Preprocessing

Translation Phases

- 1. multibyte character mapped, trigraphs replaced
- 2. \ newline deleted to form logical lines
- 3. decomposed into preprocessing tokens
- 4. preprocessing directives executed (#includes phases 1-4 recursively)
- 5. source character set and escape sequences mapped
- 6. adjacent string literals are concatenated
- 7. preprocessing tokens converted to tokens, translation unit is semantically analysed and translated

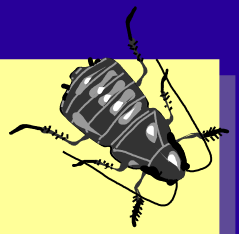
gotcha

- **phase 6:**
  - adjacent string literals are concatenated

```
const char * lines[] =
{
    "the boy stood on the burning deck",
    "his hearts was all a quiver",
    "he gave a cough, his leg fell off",
    "and floated down the river"
};
assert(sizeof(lines) / sizeof(lines[0]) == 4);
```

commas

```
const char * lines[] =
{
    "the boy stood on the burning deck",
    "his hearts was all a quiver",
    "he gave a cough, his leg fell off"
    "and floated down the river"
};
assert(sizeof(lines) / sizeof(lines[0]) == 3);
```



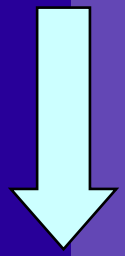
no comma

a function-like macro accepts arguments

```
# define identifier( identifier-list_opt )
      pp-tokens_opt
```

space here is not allowed

```
#define MAX(a,b)   ((a) > (b) ? (a) : (b))

func(MAX(precision, delta + epsilon));
```



```
func(((precision) > (delta + epsilon)
    ? (precision) : (delta + epsilon)));
```

function macros

- can accept a variable number of arguments
  - __VA_ARGS__ expands to the elided arguments

space here is not allowed

```
# define identifier( identifier-list_opt , ... )
    pp-tokens_opt
```

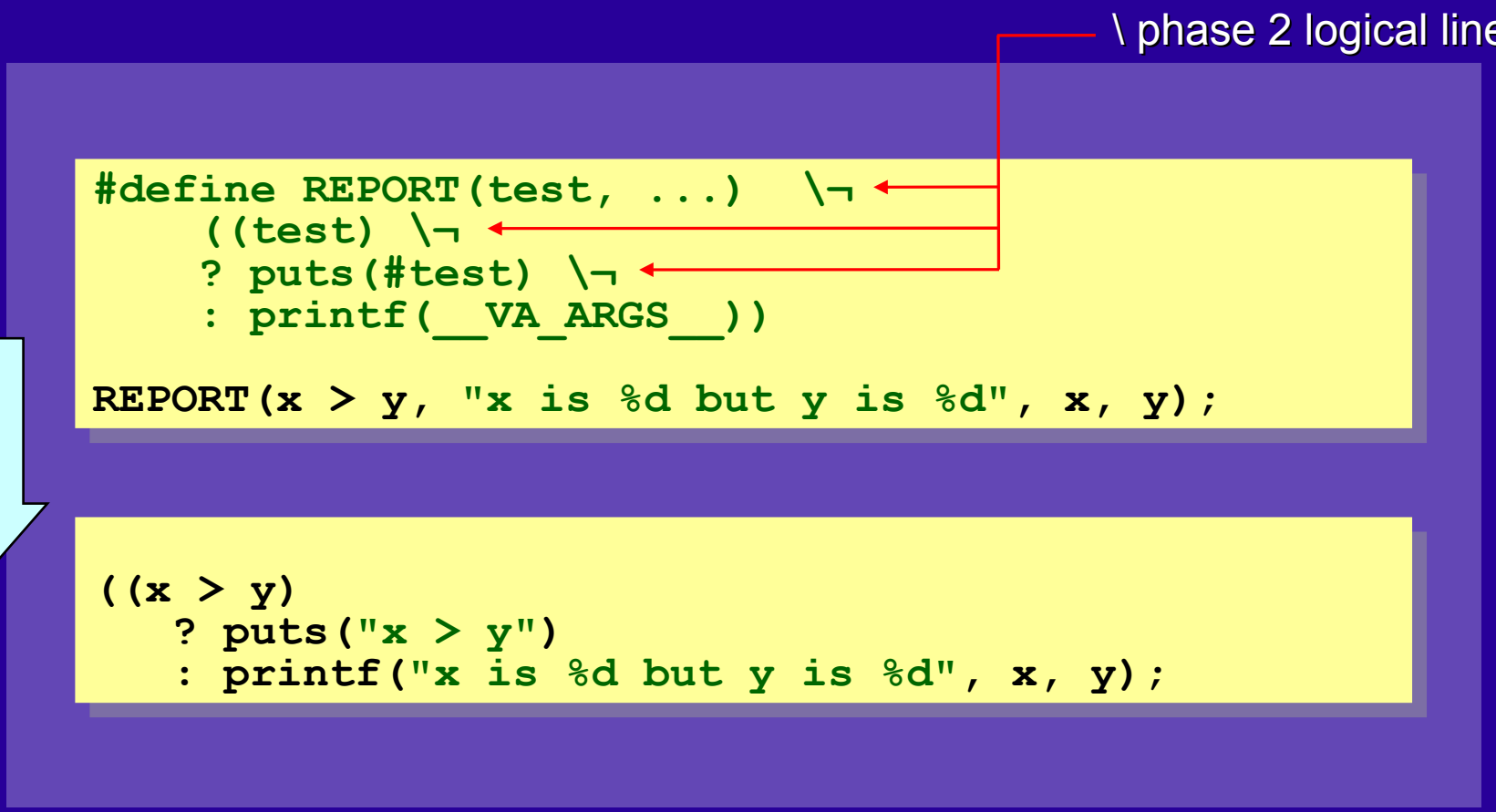
```
#define DEBUG(...)  fprintf(stderr, __VA_ARGS__)

DEBUG("error: %s", message);
```

```
fprintf(stderr, "error: %s", message);
```

