ECE 220

Lecture x0006 - 09/12

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

Recap

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- Last time we discussed C language:

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      - `const`

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Requires `#include<stdbool.h>`

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

Makes a variable *immutable*

“Recap”

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```c
#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;
}
```

“Recap”

```c
#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!

Operators: basic concepts

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

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

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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

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

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

Operators: basic concepts

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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

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- Associativity
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Operators: basic concepts

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- **Statements vs. expressions**
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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.

Operators: basic concepts

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- **Statements vs. expressions**
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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
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Operators: basic concepts

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Expressions are evaluated in order of precedence following associativity rules

Operators: basic concepts

- Operator precedence
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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**

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

Operators: basic concepts

- Operator precedence
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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

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- Evaluates whatever is to the right of “=" and assigns that value to whatever is to the left of the “=“

Operators: basic types

- **Assignment**
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- 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
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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
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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;
```

(x & (z + 3)) || (9 – (w % 6))

```
x & z + 3 || 9 – w % 6
```

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	`^` (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
```

```
(x & (z + 3)) || (9 - (w % 6))
```

```
x & z + 3 || 9 - w % 6
```

Basic output

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

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

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- **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);`

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- **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);`

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);`

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- **Examples:**
  - `scanf("%d", &some_int);`

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- **Examples:**
  - `scanf("%d", &some_int);`
  - `scanf("%f", &some_float);`

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scanf(format_specifier, varMemAddress)
```

- **Examples:**
  - `scanf("%d", &some_int);`
  - `scanf("%f", &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?

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```
#include <stdio.h>

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

Basic input/output

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

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#include <stdio.h>

int main(void){
  int num1, num2;
  printf("Enter the first number:\t");
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  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;
}
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Basic input/output

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#include <stdio.h>

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   printf("The sum of %i and %d is: %d", num1, num2, mysum);
   return 0;
}
```

Remark about floats

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```
#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;
}
```

Remark about floats

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#include<stdio.h>

int main(void){
  float my_float = 3.14;

  if (my_float==3.14)
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}
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```
My float is not PI
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Remark about floats

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  float my_float = 3.14;

  if (my_float==3.14)
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  if (my_double == 3.14)
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  return 0;
}
```

My float is not PI

My double is PI

Remark about floats

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int main(void){
  float my_float = 3.14;

  if (my_float==3.14)
    printf("My float is PI\n");
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  double my_double = 3.14;
  if (my_double == 3.14)
    printf("My double is PI\n");
  else
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  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

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

Control structures in C

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Executing code multiple times, ending based on evaluated expression

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2. Iteration

Executing code multiple times, ending based on evaluated expression

- `while`

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

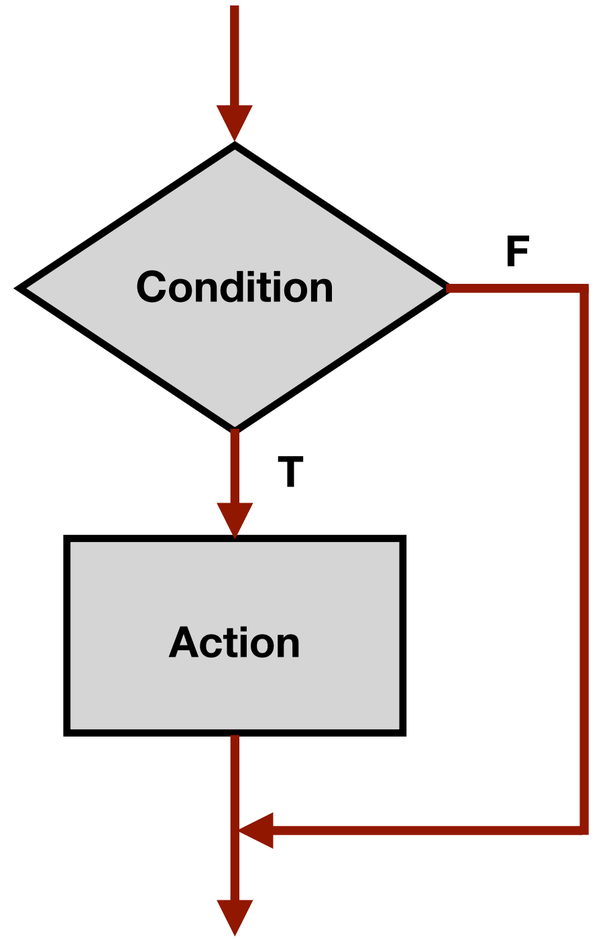
- `if`
- `if-else`
- `switch`

2. Iteration

Executing code multiple times, ending based on evaluated expression

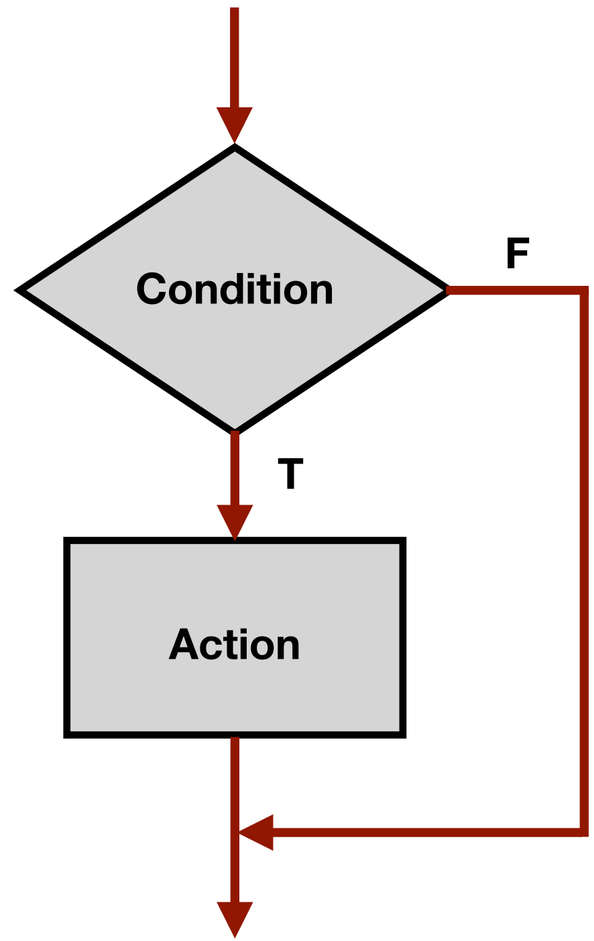
- `while`
- `for`
- `do-while`

The if statement



The if statement

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



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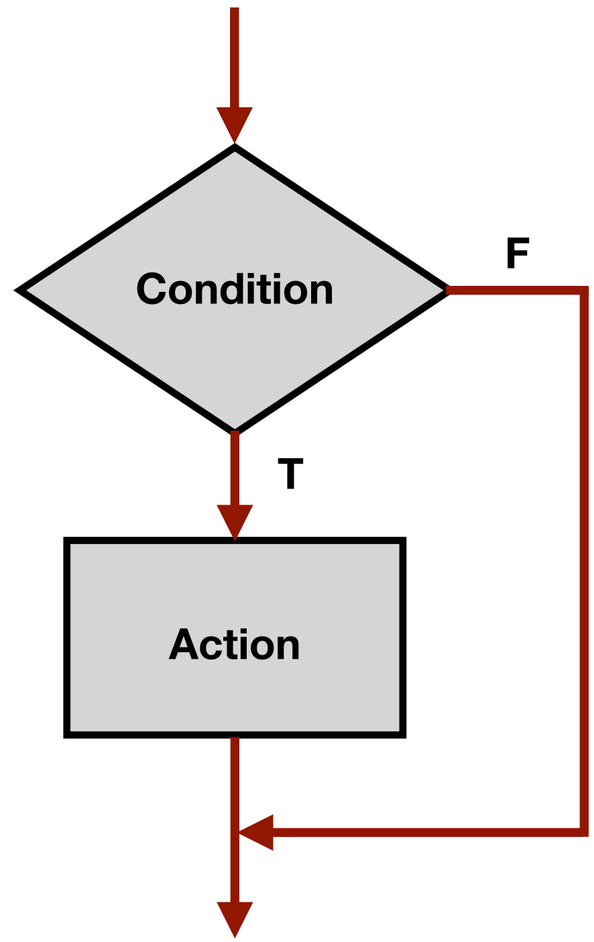

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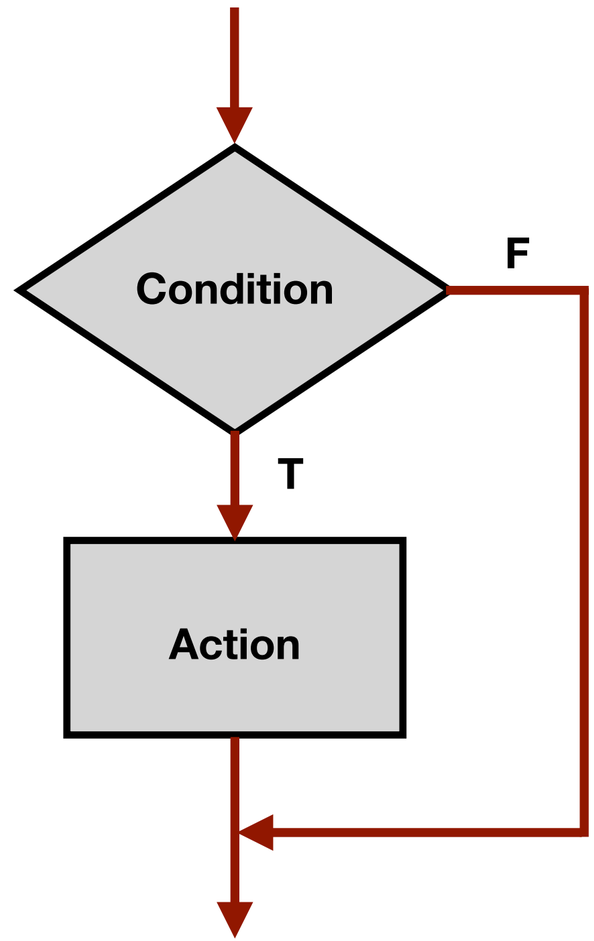

