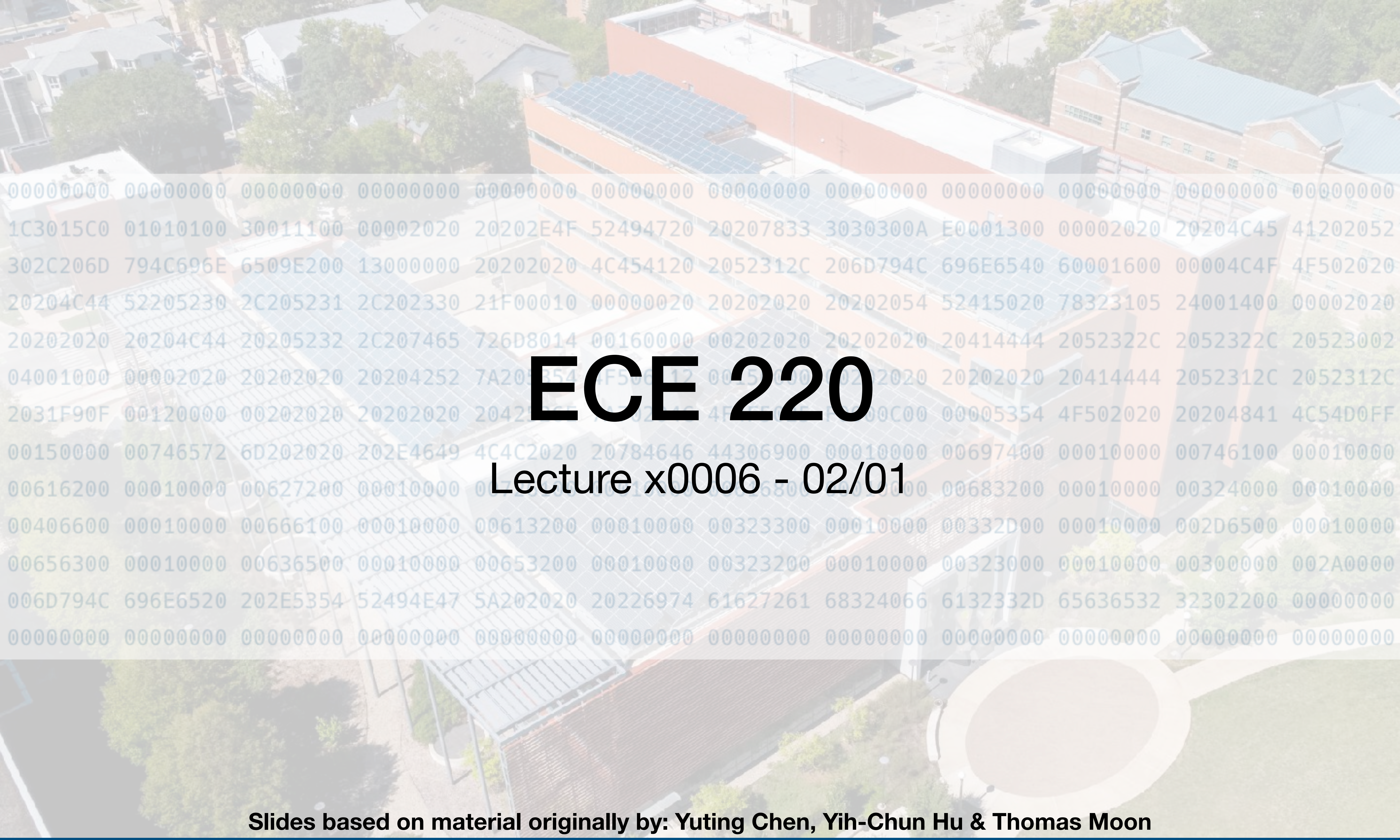


```
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
1C3015C0 01010100 30011100 00002020 20202E4F 52494720 20207833 3030300A E0001300 00002020 20204C45 41202052
302C206D 794C696E 6509E200 13000000 20202020 4C454120 2052312C 206D794C 696E6540 60001600 00004C4F 4F502020
20204C44 52205230 2C205231 2C202330 21F00010 00000020 20202020 20202054 52415020 78323105 24001400 00002020
20202020 20204C44 20205232 2C207465 726D8014 00160000 00202020 20202020 20414444 2052322C 2052322C 20523002
04001000 00002020 20202020 20204252 [illegible] 20202020 20414444 2052312C 2052312C
2031F90F 00120000 00202020 20202020 [illegible] 00005354 4F502020 20204841 4C54D0FF
00150000 00746572 6D202020 202E4649 4C4C2020 20784646 44306900 00010000 00697400 00010000 00746100 00010000
00616200 00010000 00627200 00010000 [illegible] 00683200 00010000 00324000 00010000
00406600 00010000 00666100 00010000 00613200 00010000 00323300 00010000 00332D00 00010000 002D6500 00010000
00656300 00010000 00636500 00010000 00653200 00010000 00323200 00010000 00323000 00010000 00300000 002A0000
006D794C 696E6520 202E5354 52494E47 5A202020 20226974 61627261 68324066 6132332D 65636532 32302200 00000000
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
```

ECE 220

Lecture x0006 - 02/01

Slides based on material originally by: Yuting Chen, Yih-Chun Hu & Thomas Moon

Recap

- Last time we discussed C language:
  - Dynamic vs. static typing
  - Compiled vs. interpreted languages
  - Variables in C
    - Identifiers, scope, linkage, storage class

- Data types:
  - `int, float, char, bool`

Requires `#include<stdbool.h>`

  - qualifiers
    - `static, extern`
    - `const`

Makes a variable *immutable*

“Recap”

```
#include <stdio.h>

int main(){
// defining integer constant using const keyword
const int int_const = 25;

// defining character constant using const keyword
const char char_const = 'A';

// defining float constant using const keyword
const float PI;
PI = 3.14;

printf("Printing value of Integer Constant: %d\n", int_const);
printf("Printing value of Character Constant: %c\n",char_const);
printf("Printing value of Float Constant: %f",PI);

    return 0;
}
```

Illegal, declaration & definition must be combined!

Remark: const

Note: `const` variables **not** immune to pointer manipulation just like `static` variables.

```c
#include <stdio.h>

int main(){
   // defining an integer constant
   const int var = 10;

   printf("Initial Value of Constant: %d\n", var);

   // defining a pointer to that const variable
   int* ptr = &var;

   // changing value
   *ptr = 500;
   printf("Final Value of Constant: %d", var);
   return 0;
}
```

Operators: basic concepts

- **Operator precedence**
- Associativity
- Statements vs. expressions
- Order of evaluation

The “rank” of an **operator** is called its **precedence**, and an operation with a higher **precedence** is performed before operations with lower **precedence**.

ASIDE: Note that this can be confusing sometimes - is highest ranked the same as ranked 1st (typical usage) or is lower rank associated smaller numbers (c.f mathematics; think low-rank matrices).

Operators: basic concepts

- Operator precedence
- **Associativity**
- Statements vs. expressions
- Order of evaluation

The **associativity** of an operator is a property that determines how operators of the *same precedence* are grouped in the absence of parentheses.

Left associative `a + b + c = (a + b) + c`

Right associative `a + b + c = a + (b + c)`

Operators: basic concepts

- Operator precedence
- Associativity
- **Statements vs. expressions**
- Order of evaluation

Statements represent a *complete* unit of work to be carried out by the digital hardware.

Expressions are syntactically valid groupings of variables, operators, and *literal* values.

```
2*(x+2)

k = k + 1;
```

Operators: basic concepts

- Operator precedence
- Associativity
- Statements vs. expressions
- **Order of evaluation**

Expressions are evaluated in order of precedence following associativity rules

```
2 + 3 - 4 + 5 = ((2 + 3) - 4) + 5
```

Operators: basic concepts

- Operator precedence
- Associativity
- Statements vs. expressions
- **Order of evaluation**

Note: The compiler order of evaluation is independent of precedence and associativity and may change between consecutive calls to the same code snippet.

`f1() + f2() + f3()` is parsed as `(f1() + f2()) + f3()` due to left-to-right associativity of operator `+`, but the function call to `f3` may be evaluated first, last, or between `f1()` or `f2()` at run time.