c99

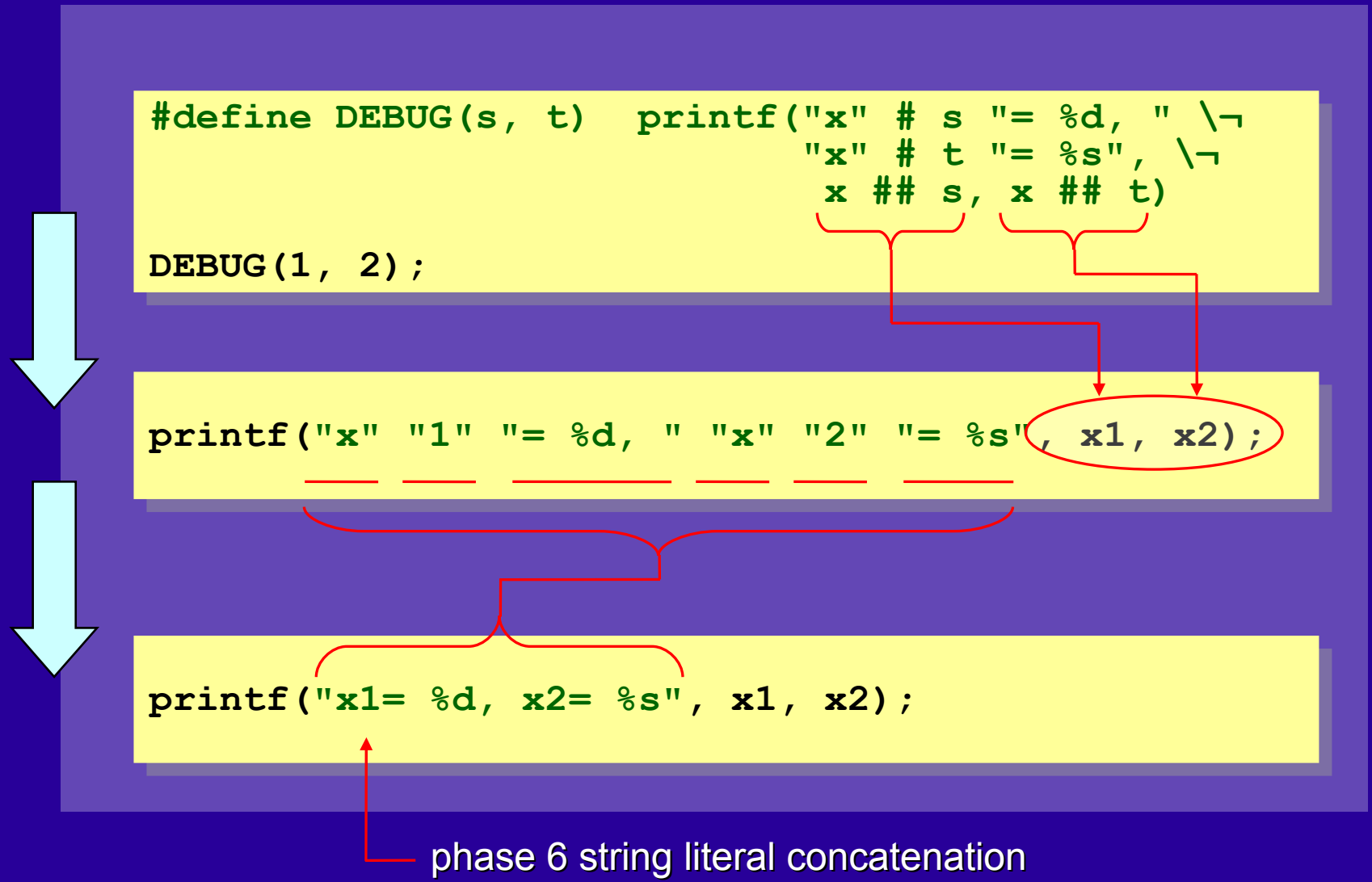
operator

- the # operator converts its argument to a string literal
  - if the argument is a string literal or character constant \ is inserted before " and \



operator

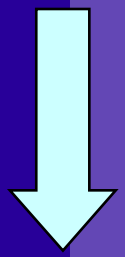
operator concatenates two arguments



- you can define an identifier as a macro name with a replacement list

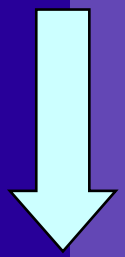
```
# define identifier  pp-tokens_opt
```

```
#define BUFFER_SIZE (100)

char buffer[BUFFER_SIZE];
```



```
char buffer[(100)];
```

```
#define printf my_printf

printf("error: %s", message);
```

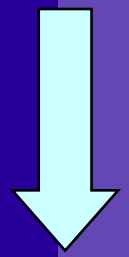


```
my_printf("error: %s", message);
```

#define #undef

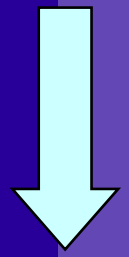
- you can define and undefine an identifier as a macro name

```
# define identifier
# undef  identifier
```



```
#define BUFFER_SIZE /*nothing*/

char buffer[BUFFER_SIZE];
```

```
char buffer[];
```



```
#define BUFFER_SIZE (100)
#undef  BUFFER_SIZE

char buffer[BUFFER_SIZE];
```

```
char buffer[BUFFER_SIZE];
```

predefined macros

- __func__
  - the name of the current function (a string literal)
- __FILE__
  - the name of the current source file (a string literal)
- __LINE__
  - the line number of the current source line (an integer constant)
- __DATE__
  - the date of translation of the preprocessing translation unit (a string literal)
- __TIME__