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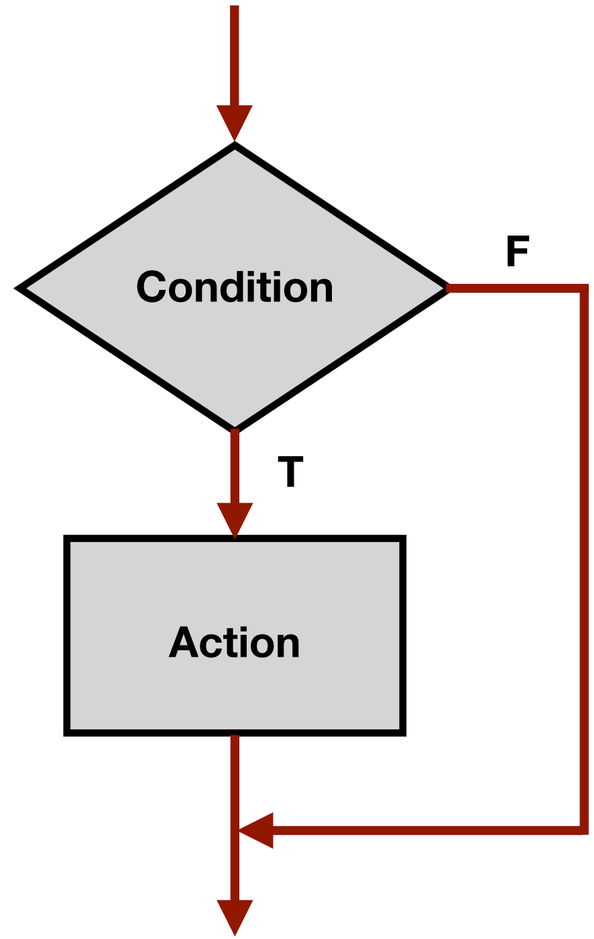


```
if (x <= 10){
    y = x * x + 5;
    z = (2 * y) / 3;
}
```

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

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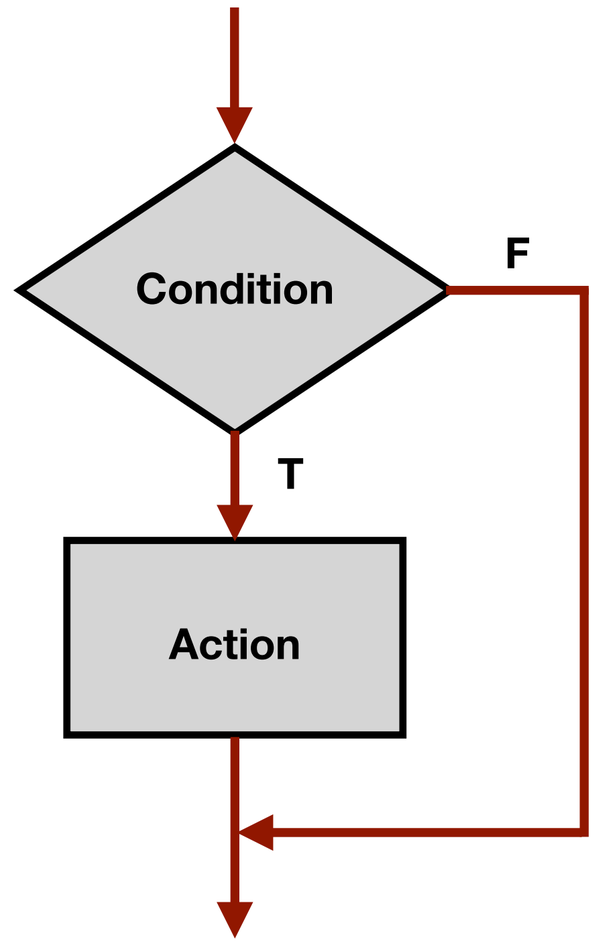


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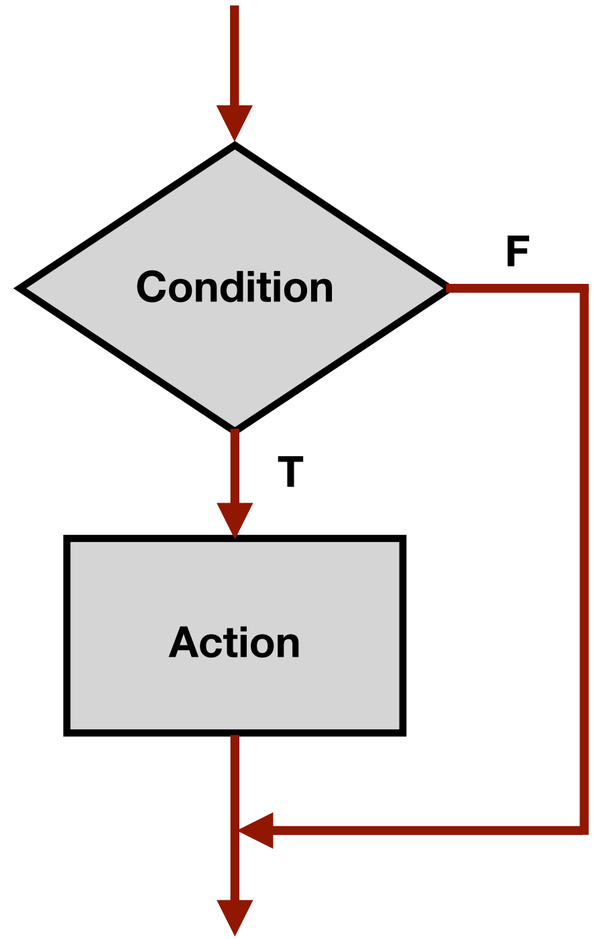
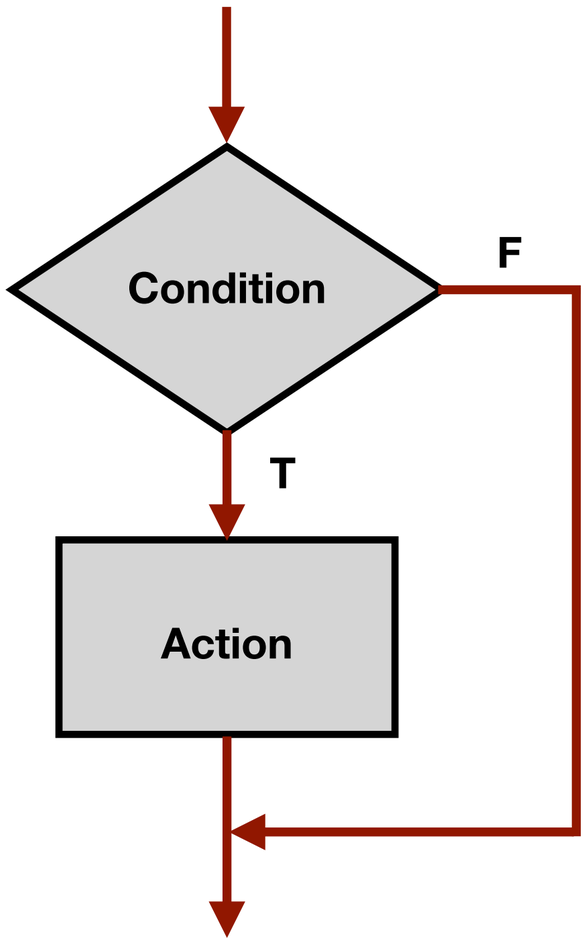