Operators: basic types

- **Assignment**
- Arithmetic
- Bitwise
- Relational
- Logical
- Increment/decrement

- Evaluates whatever is to the right of “=" and assigns that value to whatever is to the left of the “=“
- Beware comparison vs assignment: == vs =

Operators: basic types

- Assignment
- **Arithmetic**
- Bitwise
- Relational
- Logical
- Increment/decrement

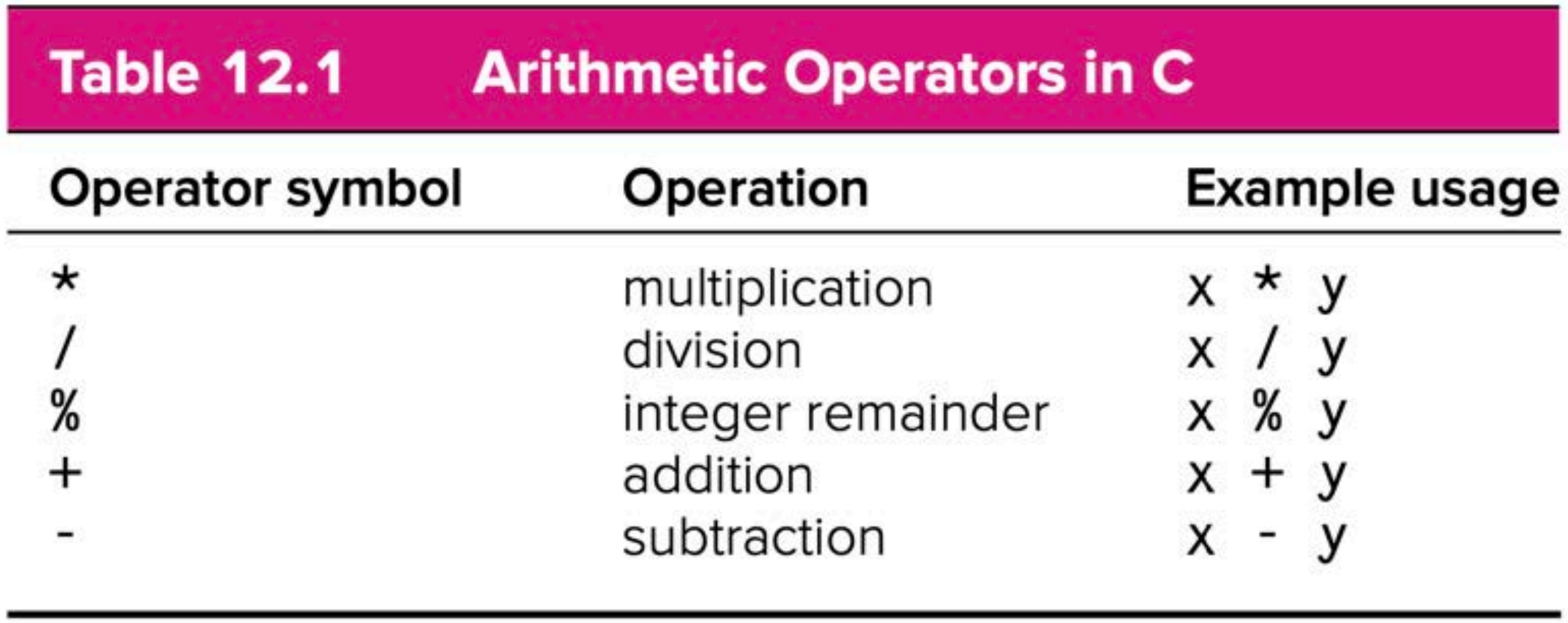


Table 12.1 Arithmetic Operators in C

Operator symbol	Operation	Example usage
*	multiplication	x * y
/	division	x / y
%	integer remainder	x % y
+	addition	x + y
-	subtraction	x - y

Operators: basic types

- Assignment
- Arithmetic
- **Bitwise**
- Relational
- Logical
- Increment/decrement

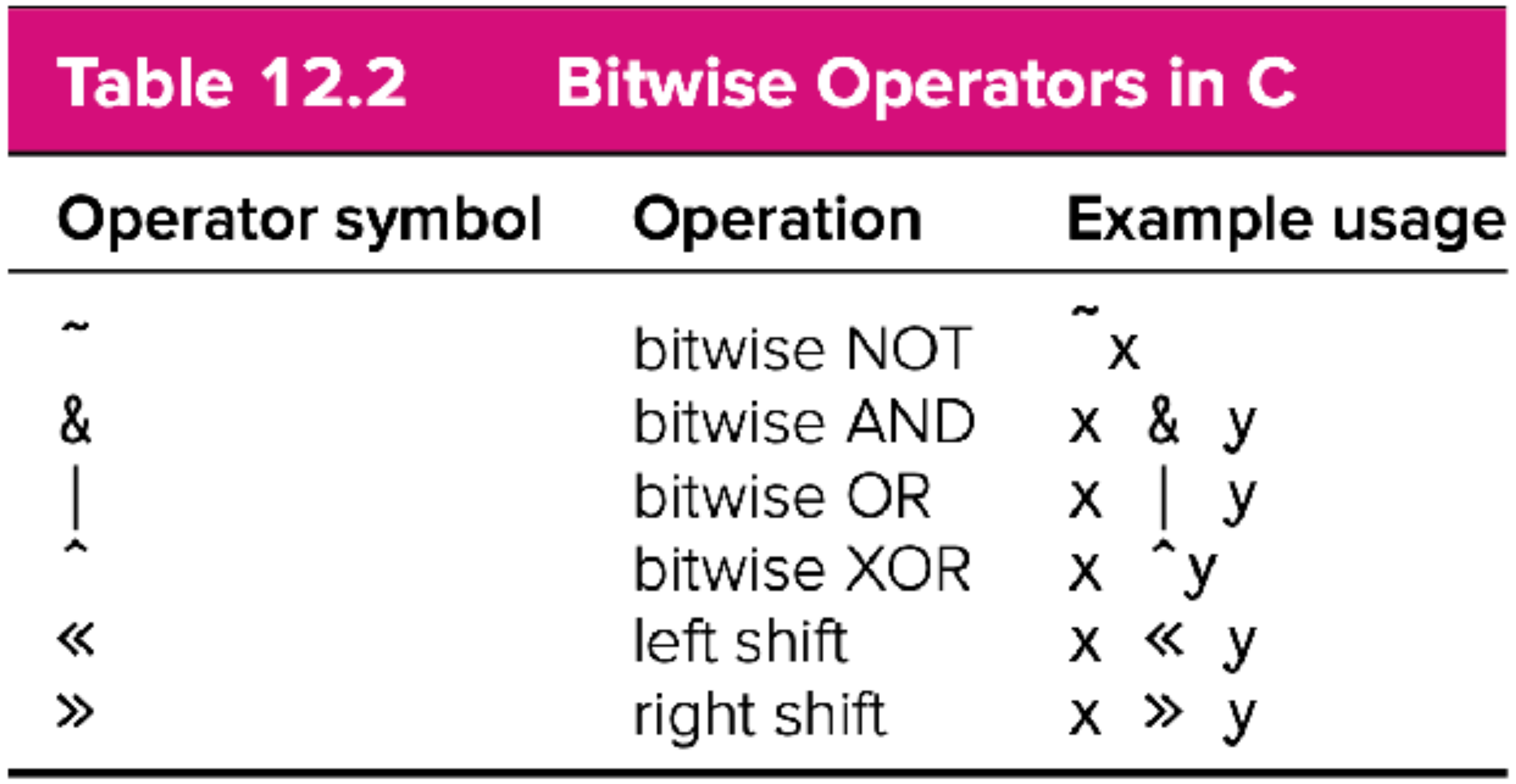


Table 12.2 Bitwise Operators in C

Operator symbol	Operation	Example usage
~	bitwise NOT	~x
&	bitwise AND	x & y
|	bitwise OR	x | y
^	bitwise XOR	x ^y
«	left shift	x « y
»	right shift	x » y

Operators: basic types

- Assignment
- Arithmetic
- Bitwise
- **Relational**
- Logical
- Increment/decrement