  - the time of translation of the preprocessing translation unit (a string literal)

- **sections of code can be conditionally included/excluded from preprocessing (and hence from translation)**

```
# if constant-expression
# elif constant-expression
# else
# endif
```

#elif == #else #if

```
#if VERSION == 1
#  define INCFILE "version1.h"
#elif VERSION == 2
#  define INCFILE "version2.h"
#else
#  define INCFILE "versionN.h"
#endif
```

```
#if 0
...
#endif
```

how to exclude code when the excluded code contains /*comments*/
(remember /* comments */ do not nest)

the #if expression can determine if a macro token has been #defined or not

```
# if defined(identifier)
# if !defined(identifier)
```

```
# ifdef identifier
# ifndef identifier
```

equivalent

This is the idiomatic way to make header files idempotent†

outer/table.h

```
#ifndef OUTER_TABLE_INCLUDED
#define OUTER_TABLE_INCLUDED
...
...
...
#endif
```

in a single translation make sure every source file has a unique token

†an idempotent operation produces the same results no matter how many times it is performed

#include

- **the commonest directive**
  - **#include X is replaced by the entire contents of X**
  - **>50% of compilation is typically for #inclusions**

h-char == any character except > or newline

```
# include < h-chars >
```

q-char == any character except " or newline

```
# include " q-chars "
```

much rarer third form must expand to <> or ""

```
# include pp-tokens
```

is this a tab character?