Example : if statement



Example : if statement

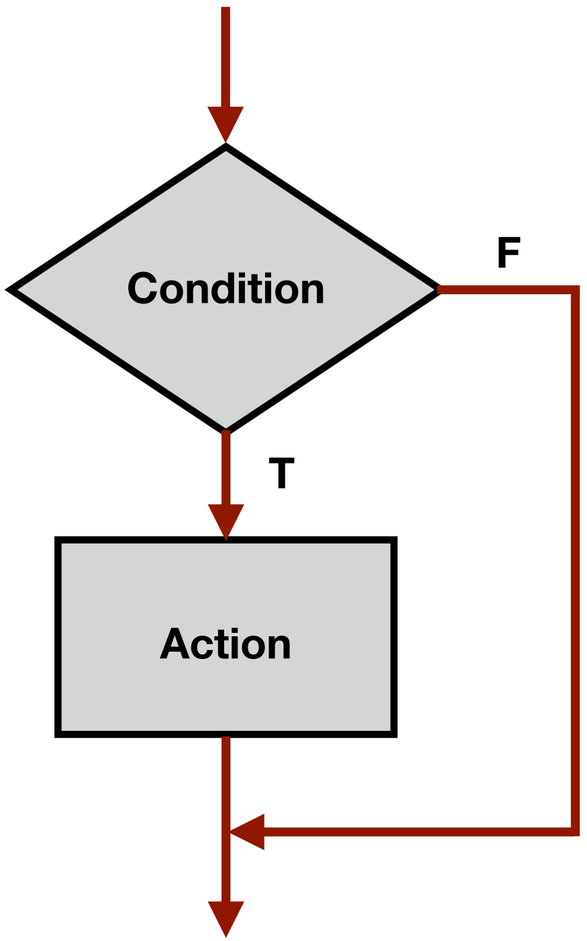
```
if (x < 0)
     x = -x;     // invert x only if x < 0


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

}

printf(“y = %d\n”, y);

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



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    x = -x;     // invert x only if x < 0

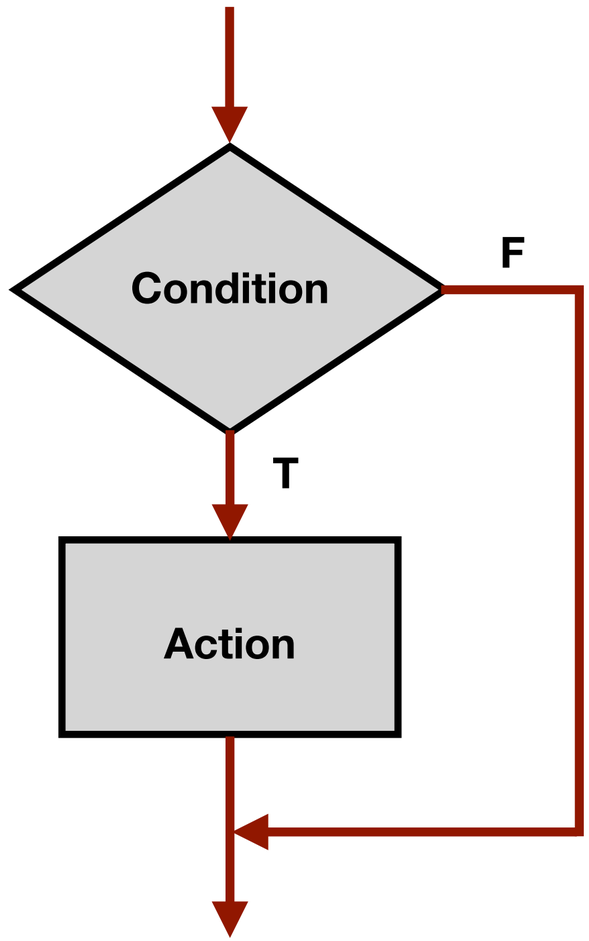

if ((x > 5) && (x  < 25))
{
    int y = x * x + 5;

}

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

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

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



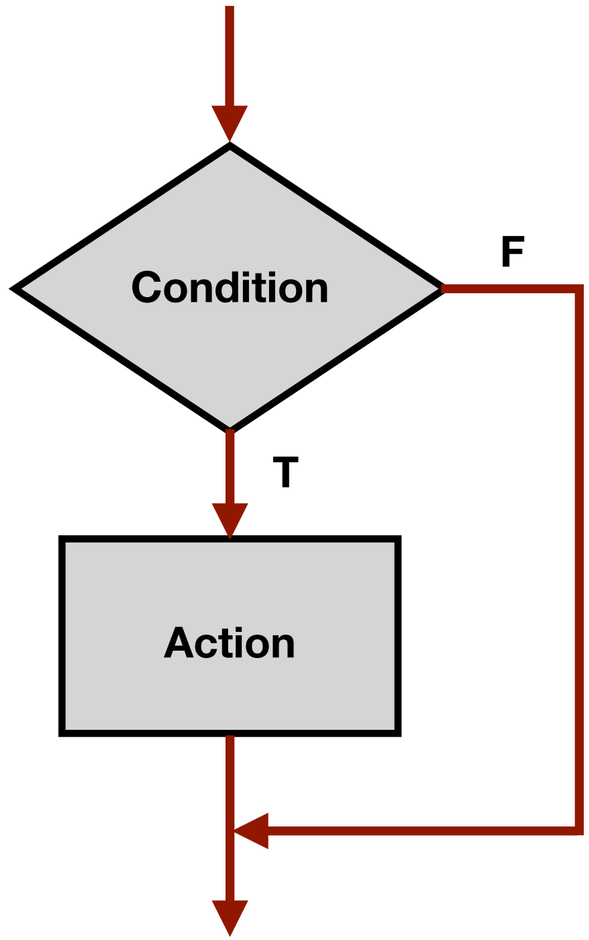
Example : if statement

