int x, int a) {
    int b;
    ...
    y = x + a*b;
    if (...) {
        int a;
        ...
        y = x + a*b;
    }
}
```

```
struct a {
  int a;
  float b;
} *f;

float a = 1;

typdef int a;

int a(void){
  char *a;
  {
  double a;
  ...
  }
}
```

-
```
f(int x) {
int x;
...
}
```

Scope, cont’d

- Formal parameter and local declarations “hide” outer-level declarations



```
int x, y;
...
f(int x, int a) {
    int b;
    ...
    y = x + a*b;
    if (...) {
        int a;
        ...
        y = x + a*b;
    }
}
```

formal parameter x hides global x

local a hides formal parameter a

- Cannot declare the same variable name ***twice*** in one scope

-
  ```
  f(int x) {
  int x;
  ...
  }
  ```
  error!

- Different ***name spaces*** allow same identifier to be multiply declared in a scope

  - function and typdef names; labels; struct/union tags; struct/union members

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Function Arguments and Local Variables

- ***Local*** variables are ***temporary*** variables (unless declared static)

  created upon entry to the function in which they are declared

  destroyed upon return

- ***Arguments*** are transmitted ***by value***

  the values of the arguments are ***copied*** into “local variables”

- **Arguments are *initialized local variables***

```
int a, b;
main(void) {
    a = 1; b = 2;
    f(a);
    print(a, b);
}
```

output:

```
3 4
3 2
1 5
```

```
void f(int a) {
    a = 3;
    {
        int b = 4;
        print(a, b);
    }
    print(a, b);
    b = 5;
}
```

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Function Declarations

- Declares the type of the value returned and the types of arguments

```
extern int f(int, float);
extern int f(int a, float b);
```

- A **`void`** function is a ***procedure***
- A **`void`** argument list means ***no*** arguments

```
void hello(void)
```

- Unlike Pascal, functions can be used ***before*** they are declared

  as long as defined in same file or declared extern

- **A function without a declaration**

  assumes the function returns an **`int`**

  assumes arguments have the types of the corresponding expressions

  `“i = f(2.0, 1);” implies “int f(double, int);”`

  if **`f`** is defined otherwise, ***anything goes!***

Static Variables

- **`static`** keyword in a declaration specifies

  lifetime: static vs dynamic

  scope: static vs global

- ***Static*** variables are

  allocated at *compile time* and exist throughout program execution

- ***Statics*** are ***permanent***; ***locals*** are ***temporary***

```
void f(int v) {
   static int lastv = 0;

   print(lastv, v);
   lastv = v;
}
```

- Scope of static variables: within the file or block in which they are defined

  - scope versus lifetime

- What if a variable is declared `extern` inside a function?

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Static Functions

- Scope restricts the visibility of variables and functions

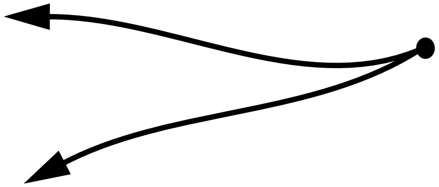
file **stack.c**:

```
static int sp;
static int stack[100];

static void bump(int n) {
    sp = sp + n;
    assert(sp >= 0 && sp < 100);
}

void push(int x) {
    bump(1);
    stack[sp] = x;
}

int pop(void) {
    bump(-1);
    return stack[sp+1];
}
```



sp & stack visible here,

but not outside **stack.c.**

so also function bump

- Static ***functions*** are visible only within the file in which they are defined

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Initialization Rules

- ***Local*** variables have ***undefined values***

- Need a variable to start with a particular value?
    - use an ***explicit*** initializer

- ***External*** and ***static*** variables are initialized to 0 by default
    - some consider it bad style to rely on this feature