

C preprocessor

- the C language is two languages
 - the language which defines data types, statements, functions and operators
 - there is also the language of the preprocessor (`#include`, `#define`) etc

- we use `#include` to include text within the current source file
 - traditionally these text files are `.h` files or library files, but they can be any text file, including `.c` files
 - however including `.c` files is generally considered bad practice
 - however there are exceptions to this rule, for example including machine generated `.c` files

Example #include

- the following is held in file `example.h`

- ```
int example_length (char *s);
```

## Example #include

- the following is main1.c

```
#include <stdio.h>
#include "example.h"

main ()
{
 printf("my length program counts %d characters\n",
 example_length("hello world"));
}
```

## example.c

```
int example_length (char *s)
{
 int i=0;

 while (s[i] != '\0')
 i++;
 return i;
}
```

## #include

- notice that `main1.c` contained two `#includes`, the first was to include the prototype for `printf`
- also notice that it used `<>` to delimit the filename
  - special meaning, it searches using an implementation defined rule to find the file
- you can modify the search path of the `gcc` compiler by supplying the `-I` argument

# Macro substitution

- the C preprocessor allows text to be substituted, for example

```
#define forever while (1)
#include <stdio.h>

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

## Macro substituted with arguments

```
#define assert(X) { if (! (X)) \
 { fprintf(stderr, "assert failed\n"); }}

main ()
{
 int r = write(1, "hello world\n", 12);

 assert(r==12);
}
```

- if you are unsure what is happening try asking the preprocessor what it is doing (use `gcc -E`)

## Macro substituted with arguments

```
$ gcc -E main2.c
1 "main2.c"
1 "<built-in>"
1 "<command line>"
1 "main2.c"

main ()
{
 int r = write(1, "hello world\n", 12);

 { if (! (r==12)) { fprintf(stderr, "assert failed\n"); }};
}
```

■ use the C preprocessor carefully...

- do not use the C preprocessor to gain execution speed (by avoiding a function call)
- the C compiler will probably make better decisions than you..



## Special tokens in the C preprocessor

- `__LINE__`, `__DATE__`, and `__FILE__` are all special tokens and are expanded into their obvious meanings, consider
- the gcc C compiler also substitutes `__FUNCTION__` (but it does this in the C language component - not during preprocessing)

## Special tokens in the C preprocessor

```
#include <stdio.h>
#include <stdlib.h>
#define assert(X,Y) do_assert(X, Y, __LINE__, __FILE__, __FUNCTION__)

void do_assert (int b, char *m, int line, char *file,
 const char *func)
{
 if (! b) {
 fprintf(stderr, "%s:%d: %s in function %s (on %s)\n",
 file, line, m, func, __DATE__);
 exit(1);
 }
}

main ()
{
 int r = write(1, "hello world\n", 11); /* should be 12 */
 assert(r==12, "write failed");
}
```

`gcc -E main3.c` | `tail -20`

```
void do_assert (int b, char *m, int line, char *file,
 const char *func)
{
 if (! b) {
 fprintf(stderr, "%s:%d: %s in function %s (on %s)\n",
 file, line, m, func, "Feb 4 2008");
 exit(1);
 }
}

main ()
{
 int r = write(1, "hello world\n", 11);
 do_assert(r==12, "write failed", 18, "main3.c", __FUNCTION__);
}
```

## Watch out for side effects

```
#define square(X) (X) * (X)

main ()
{
 int i=11;

 printf("square of %d is %d\n", i, square(i++));
 printf("square of %d is %d\n", i, square(i++));
}
```

- why is this wrong?
- never use C preprocessor for speed, unless you know the hardware better than the compiler author..

## Correct solution

```
#include <stdio.h>

int __inline__ square (int x)
{
 return x*x;
}

main ()
{
 int i=11;

 printf("square of 11 is %d\n", square(i++));
 printf("square of 12 is %d\n", square(i++));
}
```

- and compile with `gcc -O3 -g main4.c` it will produce great code

## Compiler assembler output

- check this is the case!
- compile with `gcc -g -O3 main4.c`

## main4.s

```
main:
 subq $8, %rsp
 .loc 1 12 0
 movl $121, %esi
 movl $.LC0, %edi
 xorl %eax, %eax
 call printf
 .loc 1 13 0
 movl $144, %esi
 movl $.LC1, %edi
 xorl %eax, %eax
 .loc 1 14 0
 addq $8, %rsp
 .loc 1 13 0
 jmp printf
```

## C preprocessor conditionals

- C preprocessor allows the following conditionals
  - `#if defined(MACRONAME)`
    - also abbreviated to `#ifdef MACRONAME`
  - first method is preferable as it can be used with conditional logic



# C preprocessor conditionals

```
#define FOO
#define BAR "ok"

#if defined(FOO)
include "myfunc1.h"
#elif defined(BAR) && (BAR == "ok")
include "myfunc2.h"
#else
include "myfunc3.h"
#endif
```

## Revisiting the `example_length`

- goal is to create a prototype header file which allows external access to `example_length`
  - but also allow local prototype checking

## example2.h

```
#if !defined(EXAMPLE_H)
define EXAMPLE_H
if defined(EXAMPLE_C)
define EXTERN
else
define EXTERN extern
endif

EXTERN int example_length (char *s);

#endif
```

## example2.c

```
#define EXAMPLE_C
#include "example2.h"

int example_length (char *s)
{
 int i=0;

 while (s[i] != '\0')
 i++;
 return i;
}
```

## main5.c

```
#include "example2.h"
#include <stdio.h>

main ()
{
 printf("my length program counts %d characters\n",
 example_length("hello world"));
}
```

## Tutorial

- extend the `example2` module above to include a function `example_reverse` whose prototype is:

```
char *example_reverse (char *s)
```

- and this function must be implemented to create a new string but copy the contents of, `s`, in reverse order
  - hint you will need to use `malloc`
- extend `main5.c` to test your program
- finally read about the precedence operator `##`

# Tutorial

- finally what does the following code do?
  - check the C preprocessor transformation

# Tutorial

```
#include <stdio.h>
#define FOO(X) #X " and this is something extra"
#define DEBUG(X) ("%s:%d:the value of " #X " is %d\n", \
 __FILE__, __LINE__, X)
#define BAR(X,Y) X ## Y

main()
{
 int i=9;
 int fred=3;

 printf(FOO(hi) " to do at the end of the" " lab\n");
 printf DEBUG(i);
 printf("value of fred is %d\n", BAR(fr,ed));
}
```



## Tutorial

- finally write a macro called `check_malloc` which has the same user prototype as `malloc` but checks that the result is non NULL
  - and calls `fprintf(stderr, etc, if the result is NULL`
  
- make it as useful as possible