```
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);
}
```

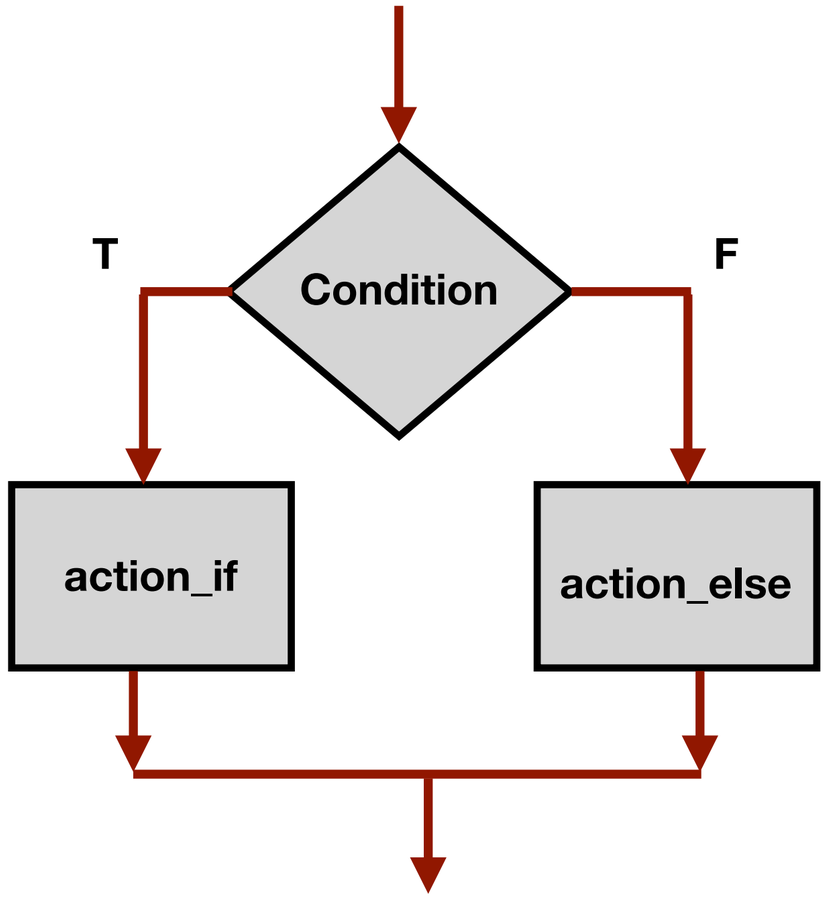
```
if (x = 2){
  y = 5;
}
```

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



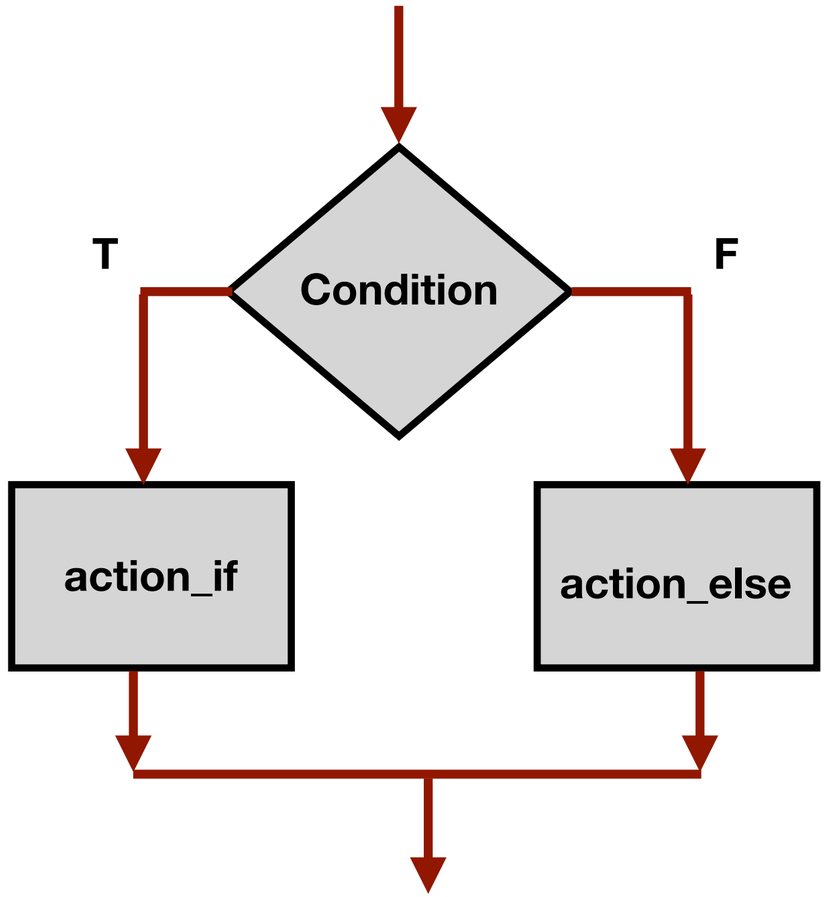
The if-else statement

The if-else statement



The if-else statement

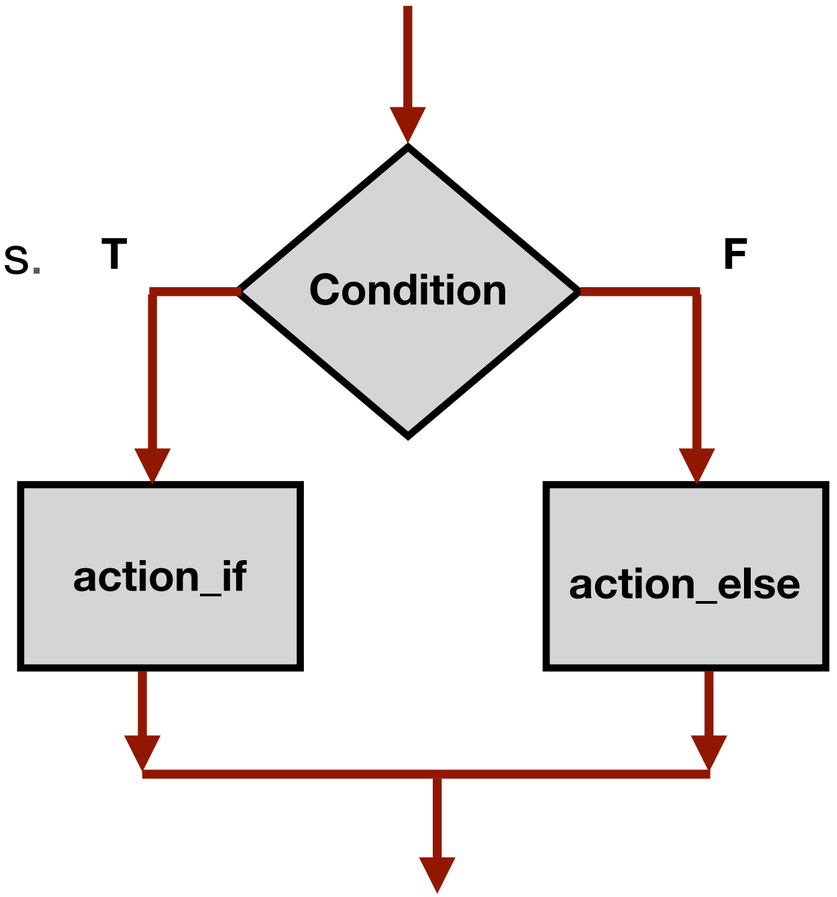
```
if (condition)
    action_if;
else
    action_else;
```



The if-else statement

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

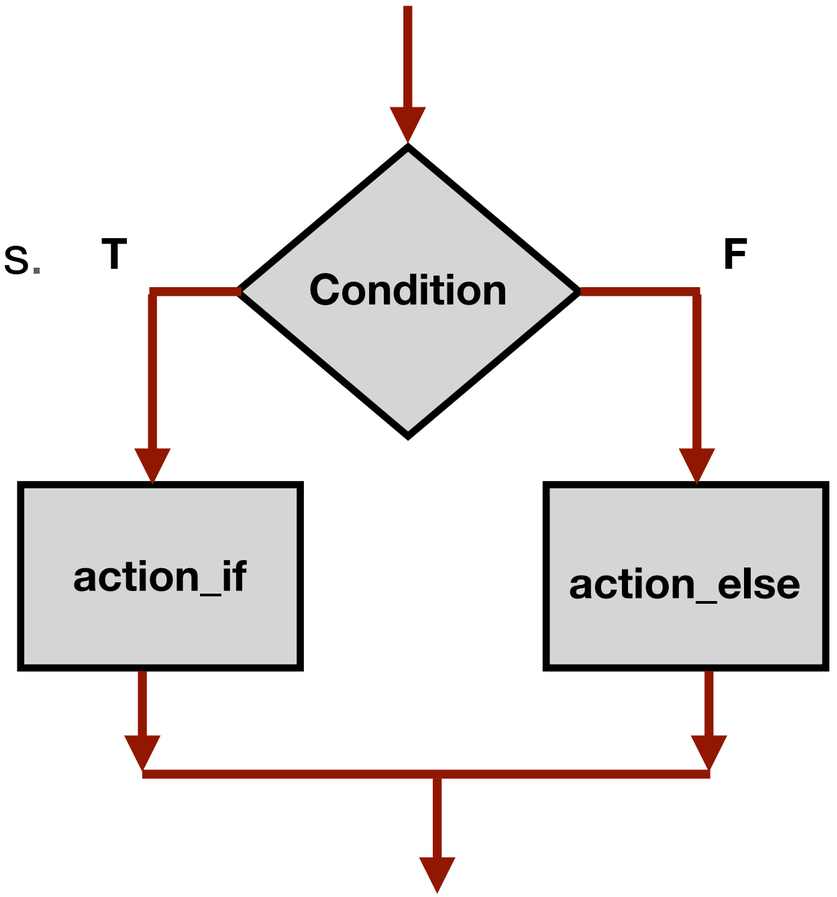
Else: allows choice between two mutually-exclusive actions.



The if-else statement

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

Else: allows choice between two mutually-exclusive actions.



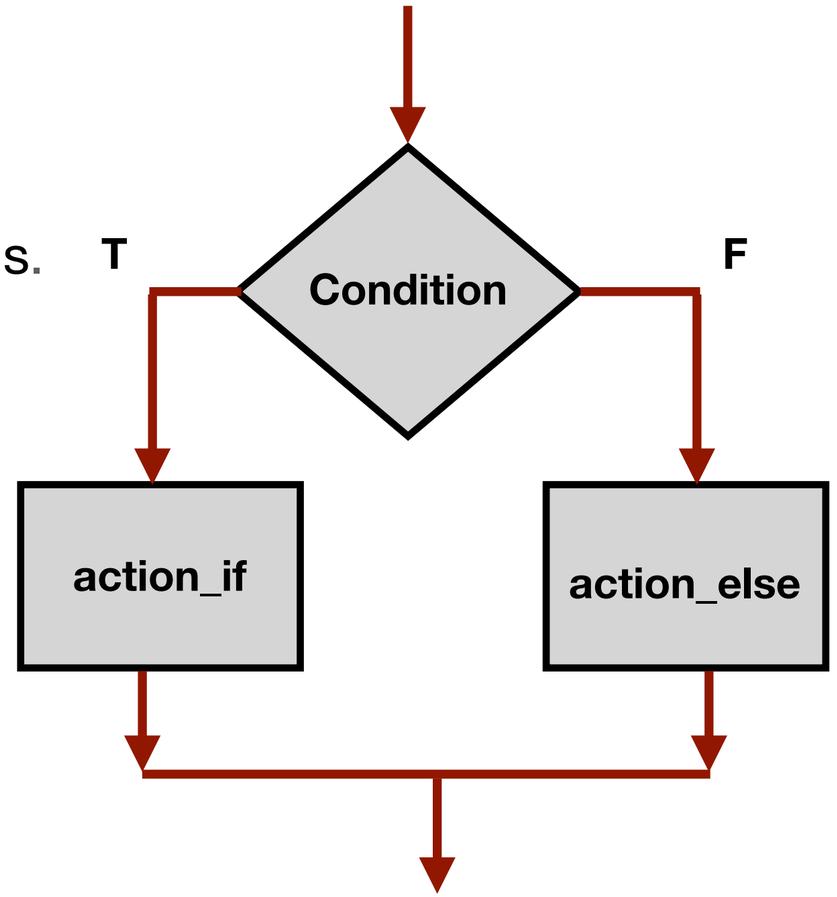
Example 1

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

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);
```

