CSC209 Summer 2015 — Software Tools and Systems Programming

www.cdf.toronto.edu/~csc209h/summer/

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Some materials courtesy of Karen Reid

Labs

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Asking for help

“It doesn’t work”

“How do I do XYZ?”

“I get an error on line 10”

Asking for help

*“I tried **X***

*and expected **Y***

*but got **Z** instead.*

Please help!”

Asking for help

I tried the following code but instead of printing 3.1415 which I expected, it instead prints 3.000000. What am I doing wrong? Please help!

```
#include <stdio.h>
int main() {
    int pi = 3.1415;
    printf("%f\n", (double) pi);
    return 0;
}
```

Agenda

- Introduction to the C language
- The memory model of the machine

The C Problem Language

- C is a high-level language — structured
  - Supports functions, records and some forms of code modularity
  - Not as high-level as Python or Java
- C is a low-level language — machine level access
- C is a small language — relatively simple syntax, with libraries for extensibility
- C does not hold your hand — it assumes that you know what you’re and how you want to do it

The C Problem Language

- **Good:**
  - Efficient
  - Powerful
  - Portable
  - Flexible

- **Bad:**
  - Easy to make errors
  - Obfuscation
  - Weak support for modularization

From Java to C

Common Syntax between Java and C (1)

- Distinction between *statements* an *expressions*
- Semicolon denotes end of statement
- Whitespace is generally ignored!
- Braces to denote scope:

```
  { statement1;
    statement2; … }
```

Common Syntax between Java and C (2)

- Binary Expressions:
  - Comparison: ==, !=, <, <=, >, >=
  - Arithmetic: +, -, /, *, %
  - Boolean logical: && (and), || (or)
  - Bitwise logical: & (and), | (or), ^ (xor)
  - Bitwise shift: << (left), >> (right)

Common Syntax between Java and C (3)

- Unary expressions:
  - Minus: -
  - Logical negation: ! (not)
  - Bitwise negation/flip: ~ (not)
  - Pre- and post- increment and decrement (with side effect): ++, --
- Ternary conditional: ?:

Common Syntax between Java and C (4)

- More expressions:
  - Assignment: =
  - Operator assignment: +=, -=, *=, /=, %=, &=, |=, ^=, <<=, >>=
- Statement
  - `return` *`expression`* (or just `return` if void return type)
- Declarations:
  - `int variable;`
  - `short var1, var2;`
  - `double array[10];`

Common Syntax between Java and C (5)

- Loops
  - `for`, `while`, `do-while`
  - `break` and `continue` statements
- `if` and `if-else`
- `switch` (with `case` and `default`)

Compiling C

```
$ gcc -Wall -g -o hello hello.c
```

`-Wall`

Include all warnings. Helps you prevent errors.

`-g`

Include debugging symbols. Allows you to debug with gdb

`-o hello`

Produce an executable called `hello`

`hello.c`

The list of source files to compile.

`main` function

- Entry point for all programs
- Each shell argument is passed in as a string
- Standard signature: (not quite true)

```
int main(int argc, char *argv[])
```

- Returns an *exit status*: non-0 indicates an error occurred, otherwise 0 for success

C data types

- Basic types and literals (King: Ch 7)

```
int i = 38;        long el = 38L;
int hex = 0x2a;    int oct = 033;
printf("i = %d, el = %ld, hex = %d, oct = %d\n",
       i, el, hex, oct);
```

```
 i = 38, el = 38, hex = 42, oct = 27
```

```
double d1 = 0.3;   double d2 = 3.0;
double d3 = 6.02e23;
printf("d1 = %f, d2 = %f, d3 = %e\n", d1, d2, d3)
```

```
d1 = 0.300000, d2 = 3.000000, d3 = 6.020000e+23
```

C literals and types

Literal	Value	Type
`38`	38	`int`
`38L`	38	`long int`
`0x2a` (hex)	42	`int`
`033` (octal)	27	`int`
`38.0`	38.0	`double`
`38.0f`	38.0	`float`

C data types

- Most things in C are ints:
  - Boolean values are ints
    - 0 means false, nonzero means true
  - characters are ints (ASCII code)
    - `'a'`==97, `'\n'`==10, `'\033'`==033==27
  - enumerations are really ints
- signed vs. unsigned types
- char, int, long, … are just different sizes of integers.

