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There is a `signed` keyword if you want to be explicit: e.g., `signed char` and `signed int`

Types

Integers

Exercise. `%d` is the `printf` specifier for `signed int`. Find the specifiers for the other integer types

Exercise. Find out what happens to the value when you overflow an `unsigned char` and a `signed char`

Exercise. An unadorned `int` is signed. Find out whether an unadorned `char` has a sign or not

Exercise. Find out the sizes of the integer types on machines you have access to

Exercise. Read up on the operators that operate on the bits of the integer types: `&`, |, <<, >>, etc.

Types

Integers

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Aside: technically a “byte” is not necessarily 8 bits; use the word “octet” to mean precisely 8 bits

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Aside: technically a “byte” is not necessarily 8 bits; use the word “octet” to mean precisely 8 bits

But the name “`char`” indicates a popular use of this type: characters encoded as ASCII integers

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Integers

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char c = 'Z' - 'A' + 1;
```

is valid C

We use the single quote syntax as it is easier (we don't have to look up the relevant value) and it is portable: not everyone uses ASCII

Exercise. Find out which character encoding your machine uses

Exercise. Is `'A' + 1` always `'B'`?

Exercise. Is `'A'` < `'B'` always true?

Exercise. What about `'A'` < `'a'` or `'a'` < `'A'`?

Types
Floating Point

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These overwhelmingly conform to a particular standard for floating point representations, namely IEEE 754

Many machines support `double` in hardware, so this is the “natural” size in programs: but not always

Types

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It turns out that the flexibility of having explicitly undefined sizes works against you when you want to do numerical analysis with floating point, so pretty much all hardware uses IEEE 754

Type	bytes
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That said, there is a significant class of hardware out there that does it differently, e.g., *fixed-point* arithmetic

Types

Floating Point

Most general-purpose hardware supports `double` (64 bit) floats with range approximately $\pm 10^{-323}$ to $\pm 10^{308}$

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These have their expected behaviours, e.g., $1.0/0.0$ returns infinity; `sqrt(-1.0)` returns a NaN

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These have their expected behaviours, e.g., $1.0/0.0$ returns infinity; `sqrt(-1.0)` returns a NaN

Also, there is a *signed zero*, namely ± 0.0. To understand why all these things are desirable you should attend a course on numerical analysis

Types

Floating Point

Exercise. Look up the documentation on the functions `atan` and `atan2`

Exercise. Read up on IEEE 754 features

Types

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For single precision (32 bit) floats, append an `f`, e.g, `3.141f`. An unadorned `3.141` indicates a `double` (64 bit)

There is little use for single precision floats in modern hardware with built-in `doubles`: some hardware doesn't even support `float` natively

Types
Floating Point

So in those kinds of machines

```
float f = 1.0f * 2.0f
```

the single floats `1.0f` and `2.0f` would be *widened* automatically by the compiler to `double`; the multiplication computed in double precision; the result is then *truncated* to fit back into `f`

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This could well actually be slower than plain double precision computation all the way through

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There is no separate specifier for `float` as any float in a `printf` argument will be automatically widened to a `double` before being passed into `printf`

Types

A note on mixing values of different types: C (in common with many other languages) has a raft of automatic *coercions* of types of values

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`char c; int n; ... n + c`
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Usually it does what you want, but you should always look at mixed-type expressions carefully

Types

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Widening a char to an int just takes the bit pattern that represents the char and puts it in a bigger, int-sized box

The bit pattern is not changed, just extended

Types

Coercing an int to a double takes the bit pattern that represents the int (2s complement, perhaps), calculates the bit-pattern that represents the closest numerically equivalent floating point (IEEE, probably) and returns that

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This will an entirely different bit pattern

Usually you don't have to care that this is happening, but you should be aware that it is

Types

On some classes of hardware, this is actually a very expensive (slow) operation!

Thus for `double x;`

```
x = 1;
```

could be a lot slower than

```
x = 1.0;
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```
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could be a lot slower than

```
x = 1.0;
```

Though this is relatively rare

Types

Exercise. Assuming standard IEEE and 2-s complement representations:

```
long int n = 42;
double x = n;
```

What is the bit pattern stored in the 8-byte integer `n`?

What is the bit pattern stored in the 8-byte float `x`?