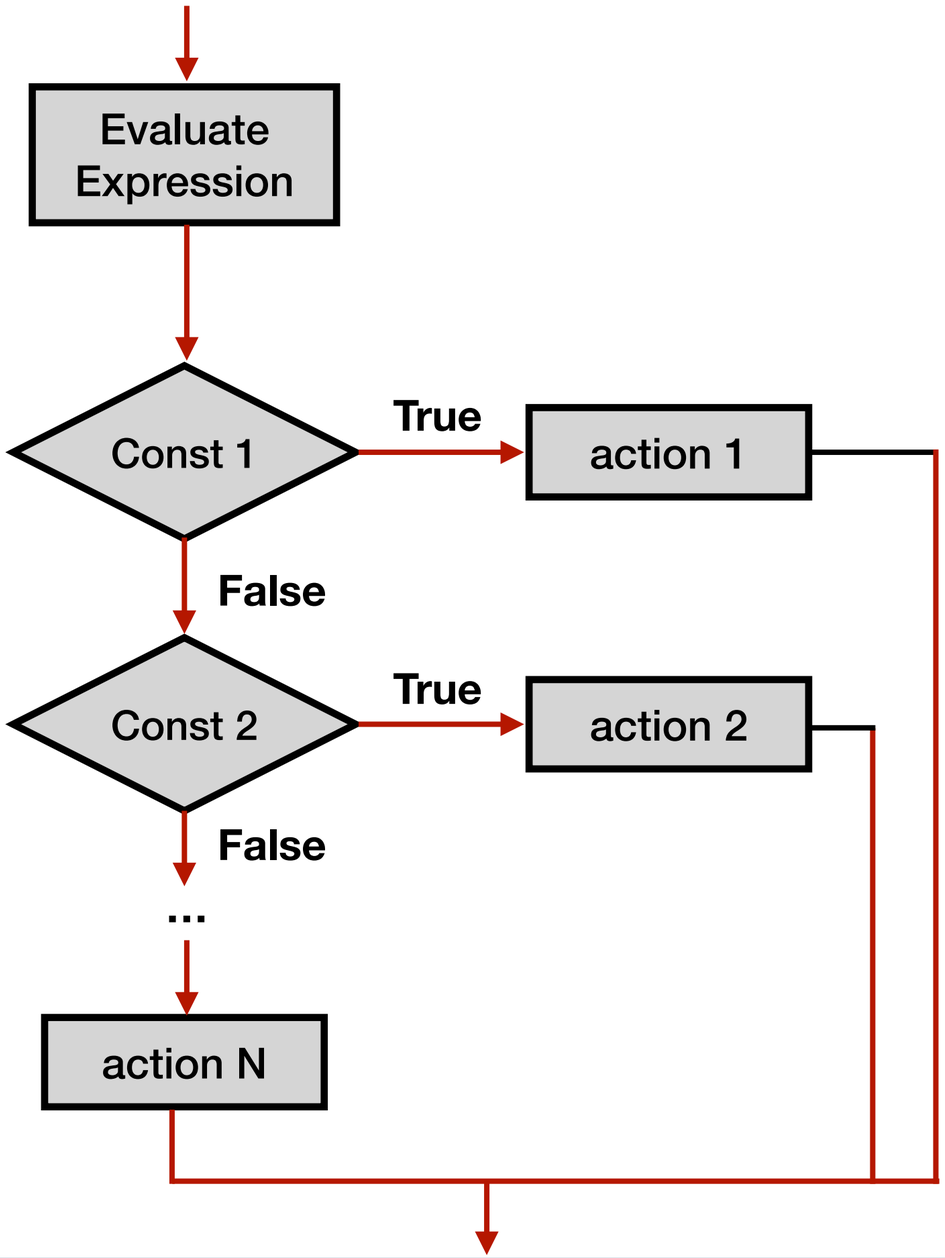
Chaining if-else

Chaining if-else

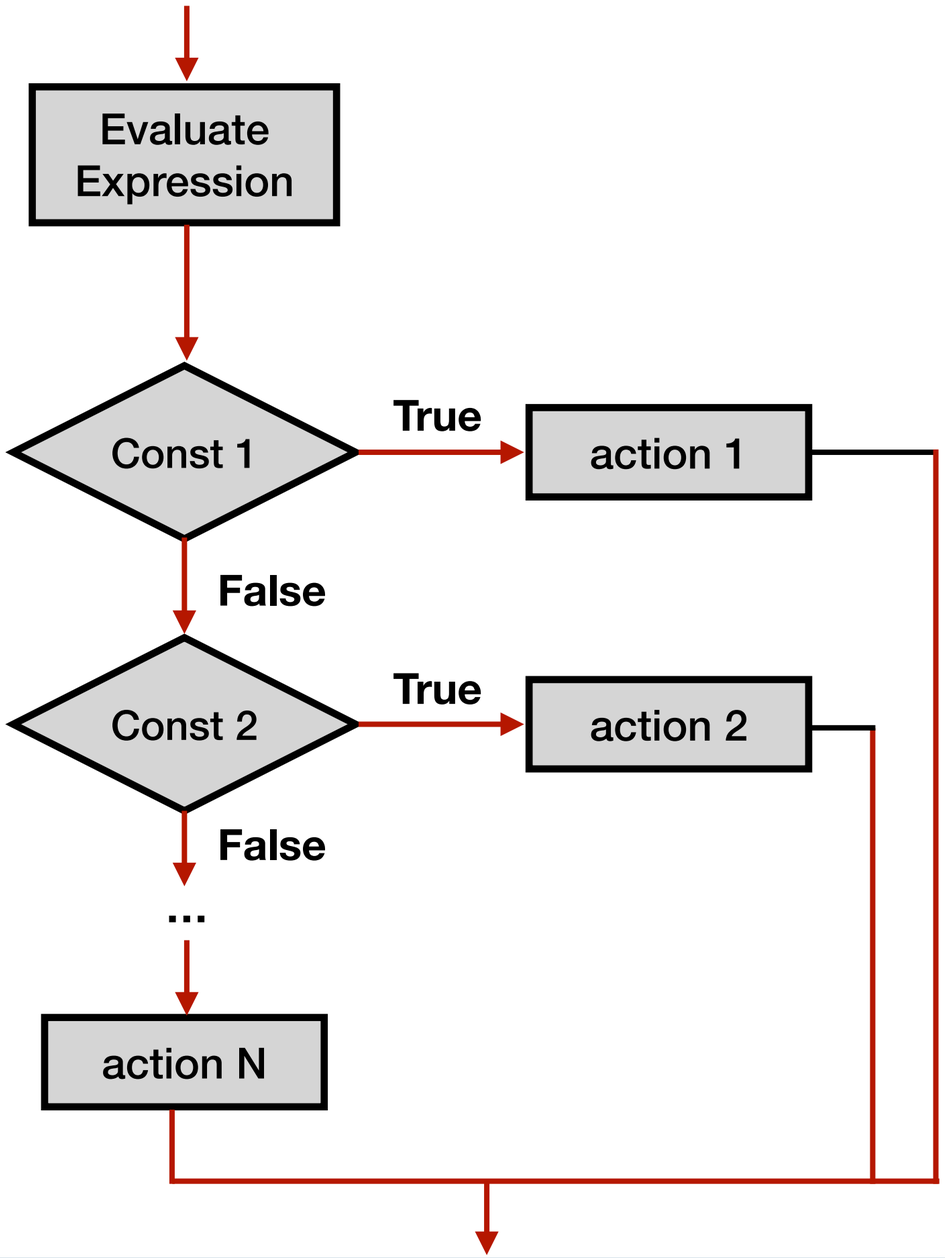
```
if (month == 4 || month == 6 || month == 9 || month == 11){
     printf(“Month has 30 days. \n”);
}
else if (month == 1 || month == 3 || month == 5 ||
         month == 7 || month == 8 || month == 10||
         month == 12 ){
      printf(“Month has 31 days. \n”);
}
else if (month == 2){
      printf(“Month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

The switch statement

The switch statement

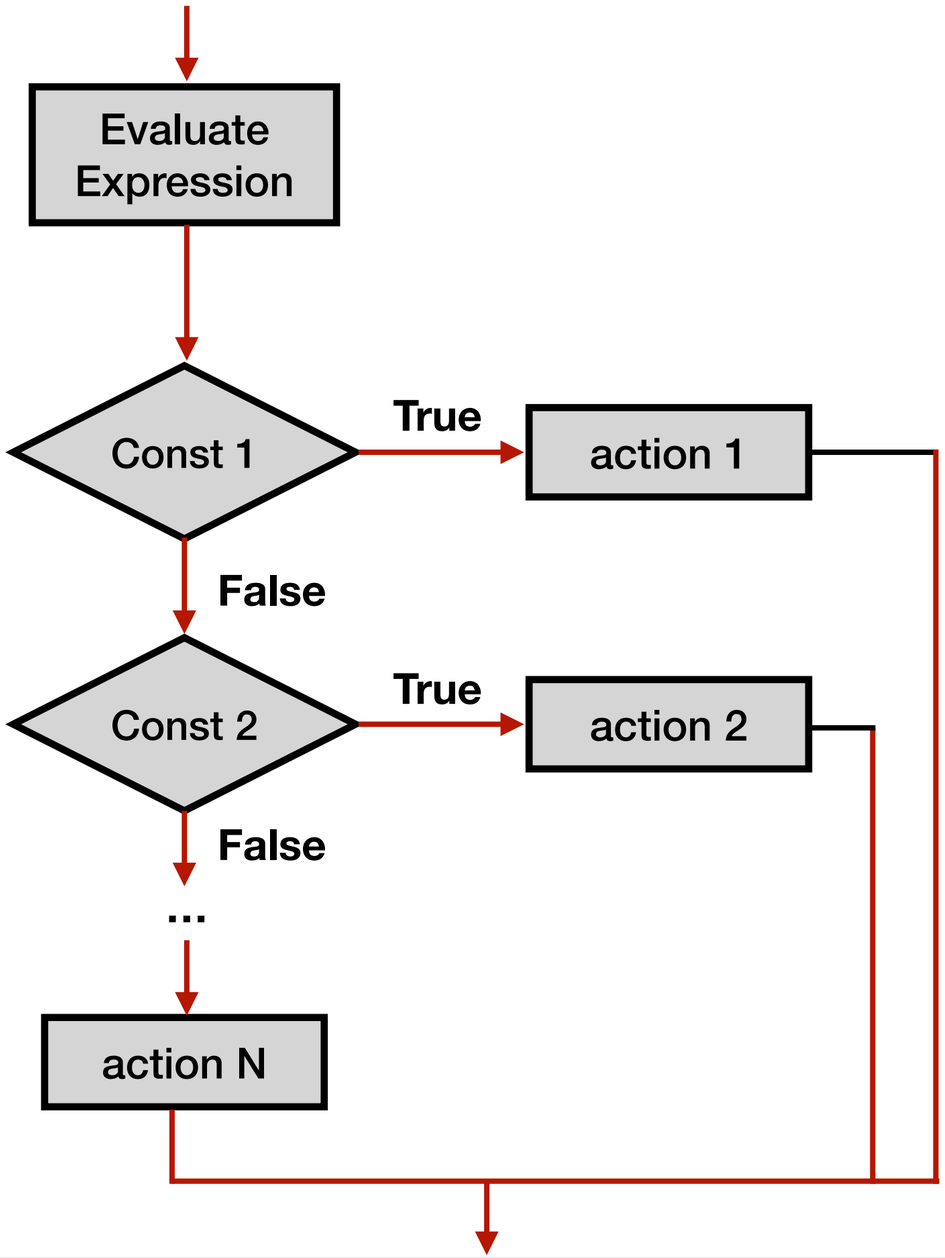


The switch statement