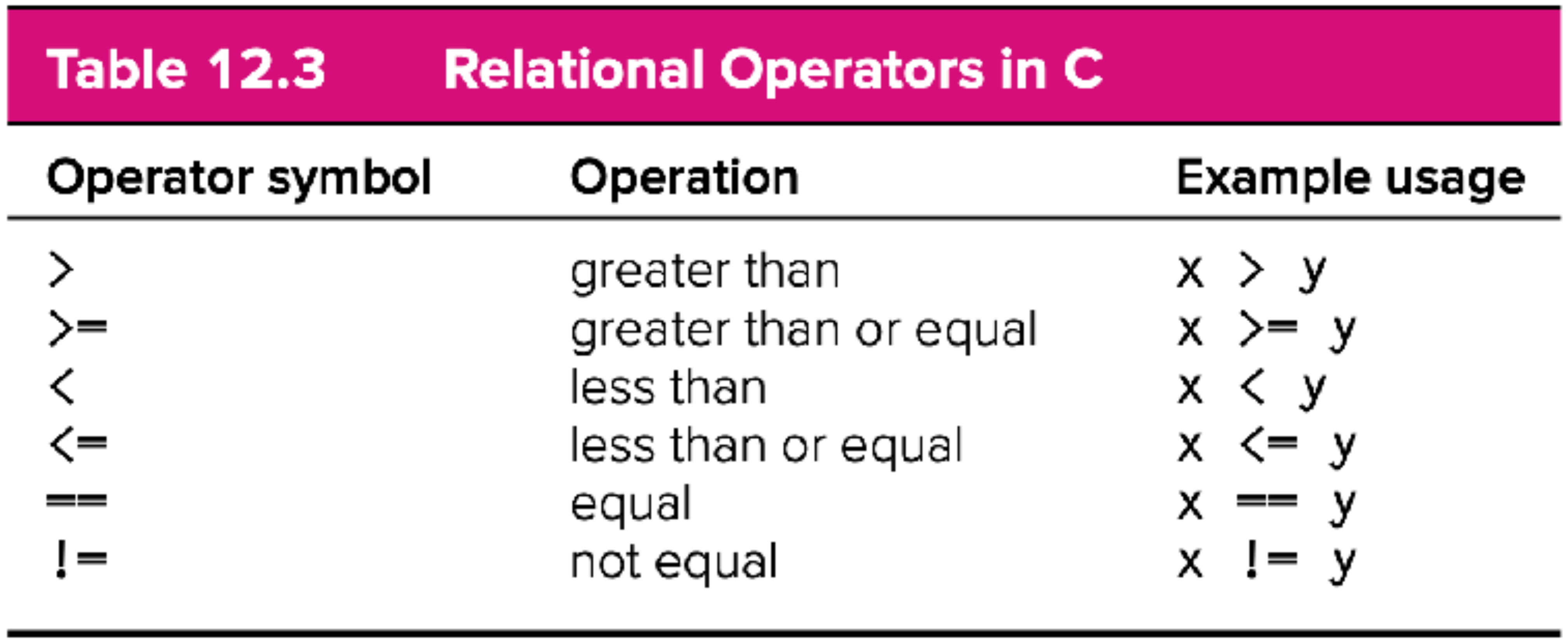


Table 12.3 Relational Operators in C

Operator symbol	Operation	Example usage
`>`	greater than	`x > y`
`>=`	greater than or equal	`x >= y`
`<`	less than	`x < y`
`<=`	less than or equal	`x <= y`
`==`	equal	`x == y`
`!=`	not equal	`x != y`

Operators: basic types

- Assignment
- Arithmetic
- Bitwise
- Relational
- **Logical**
- Increment/decrement

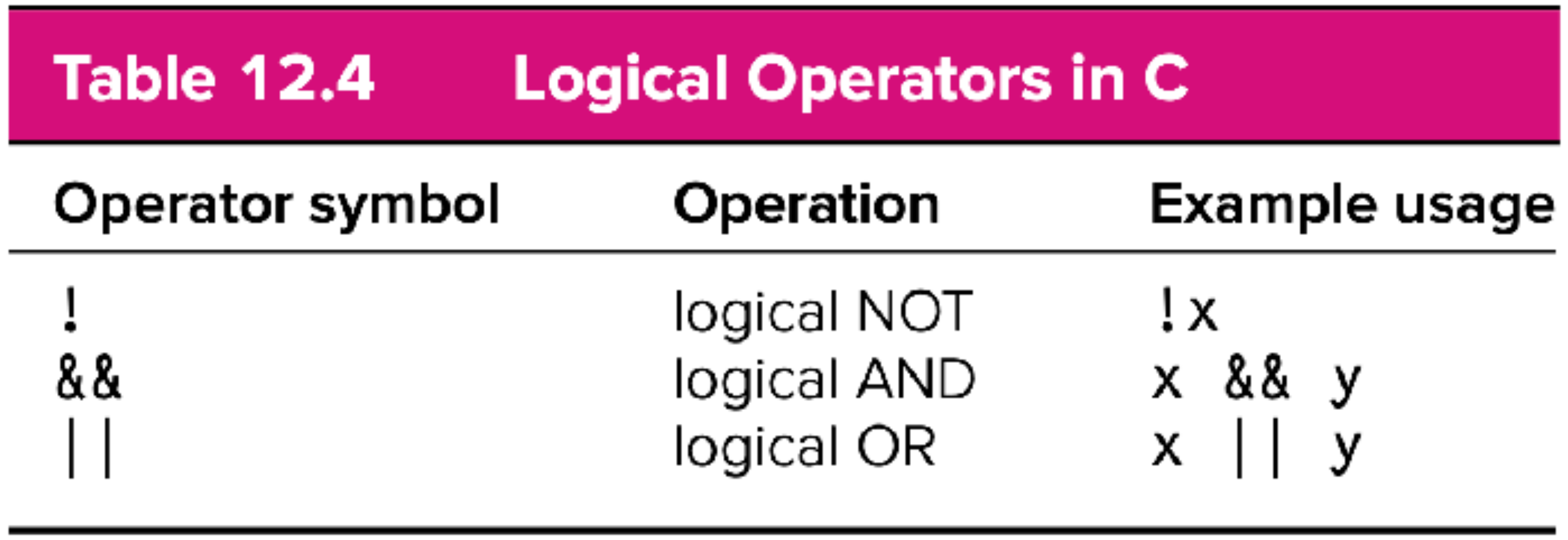


Table 12.4 Logical Operators in C

Operator symbol	Operation	Example usage
`!`	logical NOT	`!x`
`&&`	logical AND	`x && y`
`||`	logical OR	`x || y`

Operators: basic types

- Assignment
- Arithmetic
- Bitwise
- Relational
- Logical
- **Increment/decrement**

- Two flavors `pre` and `post`

```
x=4;

y=x++;

z=++x;
```

Operator precedence

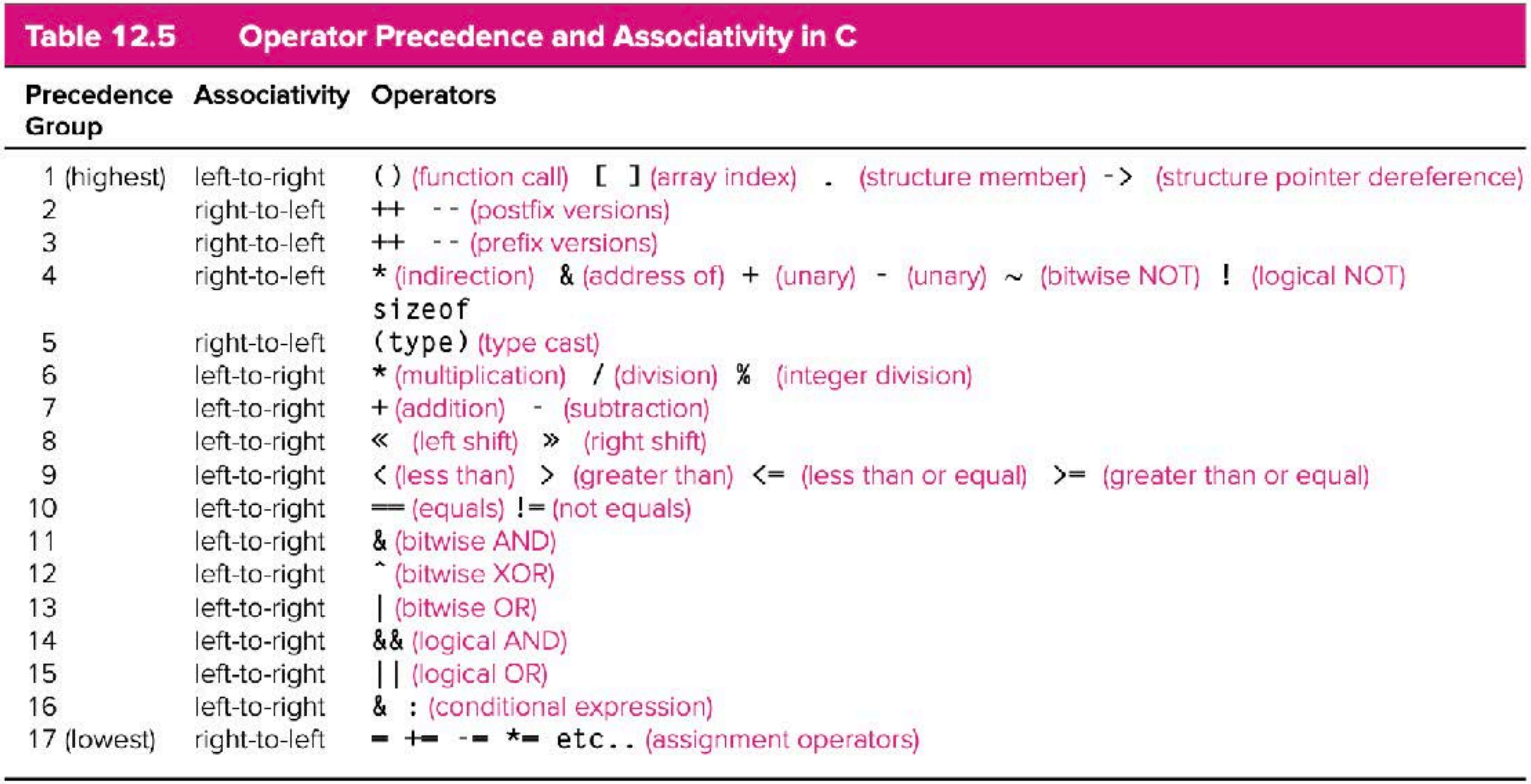


Table 12.5 Operator Precedence and Associativity in C

Precedence Group	Associativity	Operators
1 (highest)	left-to-right	( ) (function call) [ ] (array index) . (structure member) -> (structure pointer dereference)
2	right-to-left	++ -- (postfix versions)
3	right-to-left	++ -- (prefix versions)
4	right-to-left	* (indirection) & (address of) + (unary) - (unary) ~ (bitwise NOT) ! (logical NOT) sizeof
5	right-to-left	(type) (type cast)
6	left-to-right	* (multiplication) / (division) % (integer division)
7	left-to-right	+ (addition) - (subtraction)
8	left-to-right	« (left shift) » (right shift)
9	left-to-right	< (less than) > (greater than) <= (less than or equal) >= (greater than or equal)
10	left-to-right	== (equals) != (not equals)
11	left-to-right	& (bitwise AND)
12	left-to-right	ˆ (bitwise XOR)
13	left-to-right	| (bitwise OR)
14	left-to-right	&& (logical AND)
15	left-to-right	|| (logical OR)
16	left-to-right	& : (conditional expression)
17 (lowest)	right-to-left	= += -= *= etc.. (assignment operators)

More complete table: https://en.cppreference.com/w/c/language/operator_precedence

Operator precedence

- Based on the operator precedence table rewrite the following expression using parentheses to indicate precedence:

```
x & z + 3 || 9 – w % 6
```

Basic output

- We already saw the use cases for `printf` command.