"" for local headers

<> for system headers

rarer

```
#include "outer\table.h"
#include <stdio.h>
#include INCFILE
```

this is *not* a string literal

#include local header before system headers

- this helps to ensures they don't accidentally compile because of a previous #include
- a source file should #include its own header before any other header
- consider checking each header compiles individually as part of the build

eg.h

```
FILE * eg(void);
...
```

this should #include <stdio.h> itself

eg.c

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

eg.c

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

#error

- the #error directive
  - issues the specific diagnostic message
  - terminates the translation as a failure
  - useful when conditional

```
# error pp-tokens_opt
```

diagnostic message

```
#if TARGET == 1
#  define INCFILE "version1.h"
#elif TARGET == 2
#  define INCFILE "version2.h"
#else
#  error "TARGET must be 1 or 2"
#endif
```

#pragma

- causes implementation-defined behaviour

```
# pragma pp-tokens_opt
```

- also available via the _Pragma operator

```
_Pragma ( string-literal )
```

```
#pragma ivdep /* vectorization hint */

while (n-- > 0)
  ...
```

```
#define VECTOR_HINT _Pragma("ivdep")

VECTOR_HINT
while (n-- > 0)
  ...
```

guidelines

- **macro names should never use lowercase**
  - **uppercase and underscore only**

```
#define max(a,b)   ((a) > (b) ? (a) : (b))
```

??

this looks like a function call (with a sequence point) but it's not

```
max(delta, precision);
```

```
#define MAX(a,b)   ((a) > (b) ? (a) : (b))
```

?

this looks like a function macro

```
MAX(delta, precision);
```

guidelines

single expression function macros

```
#define MAX(a,b)  a > b ? a : b;
```

don't include a trailing semi-colon

better

```
#define MAX(a,b)  a > b ? a : b
```

put each argument in parentheses

better

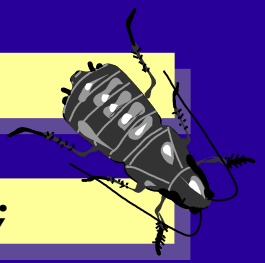
```
#define MAX(a,b)  (a) > (b) ? (a) : (b)
```

put the whole replacement text in parentheses

better

```
#define MAX(a,b)  ((a) > (b) ? (a) : (b))
```

```
f(MAX(n++, limit));
```



```
f(((n++) > (limit) ? (n++) : (limit)));
```

beware of repeated side-effects

problem

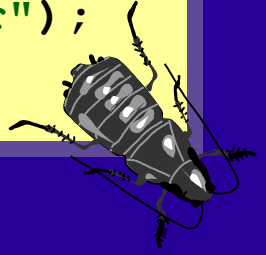
- macros bigger than a single expression…
  - can easily foul up their surrounding context

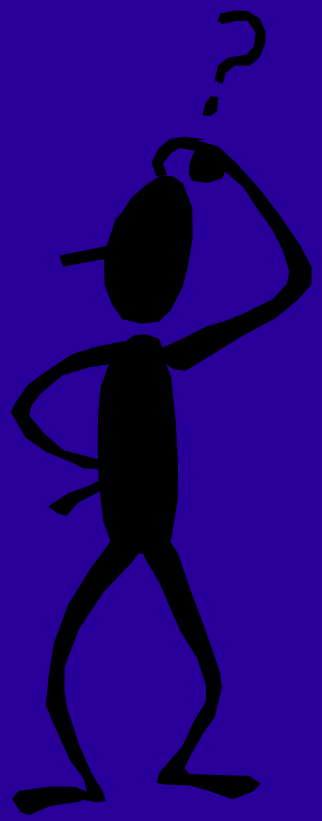
```
#define TRACE(msg)   if (dbg_mode) puts(msg)
```

??

```
if (whatever())
    TRACE("whatever");
else
    ...
```

```
if (whatever())
    if (dbg_mode)
        puts("whatever");
    else
        ...
```



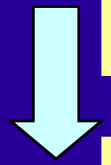


Solution 1

rephrase the logic in a single expression

```
#define TRACE(msg) \¬
    ((void) (dbg_mode && puts(msg)))
```

```
if (whatever())
    TRACE("whatever");
else
    ...
```



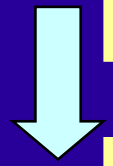
```
if (whatever())
    ((void) (dbg_mode && puts("whatever")));
else
    ...
```

Solution 2

use the do-while(0) trick

```
#define TRACE(msg)   do { \¬
                          if (dbg_mode) \¬
                              puts(msg); \¬
                     } while (0)
```

don't include a trailing semi-colon



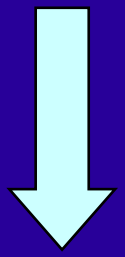
```
if (whatever())
    TRACE("whatever");
else
    ...
```

```
if (whatever())
    do {
        if (dbg_mode)
            puts("whatever");
    } while (0);
else
    ...
```

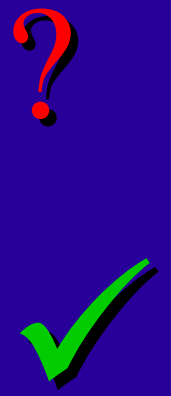
Summary

- be wary of the preprocessor
  - it knows practically nothing about C
  - it silently changes the source being compiled
  - header guards and includes are unavoidable
  - but for other #directives consider alternatives
    - function-like macro → inline function
    - object-like macro → const variable
    - object-like macro → enumerator

```
#define MAX(a,b)  ((a) > (b) ? (a) : (b))
```



```
inline int maxi(int lhs, int rhs)
{
    return lhs > rhs ? lhs : rhs;
}
```



quotes

"I'd like to see Cpp [the C pre processor] abolished."
Bjarne Stroustrup.