```
if
else if
else if
…
else
```

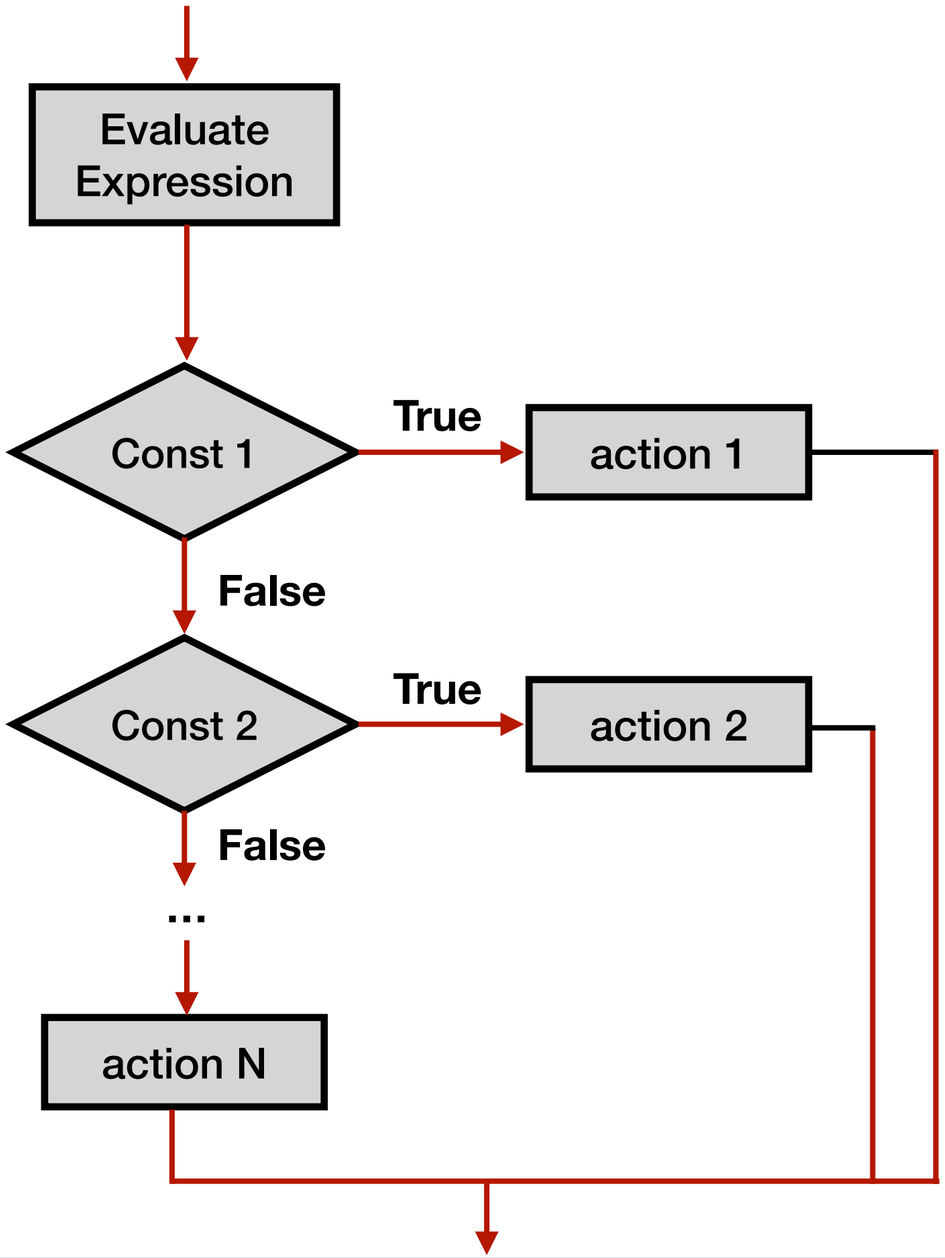
The switch statement




```
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
```

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

The switch statement

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

The switch statement

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

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

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");
}
```

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

`do-while` statement

The while / do-while statement

`while` statement

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

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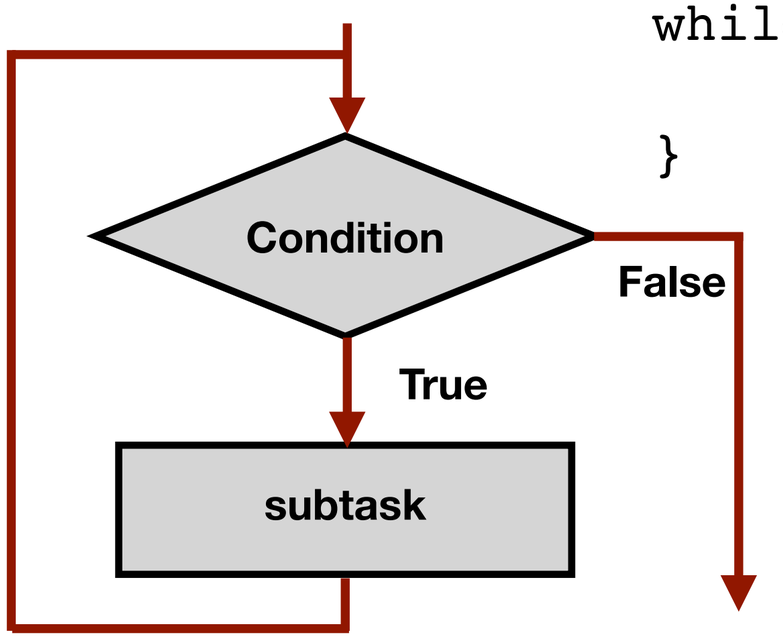


```
while(test){
    loop_body;
}
```

`do-while` statement

The while / do-while statement

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- Loop body may or may not be executed even once
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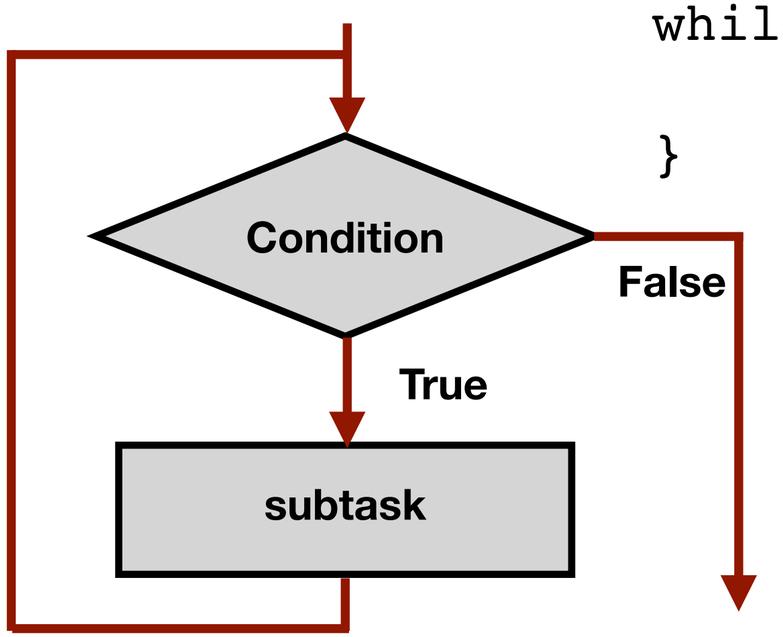
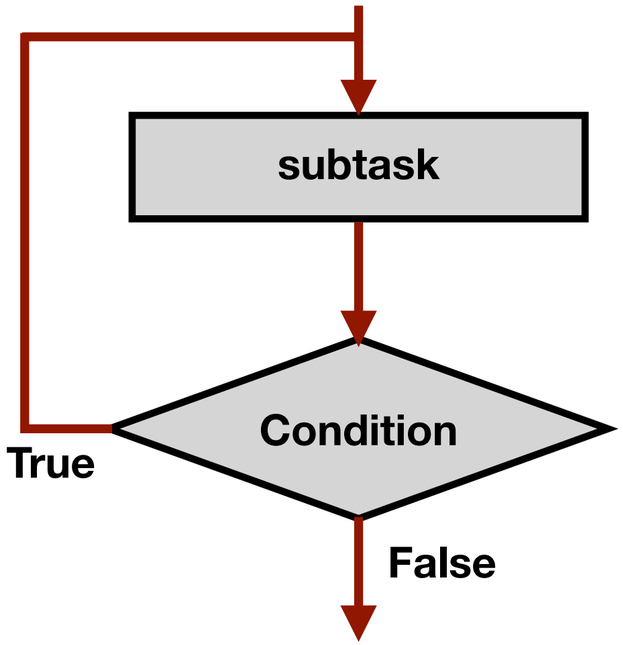



```
while(test){
    loop_body;
}
```

`do-while` statement

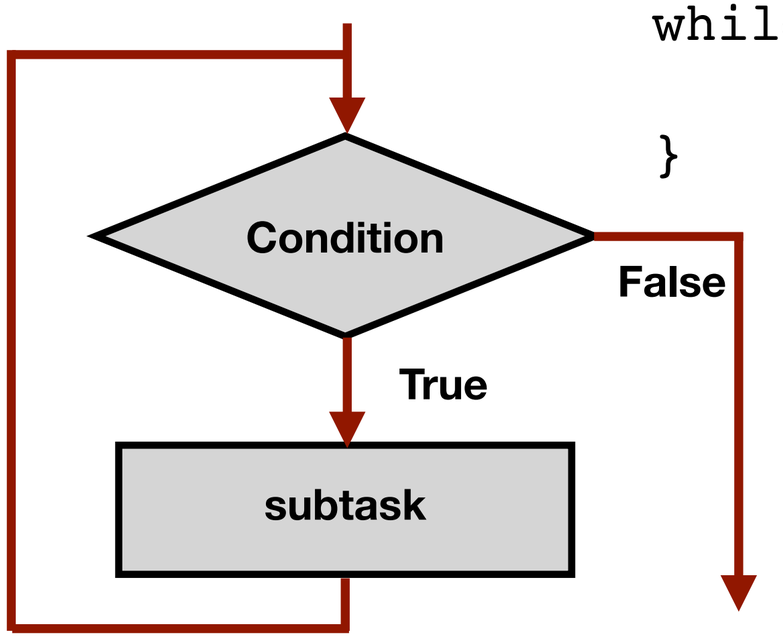



```
do{
    loop_body;
}while (test);
```