Types

Exercise. What's happening here?

```
int n = 1, m = 2;
double x = n/m;

printf("x is %g\n", x);
```

Exercise. Some compilers have flags to warn about automatic type coercions. Look this up

Summary: stick to `double` for floating point

Types

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Summary: stick to `double` for floating point

When you hear the phrase “floating point” the speaker usually means “double precision floating point”

The newest C compilers also support a *complex type*, e.g.,

```
#include <complex.h>
...
complex c = 5.0 + 3.0 * I;
c = c + 1.0;
```

The `double 1.0` will be automatically coerced (widened?) to a `complex`

Types

Floating Point

Exercise. Think about the difference between
`sqrt(-1.0)`
and
`csqrt(-1.0)`
where `csqrt` is the complex square root function

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Compilers also support *wide characters*, to support character sets from global languages

Exercise. Let $a = 1.0 \times 10^8$, $b = -1.0 \times 10^8$ and $c = 1.0$. Write code to evaluate and print the result of

$$(a + b) + c$$

and

$$a + (b + c)$$

Compare the results using `float` and `double`

Types

Boolean

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```
int bigger(double a, double b)
{
  if (a > b) return 1;
  return 0;
}
...
if (bigger(x+1.0, y)) ...
```

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Though this would not be regarded as a natural C

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Boolean

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Just like the expression “`a + b`” returns a value, “`a > b`” also returns a value, false or true, i.e., zero or non-zero

More idiomatic C would be:

```
int bigger(double a, double b)
{
  return a > b;
}
```

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Boolean

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But, again, only mix expressions like this if you really understand what you are doing

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`if (a = 2) ...`
rather than
`if (a == 2) ...`

The first is valid C: it assigns 2 to `a`, and then the expression "`a = 2`" returns the value `2`, i.e., true in a Boolean context

Exercise. Read up on the various Boolean connectives `&&`, `||` etc.

Exercise. Compare the Boolean connectives with the *bitwise operators* `&`, `|` etc.

Exercise. And the shift operators >> and <<. Particularly with regard to signed and unsigned integers

Exercise. Read up on the `?:` operator

Exercise. What happens with `n = 1 + (m = 2)` ?

Types

Boolean

Exercise. Look at what your compiler says about

```
#include <stdio.h>

int main(void)
{
  int s = 0;

  if (s = 2) printf("hi\n");
  else printf("lo\n");

  return 0;
}
```

Types

Arrays

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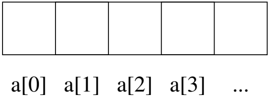
The elements are referenced as you might expect

```
int i;
...
for (i = 0; i < 1024; i++) {
  b[i] += 1.0;
}
```

Indexed from 0 to length − 1

Types

Arrays



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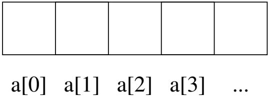

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The C standard specifies this layout, and this will become important later

Types

Arrays

Arrays of things are a type, so we can have arrays of them

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Maybe writing `(d[3])[0]` is clearer?

Types

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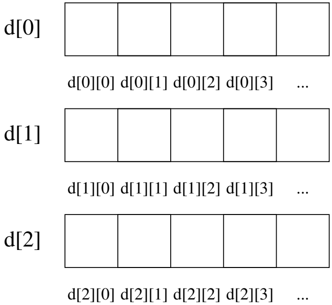

Higher dimensional arrays

Types

Arrays

```
void fill(int arr[], int n)
{
  int i;

  for (i = 0; i < n; i++) {
    arr[i] = 99;
  }
}

...

int a[5], d[6][7];

fill(a, 5);
fill(d[3], 7);
```

Exercise. What about

```
fill(d, 6);
```

Types

Arrays

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So:

- Arrays can be passed as arguments to functions
- The size of the array need not be specified in the function definition (for simple, 1D arrays)
- An array does not “know its own size”. That information has to be given separately, if needed. This is a common source of bugs

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Arrays

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int a[5];
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It might run and crash

This is one of C's chosen trade-offs

Types

Arrays

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More speed for less checking and safety

C allows the programmer to do all kinds of weird stuff, often without warning

This is good for good programmers; bad for bad programmers

Exercise. Implement a function which, given an array of integers fills that array with the squares of 0, 1, 2, and so on

Exercise. Implement a function which, given an array of integers, returns the sum of the values in the array

Exercise. Implement the Sieve of Eratosthenes to find primes