The Design and Evolution of C++. p426

"In retrospect, maybe the worst aspect of Cpp is that it has stifled the development of programming environments for C."
Bjarne Stroustrup.

The Design and Evolution of C++. p424

A compiler (or any translator) is of course free to merge these logical phases into a single physical phase to improve performance as long as it maintains their semantics; that is, as long as it appears logically to operate as distinct phases.

Putting a space between the identifier and the left parenthesis creates an object-like macro rather than a function-like macro. In other words, the parentheses and the identifier list become part of the replacement list. For example:

```
#define MAX (a,b) ((a) > (b) ? (a) : (b))
```

would cause the following

```
MAX(2,3)
```

to be expanded to

```
(a,b) ((a) > (b) ? (a) : (b))(2,3)
```

The variable argument list feature for macros is new in C99.

The intent of the #operator is to provide a string that contains the expression it was created from *as-the-developer-sees-it*. For example:

```
#define STR(exp)  #exp
const char * s = STR( "x\n" );
```

In this example, the string "x\n" looks visually as though it contains three characters: x, \, and n. Of course in a true string-literal the \ would be interpreted as an escape character and the string would actually only contain two characters: x and \n. However, in the example "x\n" is stringized via the STR macro. The stringizing operator inserts a \ character before any existing \ character. The preprocessed version becomes:

```
const char * s = "x\\n";
```

which is equivalent to:

```
const char s[] = { 'x', '\\', 'n', '\0' };
```

If we now print s (for example using the puts function) then the output will reflect the original expression *exactly* as the develop sees it.

The –D option is universally used as a command line option to define an object-like macro. For example

>gcc –DABC wibble.c

effectively places the line

#define ABC

at the start of the file wibble.c

It is not an error to #undef an identifier that has not been defined.

The –D option is universally used as a command line option to define an object-like macro. For example

>gcc –DABC wibble.c

effectively places the line

#define ABC

at the start of the file wibble.c

The C standard reserves several macro names that may not be used as the subject of a #define or #undef:

defined, __DATE__, __FILE__, __LINE__, __STDC__, __STDC_HOSTED__, __STDC_VERSION__, __TIME__.

For example:

#define __FILE__ "wibble.h" /* undefined behavior */

The C standard also reserves macro names starting with an underscore followed by an uppercase letter or a second underscore.

For example:

#define _ABC "wibble.h" /* undefined behaviour */

The values of the predefined macros __DATE__ and __TIME__ remain the same throughout the translation unit.

There are a few other predefined macros:

__STDC__ defined to be 1 on a conforming implementation

__STDC_HOSTED__ defined to be 1 if the implementation is a hosted implementation or 0 if it is not.

Another technique developers sometimes use to ensure their header files are idempotent is to include the current date/time as part of the token. For example:

```
#ifndef  TABLE_2008_April_10th_10_23AM
#define TABLE_2008_April_10th_10_23AM
…
#endif
```

The locations where the translator searches for the files named between the <> or "" characters are implementation defined.

If the location search fails for the "q-chars" version the translator will try again as if it read <q-chars>.

The sequence \t (for example) in a #include filename may or may not be a tab character. It depends on the implementation-defined mapping of the physical source file characters in phase 1. The filename can be made more portable by using a forward slash instead of a backslash.

```
#include "outer/table.h"
```

The use of the third kind of #include is less common but is quite often used by frameworks.

Many compilers do not (by default) allow you to compile a .h file.

However, compilers often have a switch which can be thrown to force a compilation. For example, on the Microsoft compiler uses the /TC command line switch for force a file to be compiled as C (regardless of its filename extension).

Another option is to copy a .h file to a file with a .c extension so it can be compiled.

The standard defines the #pragma directive in clause 6.10.6 and the _Pragma operator in clause 6.10.9

The standard reserves the following three specific #pragmas

#pragma STDC FP_CONTRACT *on-off*

#pragma STDC FENV_ACCESS *on-off*

#pragma STDC_CX_LIMITED_RANGE *on-off*

where *on-off* is either ON or OFF or DEFAULT