The while / do-while statement

`while` statement

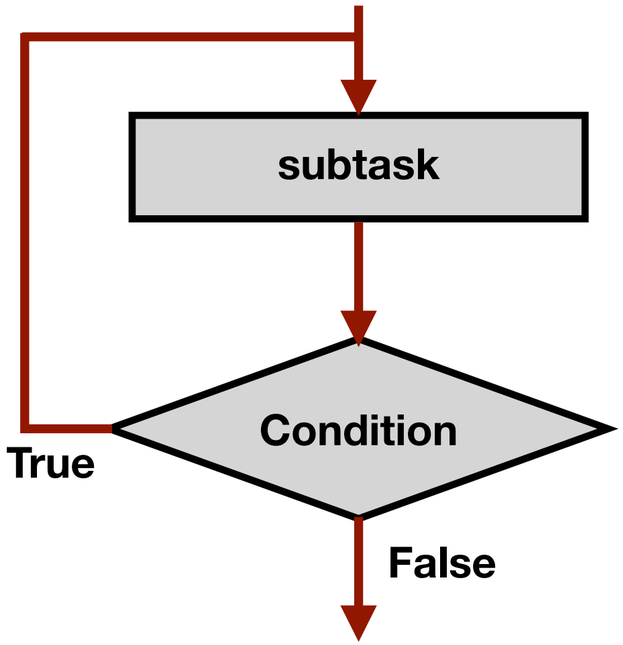
- Loop body may or may not be executed even once
- Test is evaluated **before** executing the loop.




```
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

`do-while` statement

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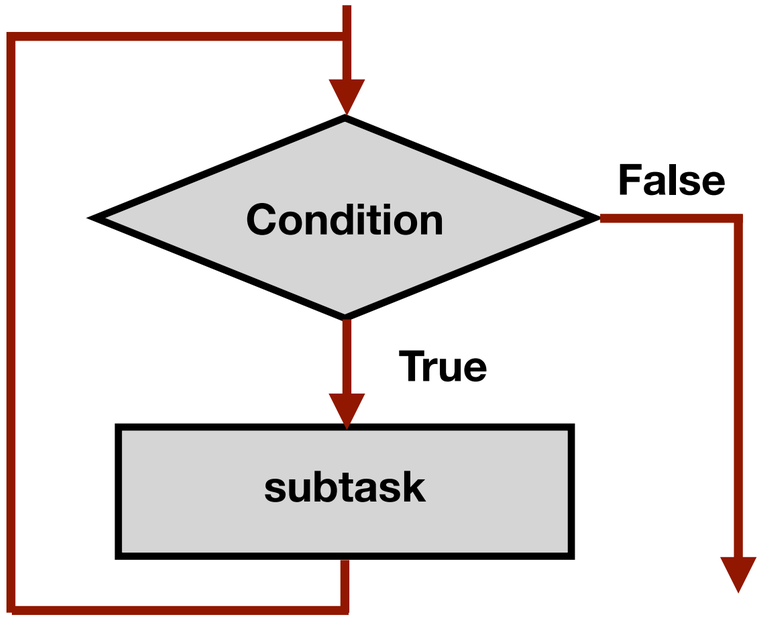
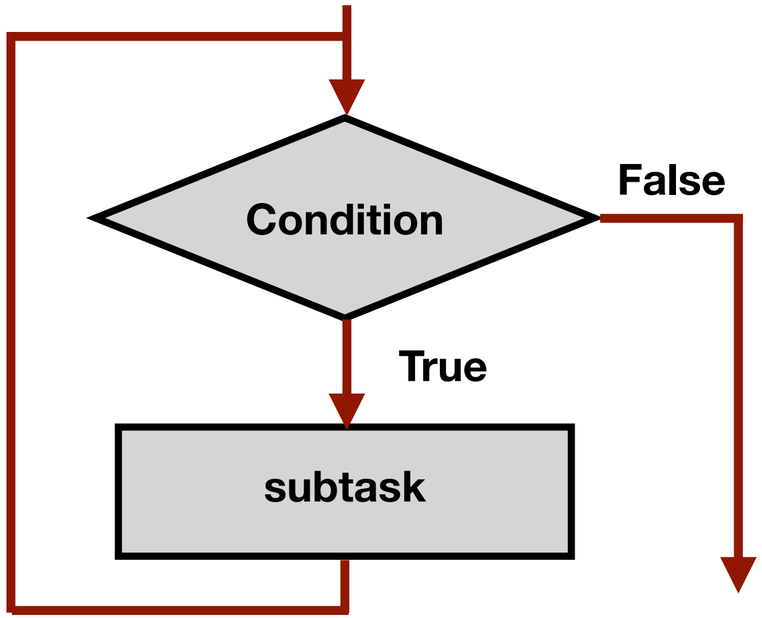


`do-while` statement

The while / do-while statement

`while` statement



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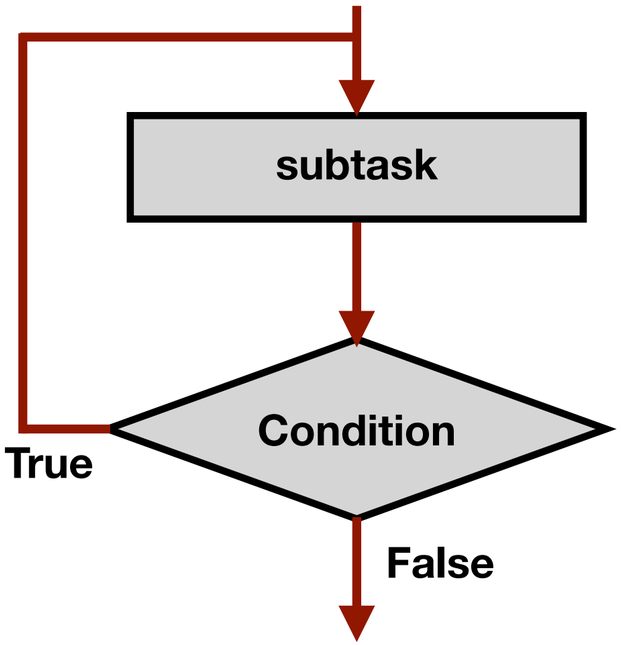
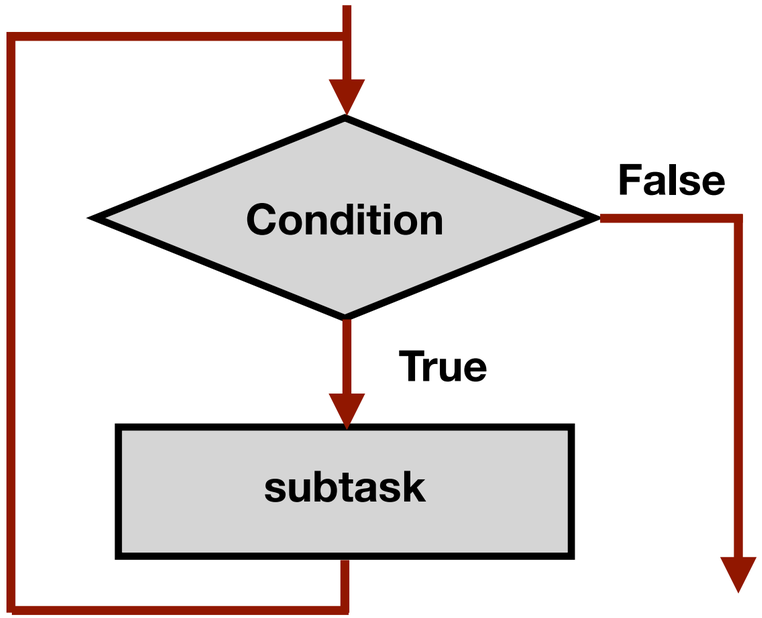


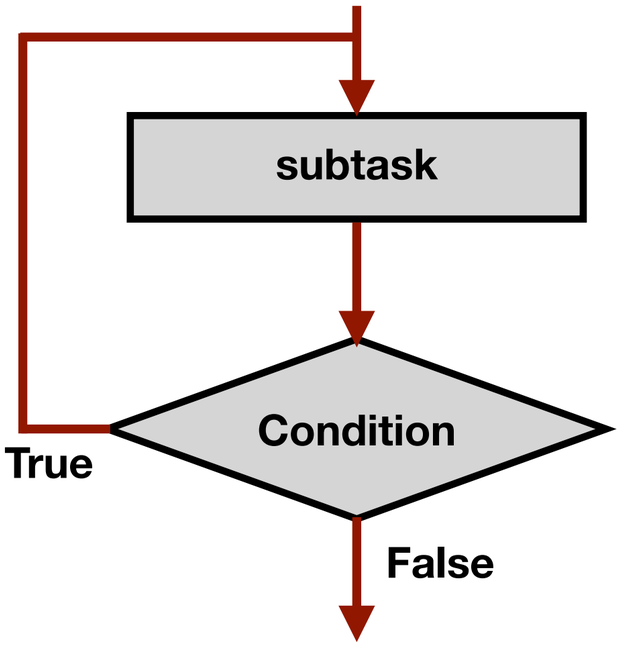
The while / do-while statement

`while` statement




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

`do-while` statement



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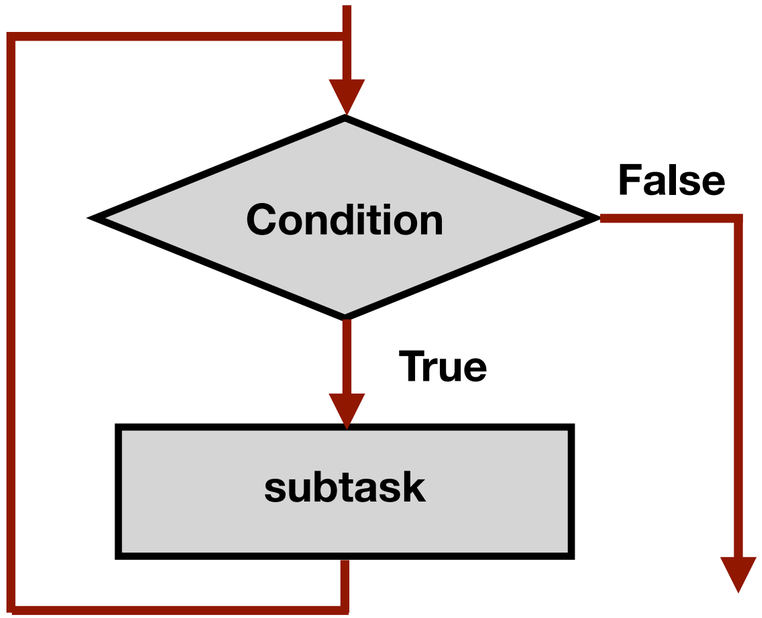


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x = 0;
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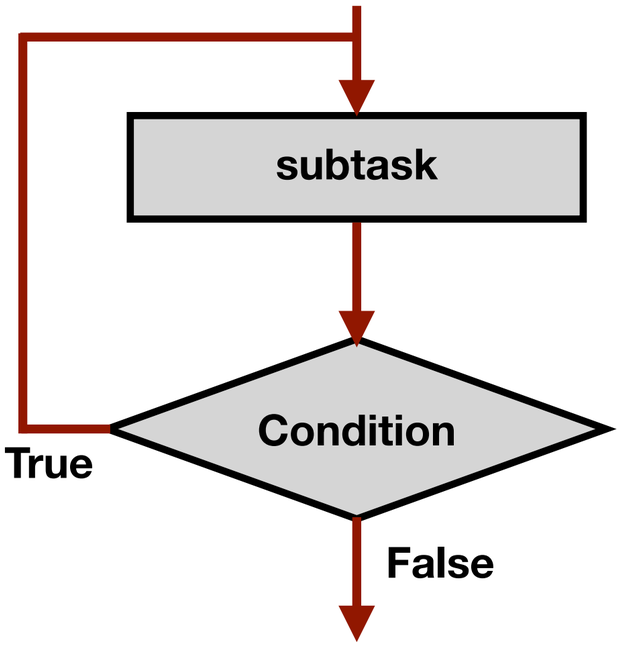
```