- **Exercise:** Type in `man printf` into the terminal. Issue any other command required. Read about format specifiers. What will the following output?

    - `printf(“%+d is a prime number\n”, 43);`

    - `printf(“43+59 in hexadecimal is: %x\n”, 43+59);`

    - `printf(“%.3f is approximately PI.\n”, 22.0/7);`

How to check?

Option 1: Compile & run

```c
#include <stdio.h>


int main(void){
   printf("%+d is a prime number.\n", 43);
   printf("43 + 59 in hexadecimal is: %x\n", 43+59);
   printf("%.3f is approximately PI.\n", 22.0/7);
   return 0;
}
```

Option 2: Check from bash (advanced)

```
$ printf "%+d is a prime number.\n" 43
+43 is a prime number.

$ printf "43 + 59 in hexadecimal is %x\n" $((43 + 59))
43 + 59 in hexadecimal is 66

$ printf "%.3f is approximately PI\n" `dc --expression "3 k 22 7 /p"`
3.142 is approximately PI
```

Basic input

- The command for reading console input is `scanf` with the following syntax.

```
scanf(format_specifier, varMemAddress)
```

- **Examples:**
  - `scanf(“%d”,` $\boxed{\texttt{\&some\_int}}$`);`
  - `scanf(“%f”,` $\boxed{\texttt{\&some\_float}}$`);`

Takes memory address of `some_int` and `some_float`

Basic input/output

- **Exercise**: What will be the output of the following code snippet?

```
        #include <stdio.h>

        int main(void){
          int num1, num2;
          printf("Enter the first number:\t");
23 ───→   scanf("%d", &num1);
          printf("Enter the second number:\t");
ef ───→   scanf("%x", &num2);
          int mysum = num1 + num2;
          printf("The sum of %i and %d is: %d", num1, num2, mysum);
          return 0;
        }
```

Control structures in C

1. Conditional

Making a decision about which code to execute, based on evaluated expression

- `if`
- `if-else`
- `switch`

2. Iteration

Executing code multiple times, ending based on evaluated expression

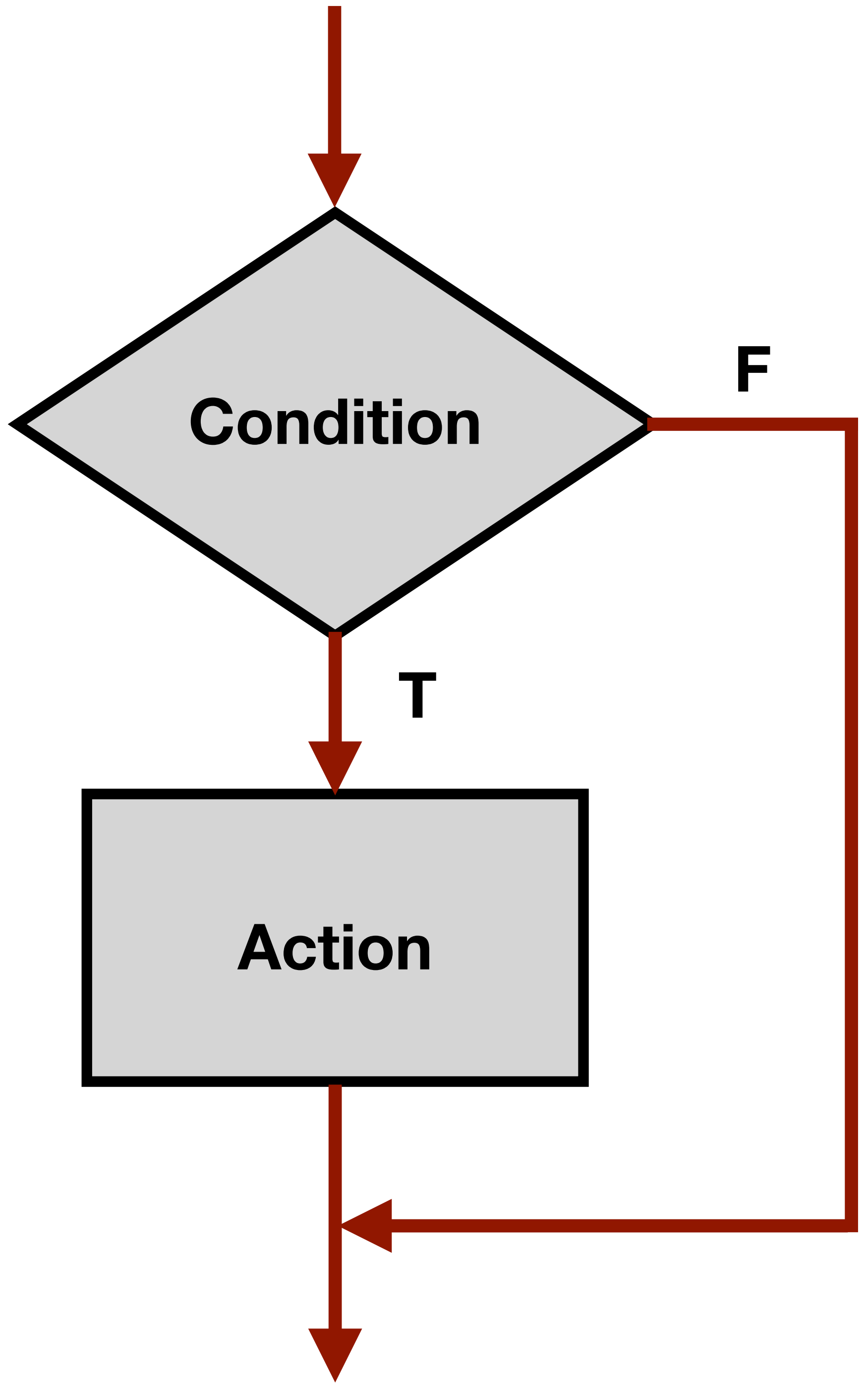
- `while`
- `for`
- `do-while`

The if statement

Condition: C expression, which evaluates to `TRUE` (non-zero) or `FALSE` (zero)

```
if (condition)
    action ;
```