Mixed Mode Arithmetic

```
double m = 5/6; /* int / int = int */
printf("Result of 5/6 is %f\n", m);
```

```
Result of 5/6 is 0.000000
```

```
double n = (double)5/6; /* double / int = double */
printf("Result of (double)5/6 is %f\n", n);
```

```
Result of (double)5/6 is 0.833333
```

```
double o = 5.0/6; /* double / int = double */
printf("Result of 5.0/6 is %f\n", o);
```

```
Result of 5.0/6 is 0.833333
```

```
int p = 5.0/6; /* double / int = double but then
                  converted to int */
printf("Result of 5.0/6 is %d\n", p);
```

```
Result of 5.0/6 is 0
```

Data Type Conversion

- The expression on the right side is converted to the type of the variable on the left.

```
char c;
int i = c;    /* c is converted to int */
double d = i; /* i is converted to double */
```

- This is no problem as long as the variable’s type is at least as “wide” as the expression.

```
char c = 500; /* compiler warning */
int k = d;
printf("c = %c, k = %d\n", c, k);
```

```
c =  , k = 0
```

`printf` and format strings

- `printf(`*`a_string`*`)` will print the given string
- *Variadic*: `printf` can take a variable number of arguments
- Whether it actually does will depend on special *format strings:*
  - **%d** for signed integers: `printf(“%d + %d = %d\n”, -3, 5, 2)`
  - **%s** for strings: `printf(“Hello %s!\n”, “CSC209”)`
  - **%f** for floating point: `printf(“pi ~ %f\n”, 3.14f)`
  - **%c** for ASCII character: `printf(“C%cC209”, ’S’);`
  - **%%** to print an actual %: `printf(“100%%!\n”)`
  - Other modifiers available: look them up with ***`man 3 printf`***

Boolean values in C

- No builtin `bool` type, nor `true` and `false` values!
- `0` is considered to be *false*, anything else is *true*
- `if (0) { printf(“Never run\n”); }`
- `if (-1) { printf(“Always run\n)”; }`

Data Type Capacity

- What happens when the following code is executed?

```
char c = 127;
int d;

printf("c = %d\n", c);
c++;

d = 512 / c;
printf("c = %d, d = %d\n", c, d);
```

Memory Model

Memory Model

- System memory is can be viewed as a sequence of *bytes* (8 bit values)
- Each location in that sequence (and thus its associated value) is assigned a unique *address*
- Each address is just a number:

1st address	→	1st byte
2nd address	→	2nd byte
3rd address	→	3rd byte
…		…

`0x0001`	→	1st byte
`0x0002`	→	2nd byte
`0x0003`	→	3rd byte
…		…

Memory Model

A 32 bit address can give a unique address number to ~4 billion (2^32) different bytes

4294967296 bytes

~4294967 thousand bytes

~4295 million bytes

~4 billion bytes

aka ~4.29 gigabytes

== 4 gibibytes (4x2^30)