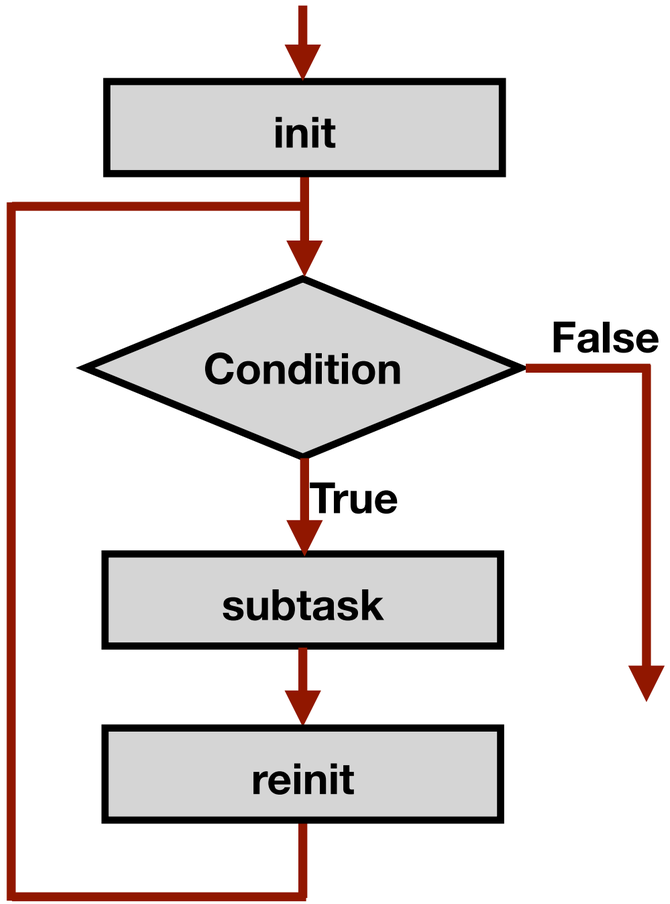
`do-while` statement



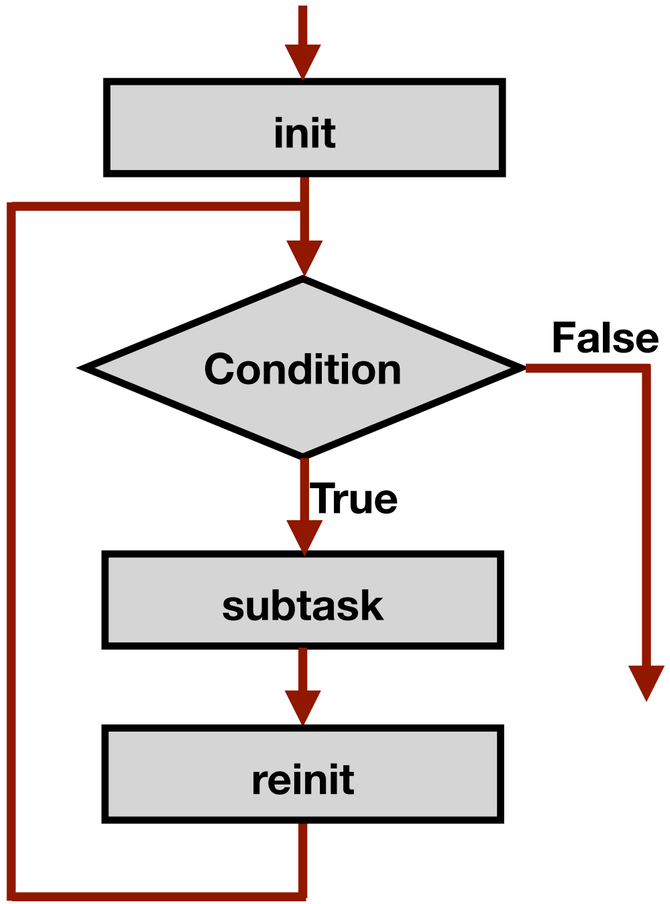

```
do
  printf("x=%d\n", x++);
while (x < 10);
```

The for statement

The for statement

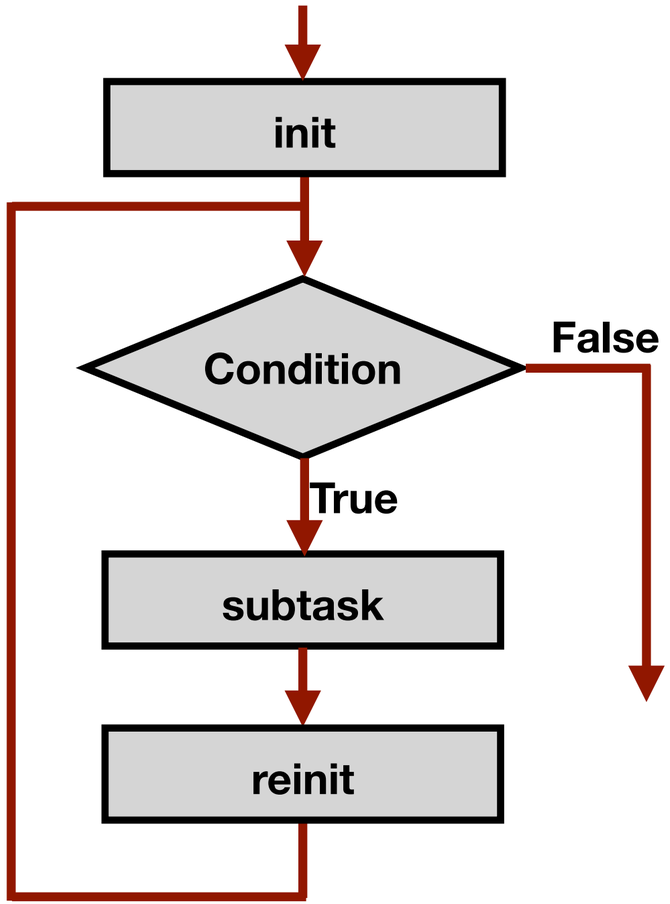


The for statement




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

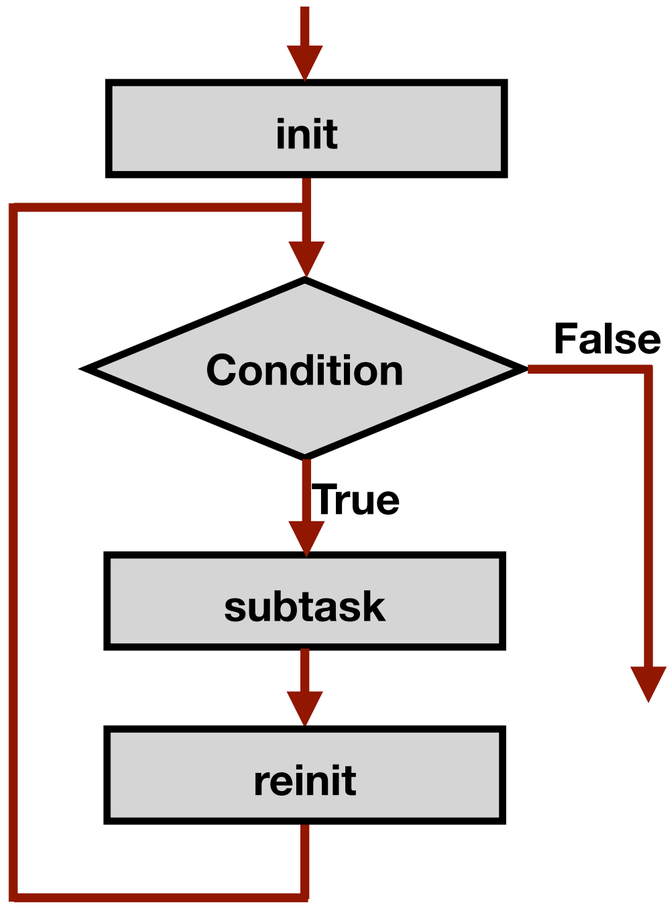
The for statement




```
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);
}
```

The for statement




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

break vs. continue

- `break`
  - Used only in switch or iteration statement
  - Used to exit a loop before terminating condition occurs
- `continue`
  - Used only in iteration statement
  - End the current iteration and start the next

break vs. continue

- `break`
  - Used only in switch or iteration statement
  - Used to exit a loop before terminating condition occurs
- `continue`
  - Used only in iteration statement
  - End the current iteration and start the next

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

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);
}
```

- `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);
}
```

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);
}
```

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

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

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- 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

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- 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.

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- 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?

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?

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

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

Exercise

- Can you rewrite using switch case?

Exercise

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```
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");
  }
}
```