Action: C statement, which will be executed if condition `if` is `TRUE`



The if statement

```
if (x <= 10)
        y = x * x + 5;
```

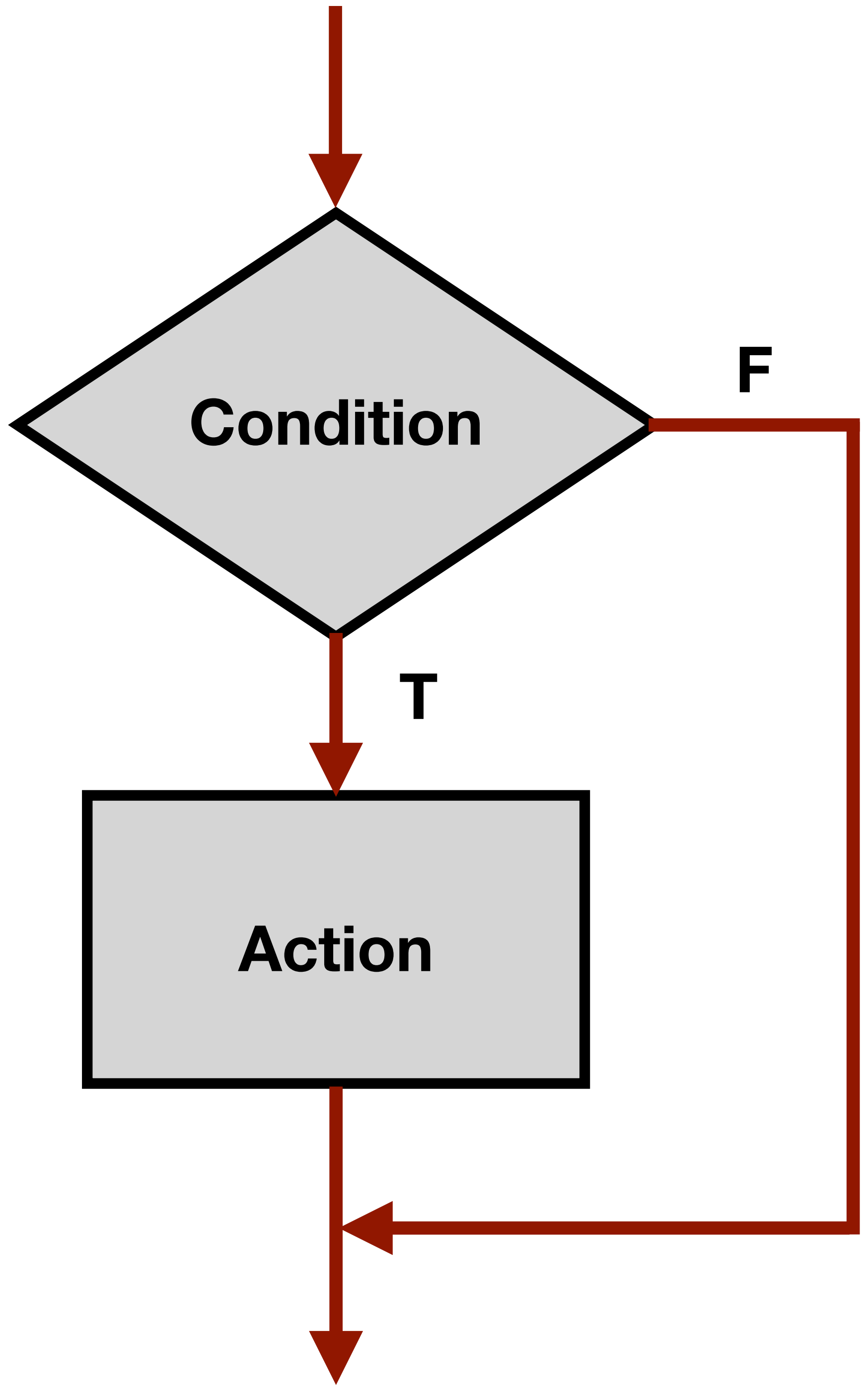
$\Longleftrightarrow$

```
if (x <= 10){
    y = x * x + 5;
}
```

```
if (x <= 10){
        y = x * x + 5;
        z = (2 * y) / 3;
}
```

$\not\Longleftrightarrow$

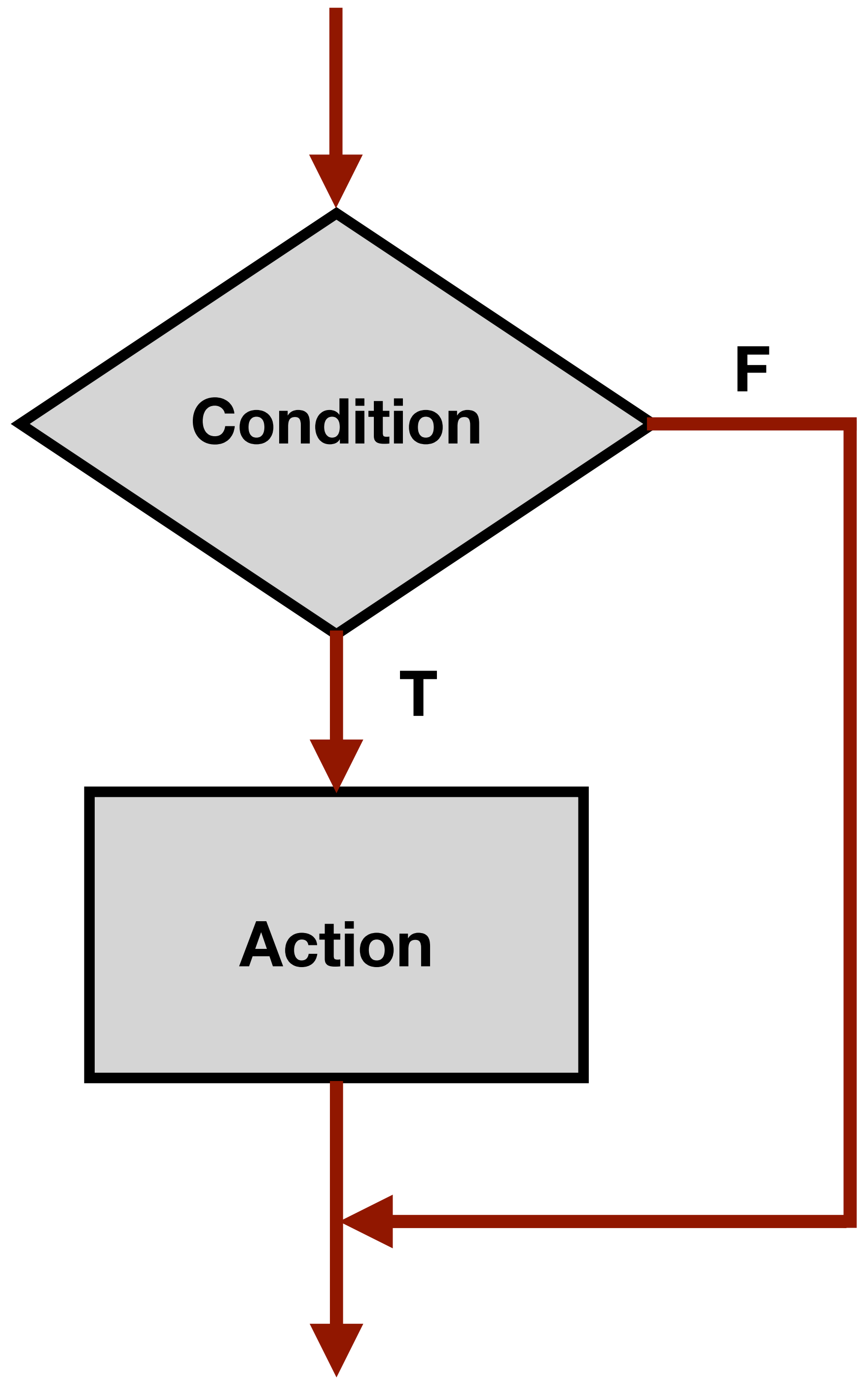
```
if (x <= 10)
    y = x * x + 5;
    z = (2 * y) / 3;
```



Example : if statement

```
if (x < 0)
    x = -x;    // invert x only if x < 0


if ((x > 5) && (x  < 25))
{
    int y = x * x + 5;

}

printf("y = %d\n", y);

if (x = 2){
  y = 5;
}
```

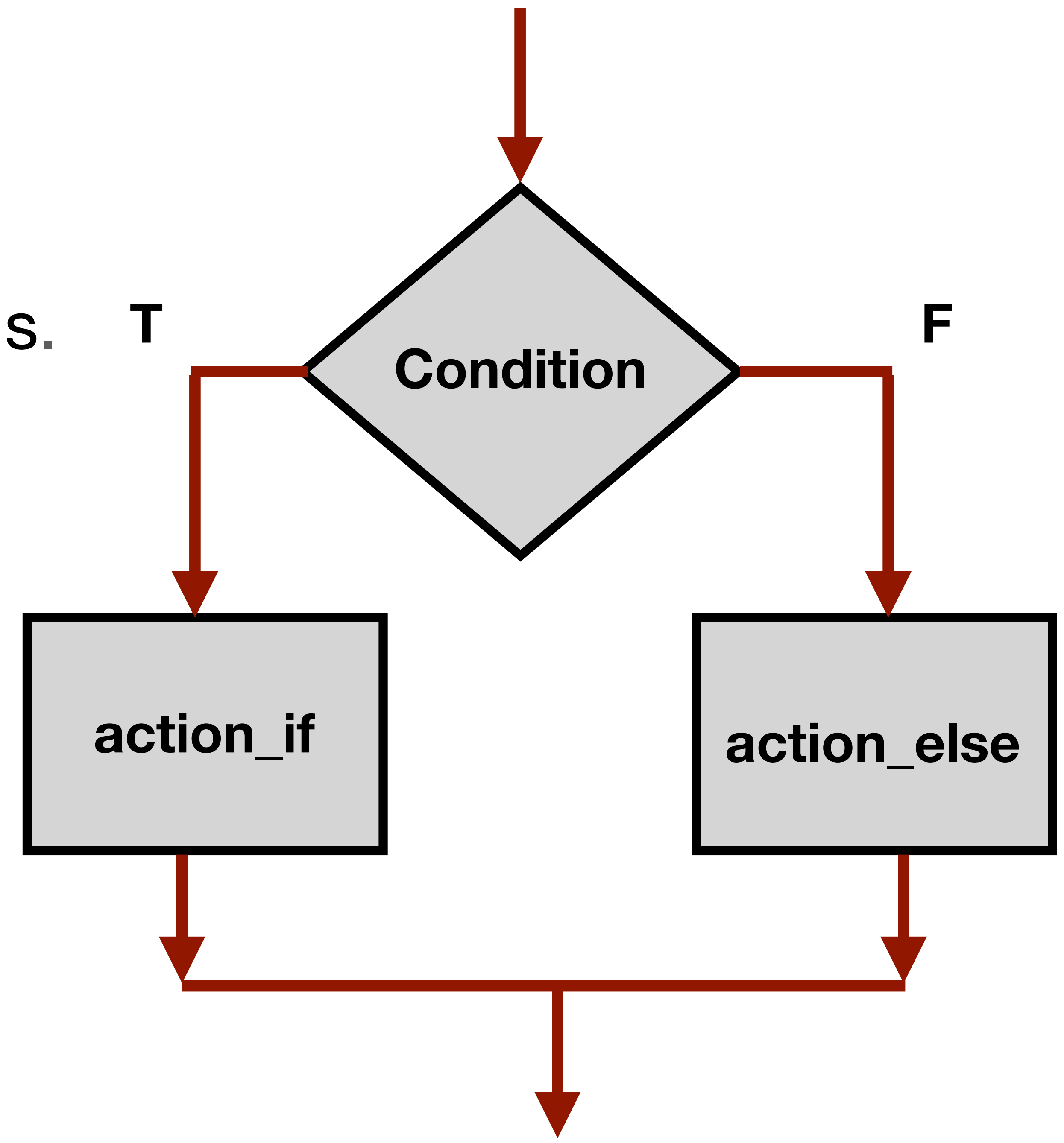
$\longrightarrow$ Always True!
Common programming error (= instead of ==)
not caught by compiler because it's syntactically correct.