Memory Model

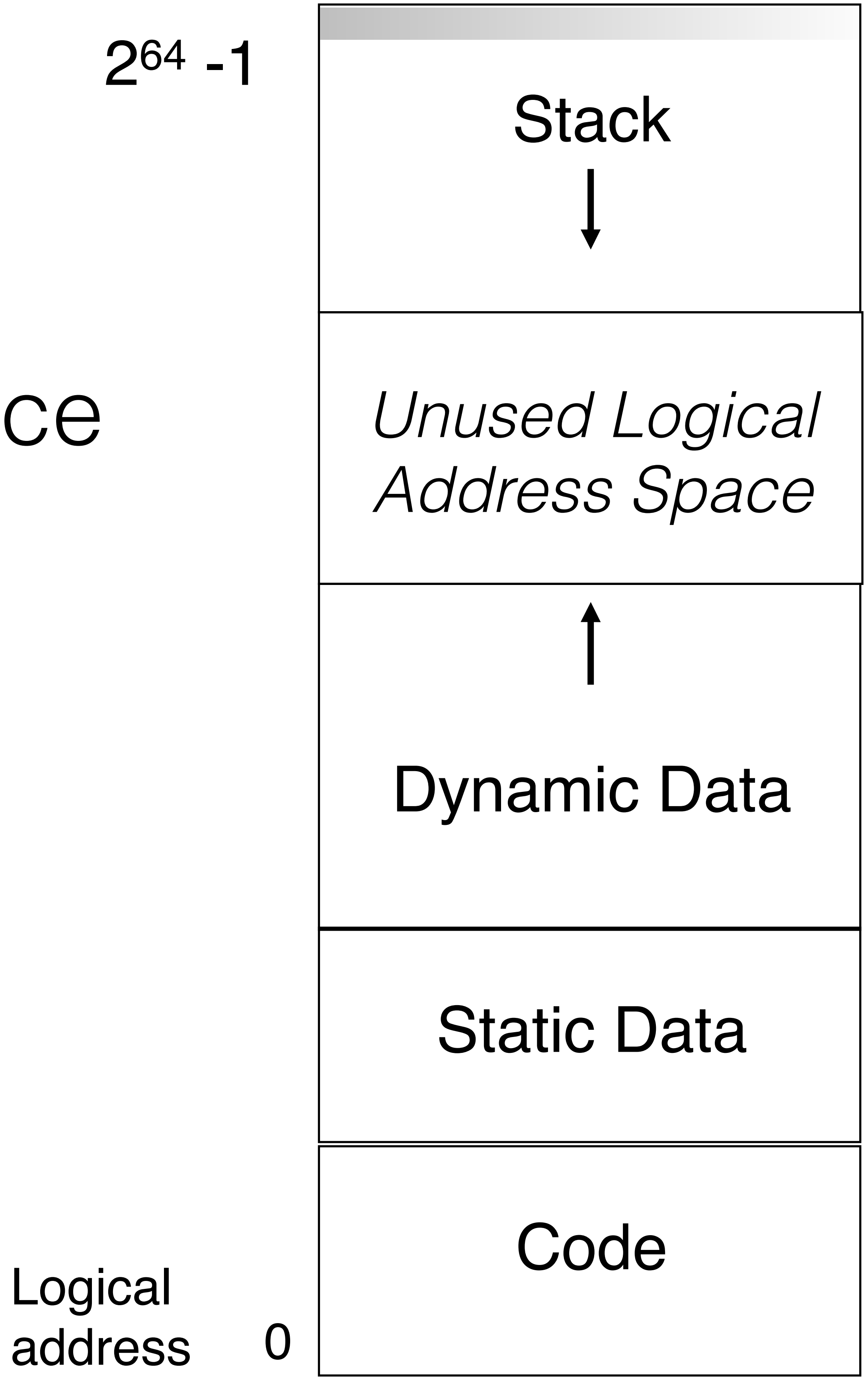
- A 32-bit system can address, and thus is limited to, a maximum of 4GB of system memory (RAM)
- A 64-bit system has a much higher limit (~16 billion GB worth of unique addresses, less usable in practise)
  - The CDF server *Wolf* is a 64-bit machine (with 64GB of physical RAM)
  - This is indicated by the string “x86_64 “in the output of **`uname -m`**

