Types

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int a[5];
double b[1024];
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```
int a[5];
double b[1024];
```

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

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But, also, `d[3]` is a valid thing to write: it refers to the 4th array of characters

So `d[3][0]`, `d[3][1]`, `...`, `d[3][6]`, are the 7 characters in that array

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

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

So:

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Arrays

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- Arrays can be passed as arguments to functions

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Arrays

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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int a[5];
...
a[10] = 42;
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It might run, not report an error and return the wrong answer

It might run and crash

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This is good for good programmers; bad for bad programmers

Types

Arrays

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

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```
char str[] = "hello world";
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C is clever enough to work out the size of the array needed here, to save you a bit of counting

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There *are* arrays of `char`

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C is clever enough to work out the size of the array needed here, to save you a bit of counting

Then `str[4]` is the character `'o'`

Types

Strings

In `printf` use `%s` for strings

```
printf("str is '%s'\n", str);
```

And `%c` for `char`s

```
printf("char is '%c'\n", str[4]);
```

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Strings

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char str[] = { 'h', 'e', 'l', 'l', 'o', ' ', 'w',
'o', 'r', 'l', 'd' };
```

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Strings

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```
char str[] = { 'h', 'e', 'l', 'l', 'o', ' ', 'w',
'o', 'r', 'l', 'd' };
```

There are two reasons why you wouldn't normally write code like this:

- it's easier to use normal quoted string syntax
- this code is semantically incorrect

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Stored as a sequence of bytes in memory: we need some way to mark the end of the string

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All it has is an array of characters of some undetermined size

Stored as a sequence of bytes in memory: we need some way to mark the end of the string

Thus, in C, all strings are conventionally terminated by a (character value/byte) 0

Types
Strings

```
char str[] = { 'h', 'e', 'l', 'l', 'o', ' ', 'w',
'o', 'r', 'l', 'd', 0 };
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is the correct version of the simpler

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char str[] = "hello world"
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So `sizeof("hello world")` is 12 bytes, including the terminating 0

This is another favourite source of bugs!

If you stick to simple uses of strings, this all just works without you having to think

Types
Strings

Exercise. Look up the ASCII encoding for characters

Exercise. Characters really are integers. What about the following?

```
char message[] = { 104, 101, 108, 108, 111, 32, 119,
  111, 114, 108, 100, 0 };
```

Exercise. And what about

```
printf("A has value %d\n", 'A');
printf("A has value %c\n", 'A');
```

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Exercise. Look up the various functions that operate on strings, e.g., `strlen`, `strcpy`, `strcat`, `strcmp` and lots more

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Structures

C has a simple *structure* type constructor, used when we need to manage more complicated combinations of values

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```
struct rational {
  int num, den;
};

...

struct rational r;
r.num = 1;
r.den = 2;
```

Types

Structures

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- The type name is "`struct rational`", always including the word "`struct`"
- The elements of the struct are accessed using the dot notation
- `r` is *not* an object in the OO sense
- There are no classes, no objects, no methods
- The declaration can only contain names of values, as **there are no methods in C**

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Structures

Structure types are just like the in-built types

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struct rational numbers[10];
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We can declare structs containing arrays

```
struct numb { int nums[10]; int dens[10]; }
```

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struct rational numbers[10];
```

So `numbers[7].num`

We can declare structs containing arrays

```
struct numb { int nums[10]; int dens[10]; }
```

Then

```
struct numb n;
n.nums[7] = 42;
```

Structs of structs, and so on

```
struct inner {
  double first[10];
  char rest;
};

struct complicated {
  int sign;
  struct rational r;
  struct inner blob;
};
...
struct complicated c;
c.sign = -1;
c.r.num = 5;
c.blob.first[3] = 7.0;
```

We can also declare structs “on the fly” as we are using them

```
struct complicated {
  int sign;
  struct rational r;
  struct inner {
    double first[10];
    char rest;
  } blob;
};
...
struct complicated c;
c.sign = -1;
c.r.num = 5;
c.blob.first[3] = 7.0;
```

