CPT109: C Programming & Software Engineering I

Lecture 3: Operators & Flow Control

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Outline of Today's Lecture (week 3)

- Short Review of Week 2
- Operators (that's mathematical functions)
- Flow control - Branching
  - **if**() choosing to do something
  - **if**()… **else**… choosing between two things
  - **if**()… **else if**()… choosing between more things
- Flow Control – Menu's
  - **switch**() **case**… multiple choice
- Flow Control – looping (repeating)
  - **while**…
  - **do while**…
  - **for**…

Review week 2

- printf statements
  - Prints whatever is in the string **“...”**
  - Prints values from arguments where the type specifier is
  - Prints arguments in whatever format is specified
- #define
  - Find and replace function
  - No memory used
  - Faster execution
- variable declaration
  - Value unknown
  - Initialisation

Review week 2

Memory Address	Value	Variable name
0x000000	????????	a
0x000001	????????	
0x000002	????????	
0x000003	????????	
0x000004	????????	b
0x000005	????????	
0x000006	????????	
0x000007	????????	
0x000008	????????	c
0x000009	????????	

Review week 2

Memory Address	Value	Variable name
0x000000	00000000	a
0x000001	00000000	
0x000002	00000000	
0x000003	00000011	
0x000004	00000000	b
0x000005	00000000	
0x000006	00000000	
0x000007	00001010	
0x000008	????????	c
0x000009	????????	

Review week 2

Memory Address	Value	Variable name
0x000000	00000000	a
0x000001	00000000	
0x000002	00000000	
0x000003	00000011	
0x000004	00000000	b
0x000005	00000000	
0x000006	00000000	
0x000007	00001010	
0x000008	????????	c
0x000009	????????	

3

10

Operators

Basic Operators

- In addition to the basic mathematical operations:
  - Multiply (*)
  - Divide (/)
  - Subtract (-)
  - Addition (+)
- There is also the modulo operator (%). It returns the remainder of a division e.g. 5/3 = 1 remainder 2

  5/3 would give the value 1

  5%3 would give the value 2

Operators in C (Unary)

- Unary operators (involve one variable)

C operation	Operator	Example
Positive	+	a=+3
Negation	-	a=-a
Increment	++	i++
Decrement	--	i--

- The first assigns positive 3 to a
- The second assigns the negative of a to a
- i++ is equivalent to i = i + 1
- i-- is equivalent to i = i - 1

Pre/Post Increment/Decrement

- ++i and i++ or --i and i—
- These are different, the location of the operation (++ or --) decides when the operation happens
- Operation before variable is a pre operation
- Operation after variable is a post operation

```
int a=9;
printf("%d\n",a++);
printf("%d",a);
```

What would the output would be?

Pre/Post Increment/Decrement

What about in this case?:

```
int a=9;
printf("%d\n",++a);
printf("%d",a);
```

Assignment Operator

- Assignments can be written in a more shorthand way:

  i = i+2 is the same as i += 2

- the shorthand is denoted **var op= value**

Question: x*= y+1

Is this equal to x=x*y+1 or x=x*(y+1)?

Relational Operations

- Used to Compare Expressions:

Operator	*Meaning*
<	is **less** than
<=	is **less** than **or equal** to
!=	is **not equal**
==	is **equal to**
>	is **greater** than
>=	is **greater** than **or equal** to

Logical Operations

Used to combine one or more relational expressions

```
if ( (number>6) && (number<12) )
   printf("You are close!");
else
   printf("You Loose!");
```

Complex test expression – tests whether number lies within a range

Operator	*Meaning*
&&	*Logical "**and**":* True if **both** arguments are true
||	*Logical "**or**":* True if **one or both** arguments are true
!	Logical "**not**": changes True in False and False in True

Logical Operations

Table 4.3 The && Operator (and)

operand1	operand2	operand1 && operand2
nonzero (true)	nonzero (true)	1 (true)
nonzero (true)	0 (false)	0 (false)
0 (false)	nonzero (true)	0 (false)
0 (false)	0 (false)	0 (false)

Table 4.4 The || Operator (or)

operand1	operand2	operand1 || operand2
nonzero (true)	nonzero (true)	1 (true)
nonzero (true)	0 (false)	1 (true)
0 (false)	nonzero (true)	1 (true)
0 (false)	0 (false)	0 (false)

Table 4.5 The ! Operator (not)

operand1	!operand1
nonzero (true)	0 (false)
0 (false)	1 (true)