Memory Model

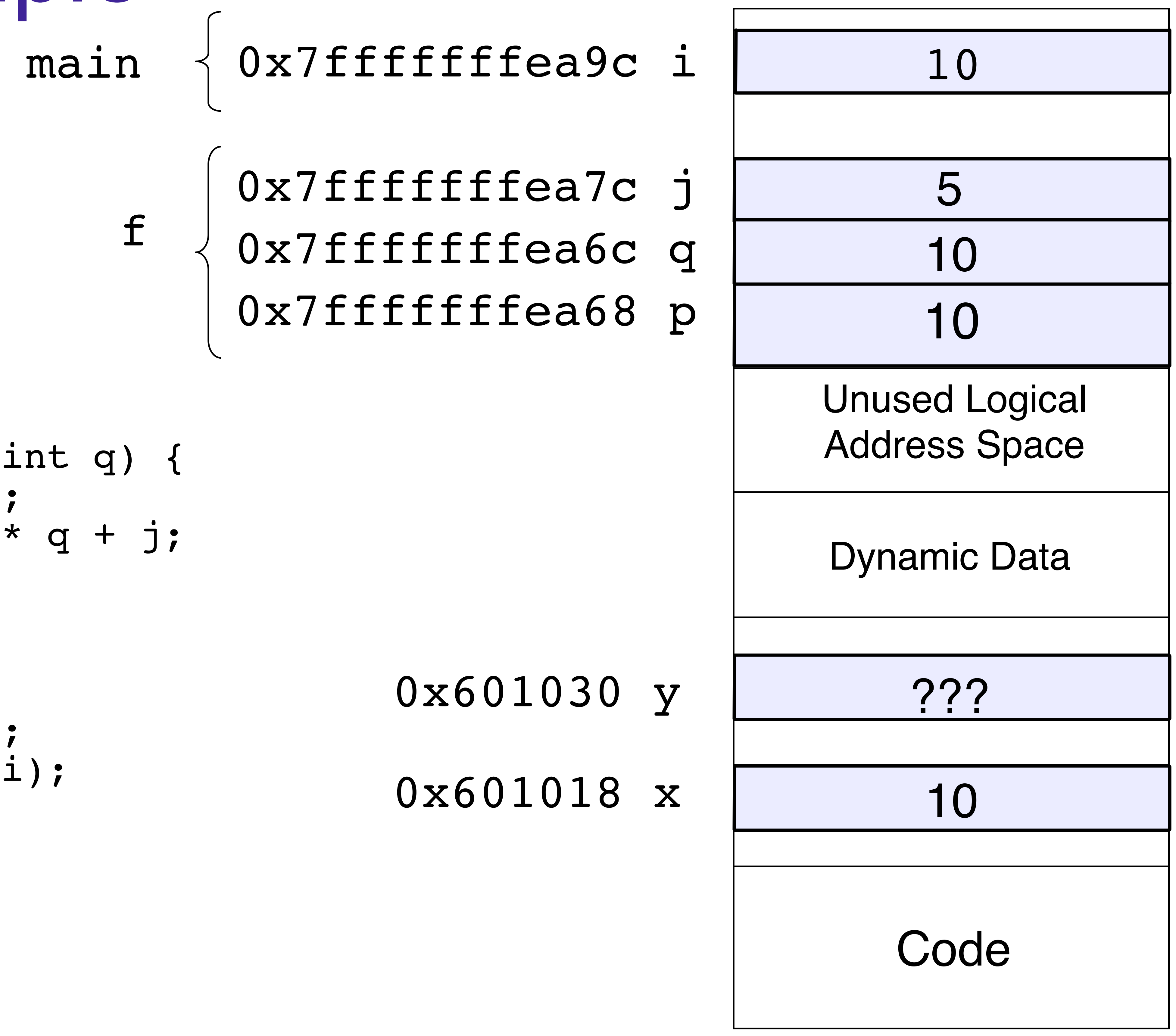
- Java and Python hide (shield?) all of this from you
- C does not

Logical Memory M

- Memory is just a sequence of bytes
- A memory location is identified by an address



Example



main
0x7ffffffffea9c i
10

f
0x7ffffffffea7c j
5
0x7ffffffffea6c q
10
0x7ffffffffea68 p
10

Unused Logical Address Space

Dynamic Data

0x601030 y
???