The if-else statement

```
if (condition)
    action_if;
else
    action_else;
```

Else: allows choice between two mutually-exclusive actions.



Example 1

```
if (x < 0){
    x = -x;
}
else{
    x = x * 2;
}
```

Example 2

```
if ((x > 5) && (x < 25))
{
  y = x * x +5;
  printf("y = %d\n", y);
}
else
  printf("x = %f\n", x);
```

Remark about floats

```
#include<stdio.h>

int main(void){
  float my_float = 3.14;

  if (my_float==3.14)
    printf("My float is PI\n");
  else
    printf("My float is not PI\n");

  double my_double = 3.14;
  if (my_double == 3.14)
    printf("My double is PI\n");
  else
    printf("My double is not PI\n");
  return 0;
}
```

```
My float is not PI

My double is PI
```

Add this line to see why. What is the fix?

```
printf("%lu, %lu, %lu\n", sizeof(3.14), sizeof(3.14f), sizeof(my_float));
```

Remark about floats

```
#include<stdio.h>

int main(void){
  float my_float = 3.14;

  if (my_float==3.14f)
    printf("My float is PI\n");
  else
    printf("My float is not PI\n");

  double my_double = 3.14;
  if (my_double == 3.14)
    printf("My double is PI\n");
  else
    printf("My double is not PI\n");
  return 0;
}
```

```
My float is not PI
```

```
My double is PI
```

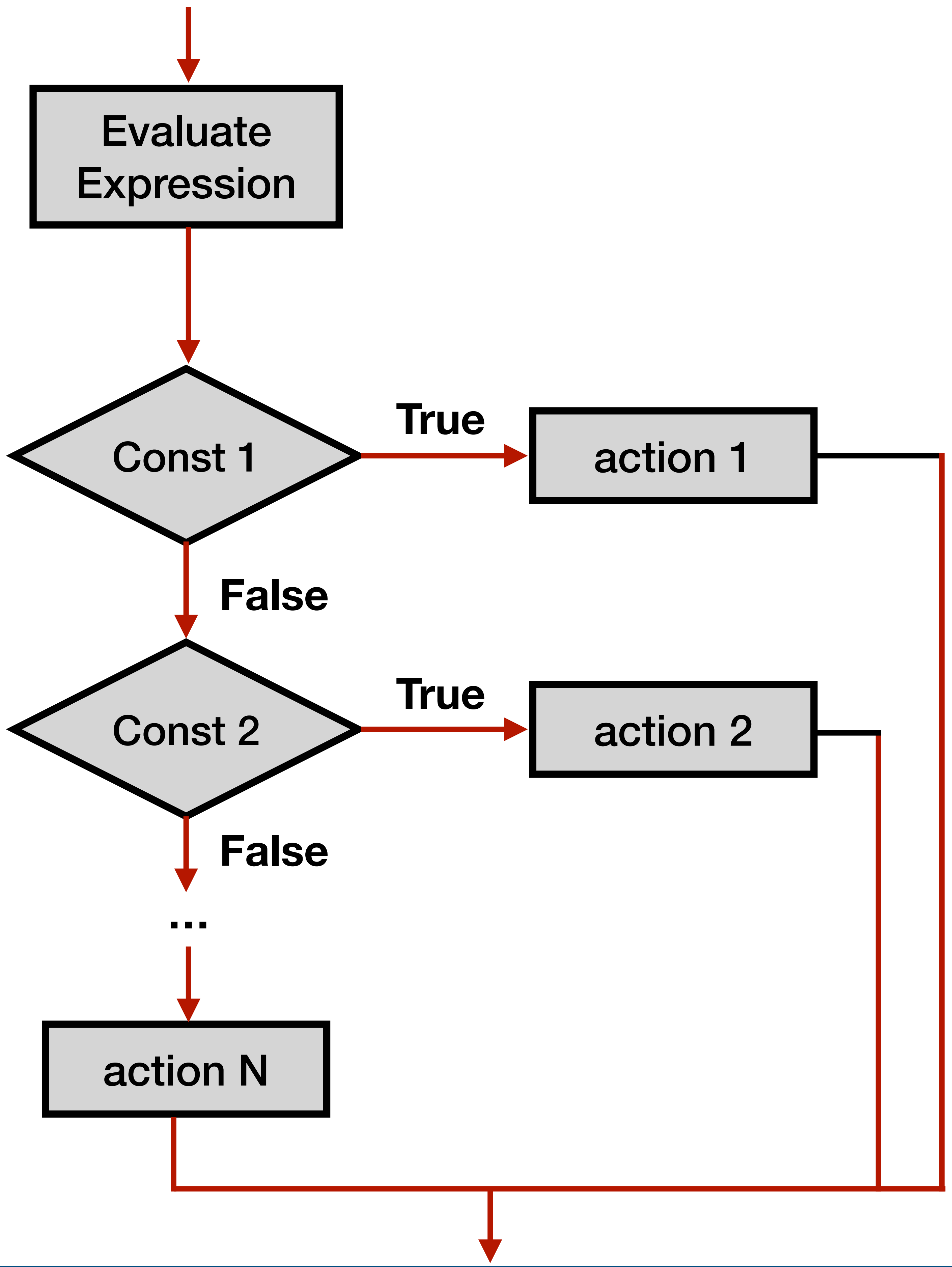
Add this line to see why. What is the fix?

```
printf("%lu, %lu, %lu\n", sizeof(3.14), sizeof(3.14f), sizeof(my_float));
```

Chaining if-else

```
if (month == 4 || month == 6 || month == 9 || month == 11){
     printf(“Month has 30 days. \n”);
}
else if (month == 1 || month == 3 || month == 5 ||
         month == 7 || month == 8 || month == 10||
         month == 12 ){
      printf(“Month has 31 days. \n”);
}
else if (month == 2){
      printf(“Month has 28 or 29 days. \n”);
}
else{
      printf(“Don’t know that month. \n”);
}
```

The switch statement



```
if
else if
else if
…
else
```

```
switch (expression)
{
    case const 1:
         action 1;
         break;
    case const 2:
         action 2;
         break;
    ...
   default:
        default action;
        break;
}
// notice the use of break
```

If **break** is not used, then cases fall through!

The switch statement

```
a = 1;
switch(a){
    case 1:
        printf("A");
        break;
    case 2:
        printf("B");
        break;
    default:
        printf("C");
        break;
}
```