Types

Exercise. Read up on `union` types

Exercise. Read up on `typedef`, a convenient way of abbreviating type names

Pointers

We now turn to one of the features of C that (a) some people find difficult, and (b) makes C so useful: pointers

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Recall that (thanks to the universal adoption of von Neumann's model) memory can be regarded as a big array of bytes; conventionally numbered from 0 upwards

Pointers

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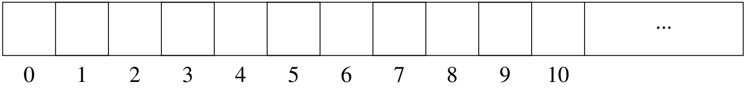
We start by reviewing the way memory is laid out in hardware

Recall that (thanks to the universal adoption of von Neumann's model) memory can be regarded as a big array of bytes; conventionally numbered from 0 upwards



Pointers

When a program is compiled, variables are mapped in some useful way to memory location by the compiler

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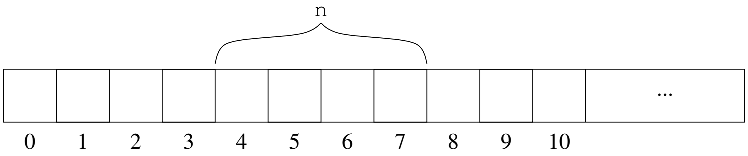
So if we have a (4 byte) integer `n` in our code, the compiler might choose to place it at memory address 4 (a very unlikely place in real systems)



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It's where the variable lives in memory

Pointers

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To get the address of a variable use the `&` operator

Pointers

```
#include <stdio.h>

int main(void)
{
  int n = 1234;

  printf("n has value %d and address %p\n", n, &n);

  return 0;
}
```

Pointers

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#include <stdio.h>

int main(void)
{
  int n = 1234;

  printf("n has value %d and address %p\n", n, &n);

  return 0;
}
```

Produces

```
n has value 1234 and address 0x7fff251f6d5c
```

Pointers

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The value of `n` will always be 1234; the address will be different on different machines, different on different compilers, possibly different on different runs on the same machine

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The value of `n` will always be 1234; the address will be different on different machines, different on different compilers, possibly different on different runs on the same machine

It all depends on where in memory `n` happens to be placed

Pointers

So addresses are just integers; the `%p` in `printf` prints addresses in hexadecimal, as that is often useful to the programmer

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Variables that hold addresses are called *pointer variables*

Pointers

So a pointer variable contains a simple integer (the address), but to make things work nicely, C distinguishes between pointers and integers, and also between pointers to different types

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And both are different from a ordinary integer

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So a pointer to an integer is treated as different to a pointer to a double

And both are different from a ordinary integer

This is a bit subtle: they are all simple integers underneath; it's just how the compiler manipulates those integers that will be different for different types

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At one point the program might store an integer at address 4; later it might store a double there

Pointers

So the *interpretation* of that pointer integer is what is important

This is to make later manipulations much more convenient

Of course, memory doesn't "know" what kind of data is being stored at a particular address; memory is just a bunch of bytes

At one point the program might store an integer at address 4; later it might store a double there

It is up to the program to interpret the bits at a given address in whatever way it wants

Pointers

We can declare pointer variables

```
int n;
int *pn;
pn = &n;
```

The * is read as "pointer to"; the variable `pn` has type "pointer to `int`"

Pointers

Convention

Note: the convention is to write `int *pn;` rather than `int* pn;`

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The reason for this slightly awkward convention is that we can declare

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int n, *pn;
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for an `int` `n` and a pointer to `int` `pn`

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for an `int` `n` and a pointer to `int` `pn`

You can read the above as "`n` is an `int` and `pn` is an `int` pointer"

Pointers

Convention

Exercise. What are the types of the variables in the following?

```
int* a, b;
```