0x601018 x
10

Code

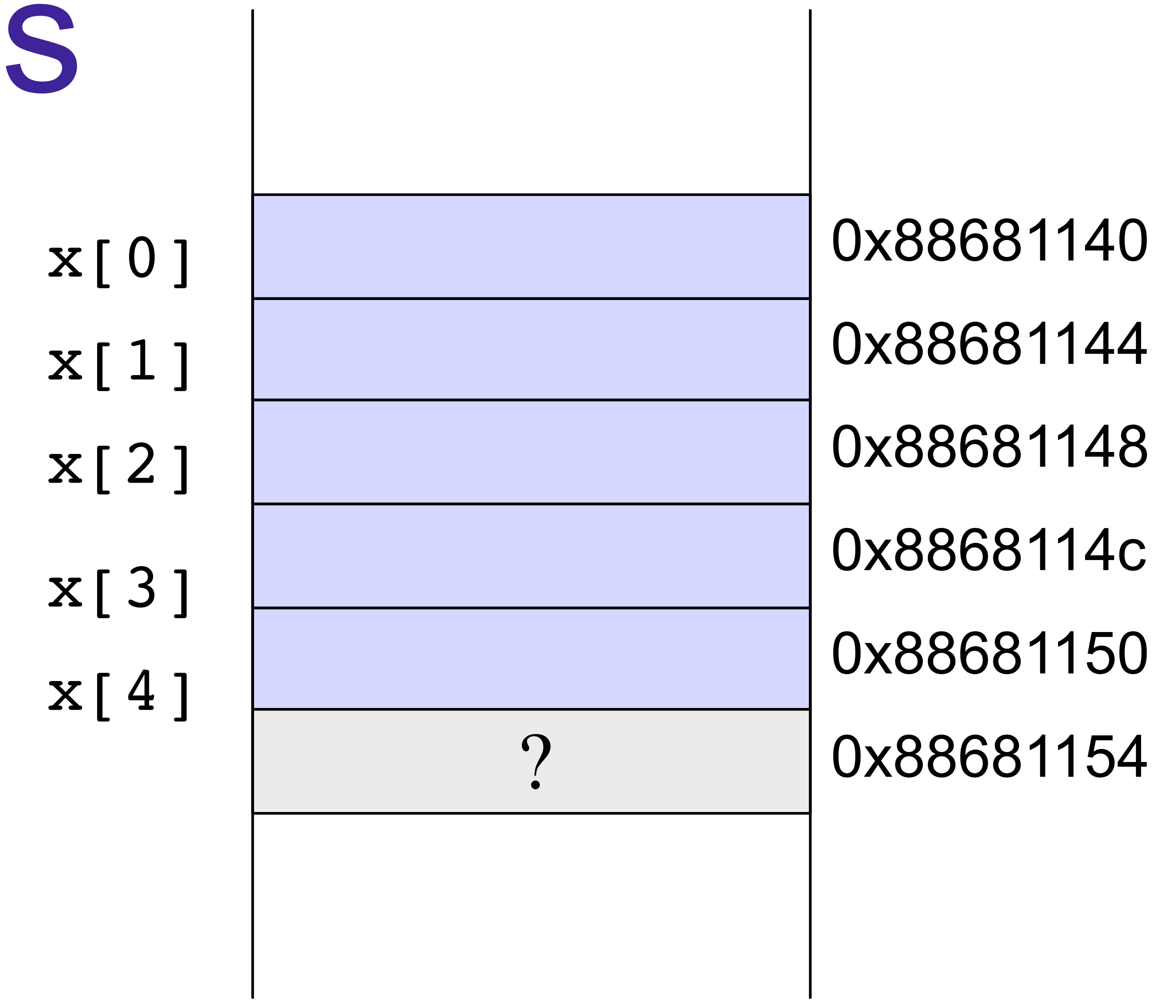
```
int x = 10;
int y;

int f(int p, int q) {
    int j = 5;
    return p * q + j;
}

int main() {

    int i = x;
    y = f(i, i);
    return 0;
}
```

Arrays

- Arrays in C are a contiguous chunk of memory that contain a list of items of the same type.
- If an array of ints contains 10 ints, then the array is 40 bytes. There is nothing extra.
- In particular, the size of the array is not stored with the array. There is *no* runtime checking.

Arrays

```
int x[5];
for (i = 0; i <= 5; i++) {
    x[i] = i*i;
}
```



- No runtime checking of array bounds
- Behaviour of exceeding array bounds is “undefined”
  - → program might appear to work
  - → program might crash
  - → program might do something apparently random

Next Week

- Assignment 1 will be posted within the next few days

- Lecture: More on C pointers and memory

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