Output : `A`

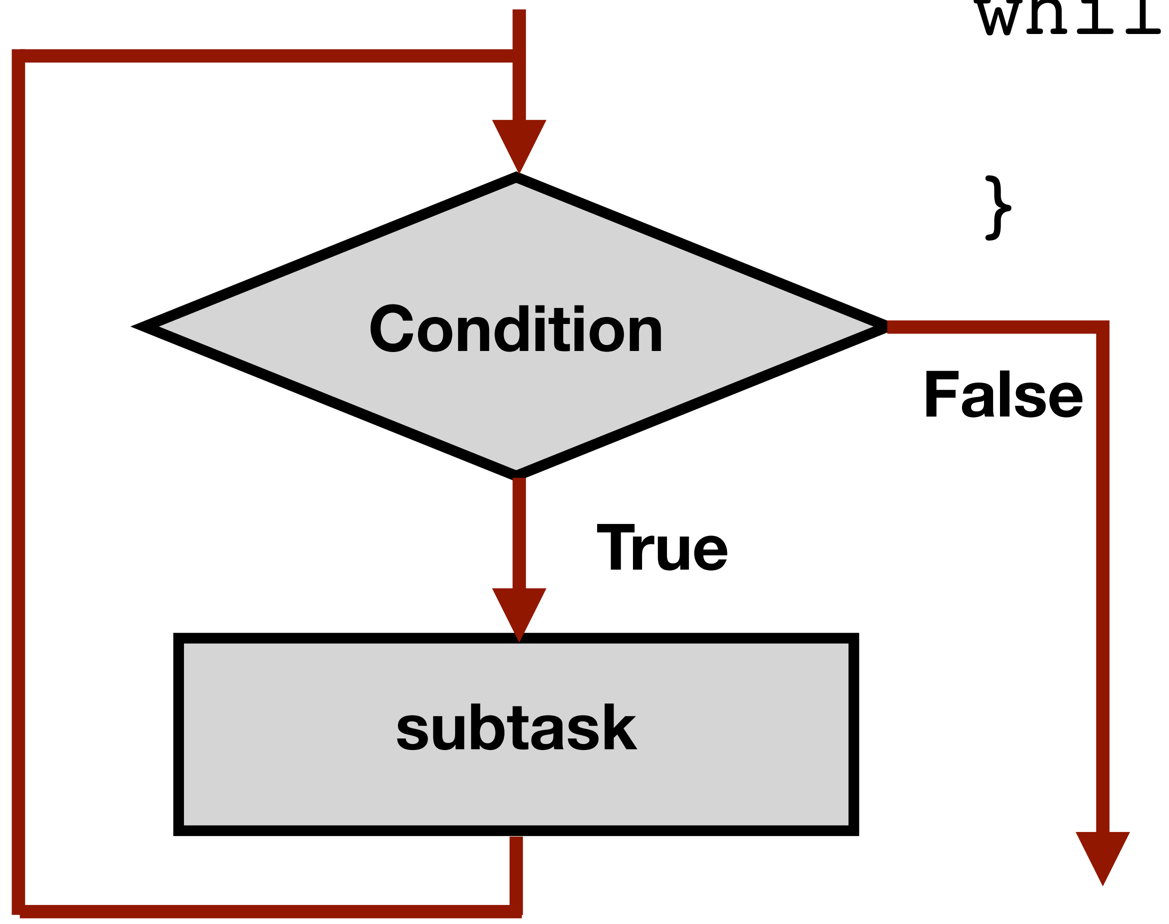
```
a = 1;
switch(a){
    case 1:
        printf("A");
    case 2:
        printf("B");
    default:
        printf("C");
}
```

Output : `ABC`

The while / do-while statement

`while` statement

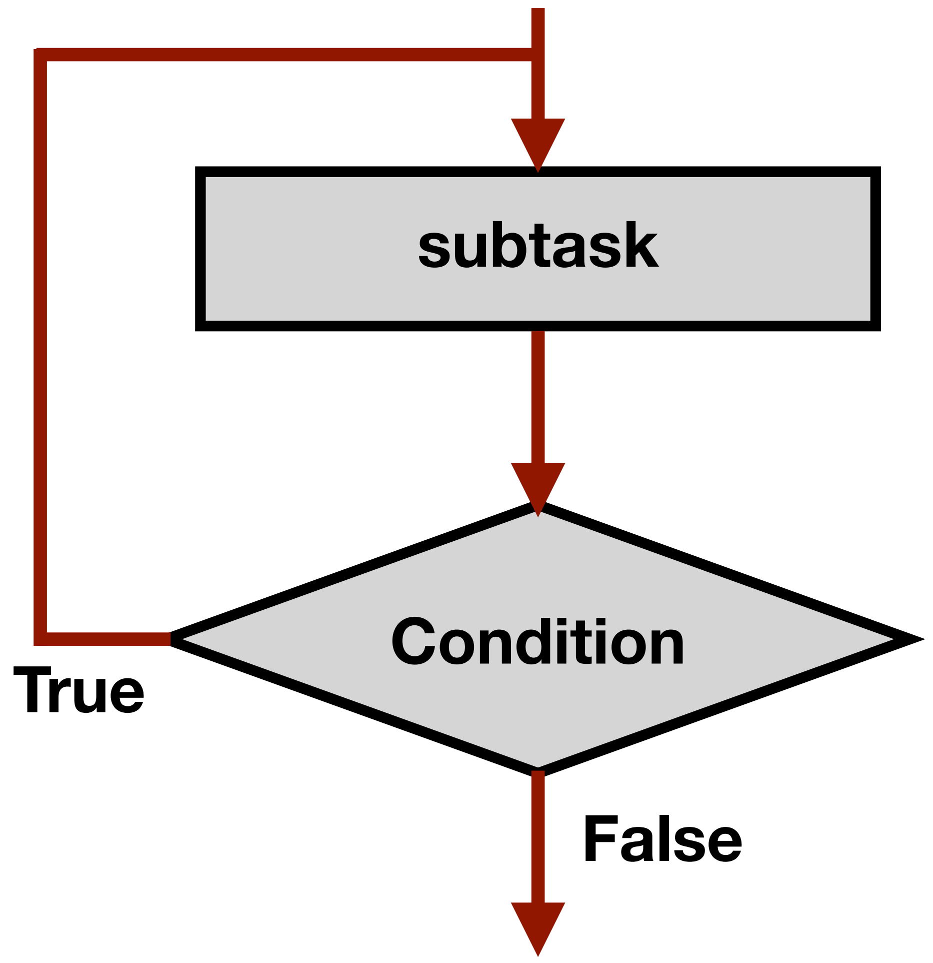
- Loop body may or may not be executed even once
- Test is evaluated **before** executing the loop.



```
while(test){
        loop_body;
}
```

`do-while` statement

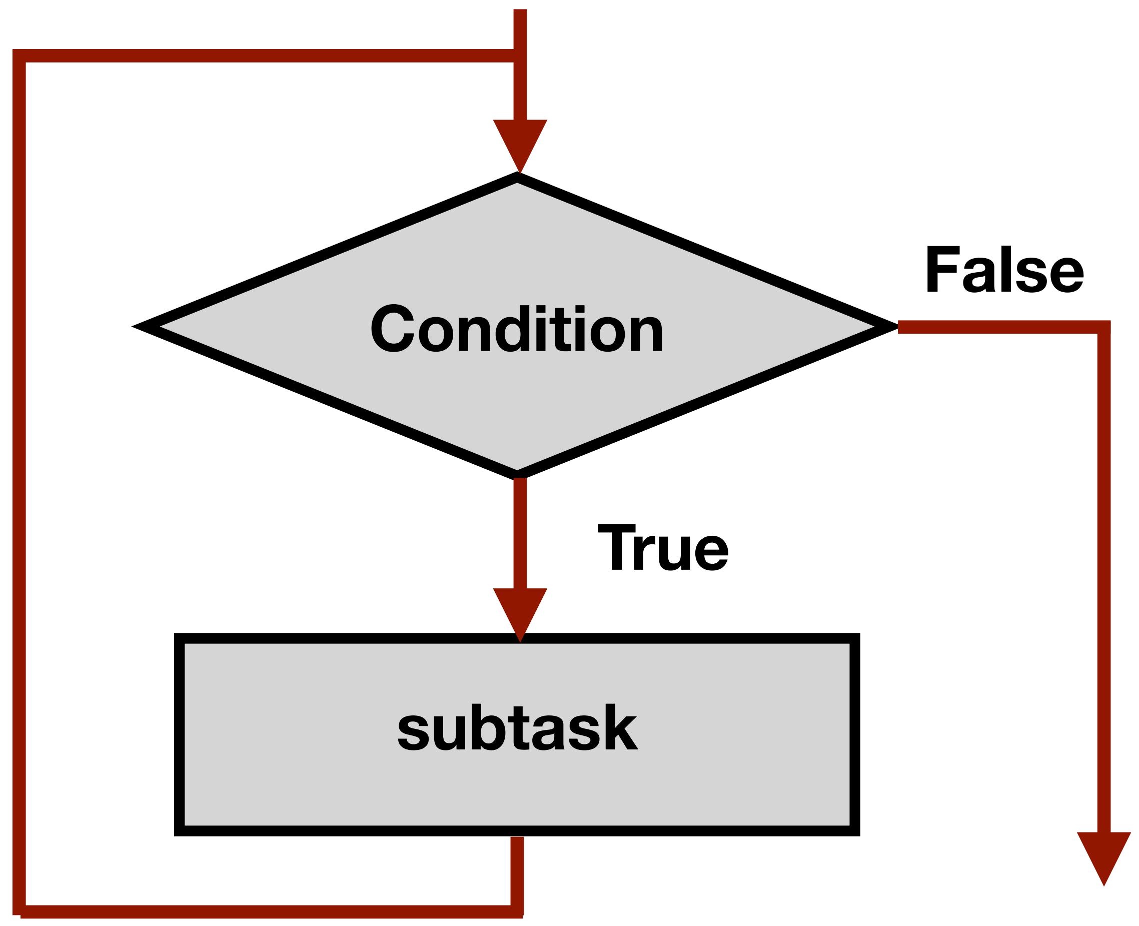
- Loop body will be executed at least once
- Test is evaluated **after** executing loop body



```
do{
        loop_body;
}while (test);
```

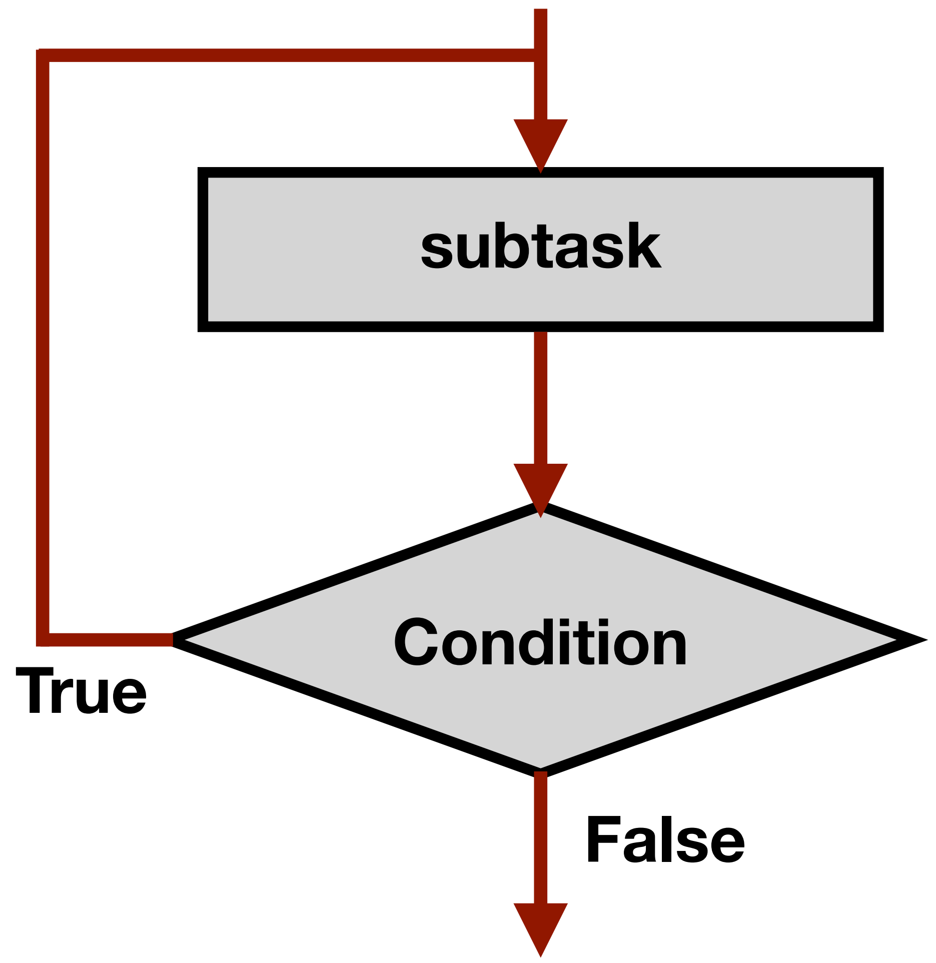
The while / do-while statement

while statement



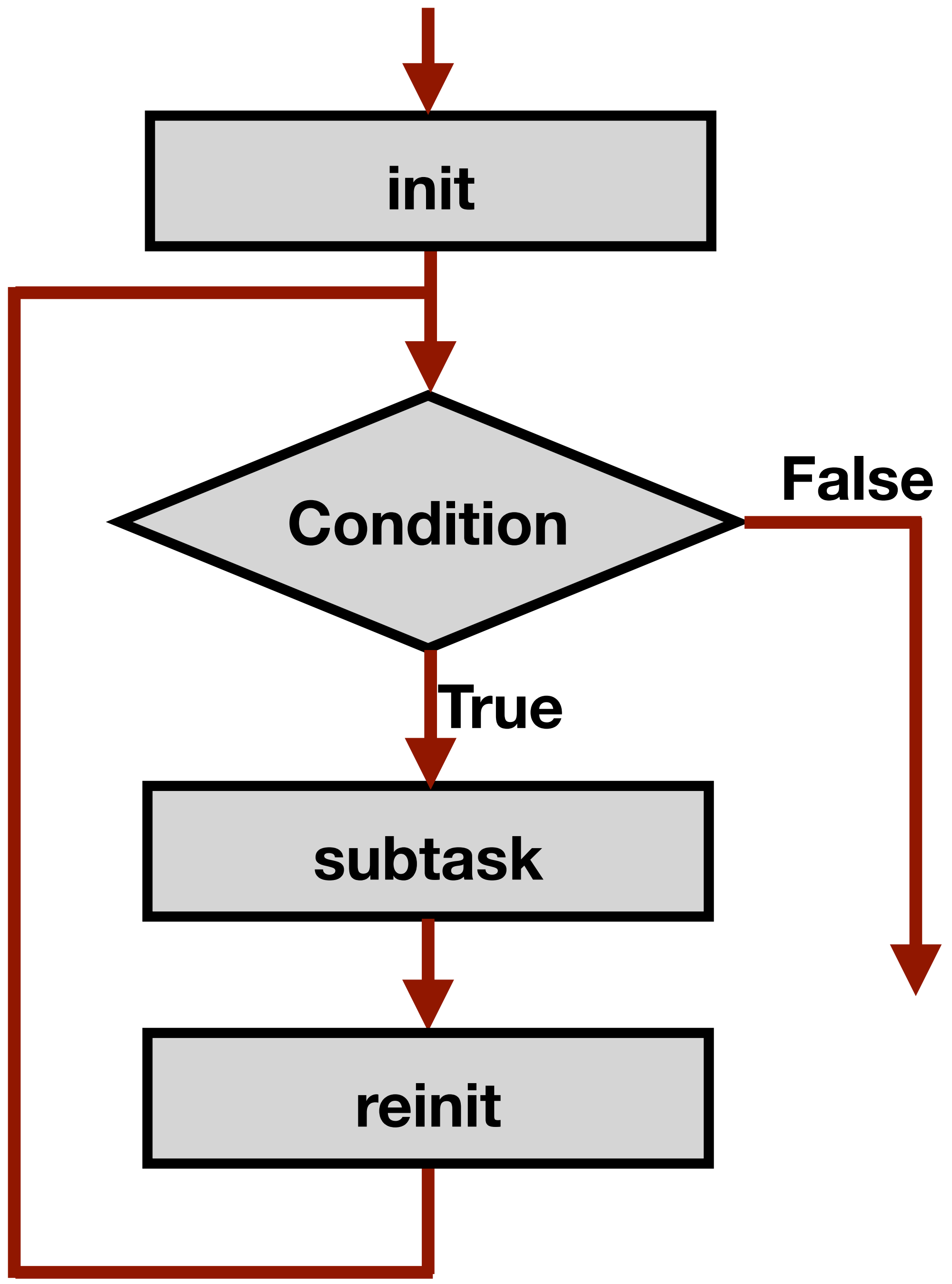
```
x = 0;
while (x < 10)
  printf(“x=%d\n”, x++);
```

do-while statement



```
do
  printf(“x=%d\n”, x++);
while (x < 10);
```

The for statement



```
for (x = 0; x < 10; x++)
{
    printf("x=%d\n", x);
}
```

```
for (x = 0; x < 10; x++)
{
    if (x == 5)
      break;
    printf("x=%d\n", x);
}
```

```
for (init; end-test; update)
      statement
```

break vs. continue

- break
  - Used only in switch or iteration statement
  - Used to exit a loop before terminating condition occurs

```
for (i = 0; i < 10; i++){
    if(i == 5)
        break;
    printf("%d ",i);
}
```

Output : `0 1 2 3 4`

- continue
  - Used only in iteration statement
  - End the current iteration and start the next

```
for (i = 0; i < 10; i++){
    if (I == 5)
      continue;
    printf("%d ",i);
}
```

Output : `0 1 2 3 4 6 7 8 9`

Exercises

- Write a program that prompts and accepts an integer valued temperature reading in Fahrenheit and displays its decimal equivalent in degrees Celsius.

  - Can you modify the program to keep running until the user enters a temperature below absolute zero in Fahrenheit?

Exercises

- Write a program that prompts and accepts an integer n from the user and then provided that $1 \leq n \leq 8$, prints out a $n \times n$ identity matrix to the console.

    - How would you modify the program to make it print out a *lower triangular* or *upper triangular* identity matrix?

$$\begin{bmatrix} 1 & & & \\ 0 & 1 & & \\ 0 & 0 & 1 & \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad \begin{bmatrix} 1 & 0 & 0 & 0 \\ & 1 & 0 & 0 \\ & & 1 & 0 \\ & & & 1 \end{bmatrix}$$

Exercise

- Can you rewrite using switch case?

```
if (month == 4 || month == 6 || month == 9 || month == 11){
     printf(“Month has 30 days. \n”);
}
else if (month == 1 || month == 3 || month == 5 ||
         month == 7 || month == 8 || month == 10||
         month == 12 ){
      printf(“Month has 31 days. \n”);
}
else if (month == 2){
      printf(“Month has 28 or 29 days. \n”);
}
else{
      printf(“Don’t know that month. \n”);
}
```

Exercise

- Can you rewrite using switch case?

```
  switch(n){
    case 1: case 3: case 5: case 7: case 8: case 10: case 
12:
      printf("Month has 31 days!\n");
      break;
    case 4: case 6: case 9: case 11:
      printf("Month has 30 days!\n");
      break;
    case 2:
      printf("Month has 28 or 29 days!\n");
      break;
    default:
      printf("Do not know that month!\n");
  }
}
```