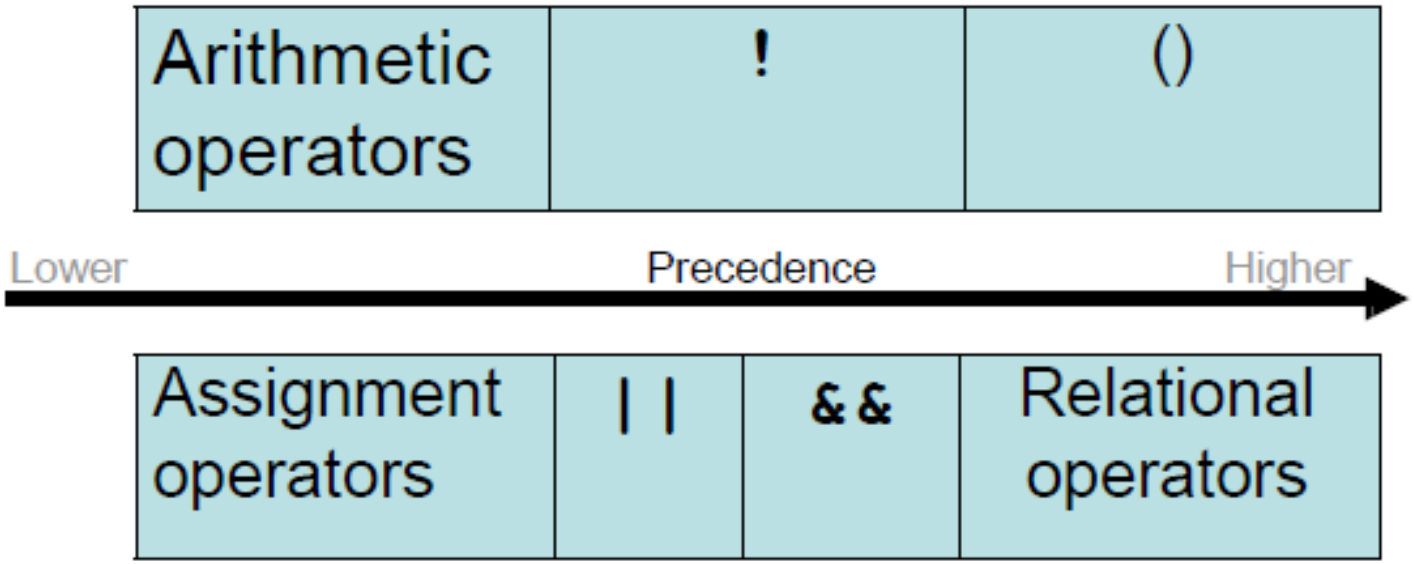
Precedence – Relational Operators

Assignment operators	Relational operators	Arithmetic Operators

`x>y+2` means the same as `x>(y+2)`

`x=y>2` means the same as `x=(y>2)`

Precedence – Logical Operators




```
x=3 > 5 && 10 > 23 || 4 > 2
```

means the same as

```
x=((3 > 5) &&(10 > 23)) || (4 > 2)

x=((False && False) || True)
```

Quiz

- Which of the following evaluates to **true**?
- Assume: P = true, Q = false, R = true

1) (!P || R) && Q
2) !(Q && R) && P
3) !(P && R) || Q
4) P && !Q && !R

Flow Control - Branching

The option to choose…or not!

- **How do you get a program to follow some particular functions and not others?**

The option to choose…or not!

- **How do you get a program to follow some particular function and not others?**
- The answer is of course **flow control**.
- In general, a programming language must provide 3 types:
  - Ordered processing of statements (**Sequential execution**)
  - Use of a test to decide between alternative sequences (branching/**conditional execution**)
  - Repeating sequences of statements until a condition is met (looping/**iterative execution**)

Flow Control Statements

- These enable you, the programmer, to make complex decision making trees, in a program
- They provide a choice of action or repetition of action.
- They require a test expression to be evaluated.
- Test expressions can have **two** values…
  What do you think these are?

Flow Control Statements

- These enable you, the programmer, to make complex decision making trees, in a program
- They provide a choice of action or repetition of action.
- They require a test expression to be evaluated.
- Test expressions can have **two** values…
- **Unsurprisingly they can be true or false:**

  0 – Means False

  1 (or nonzero) – Means True

  Test expressions commonly use **relational** or **logical** operations.

Statements and Blocks

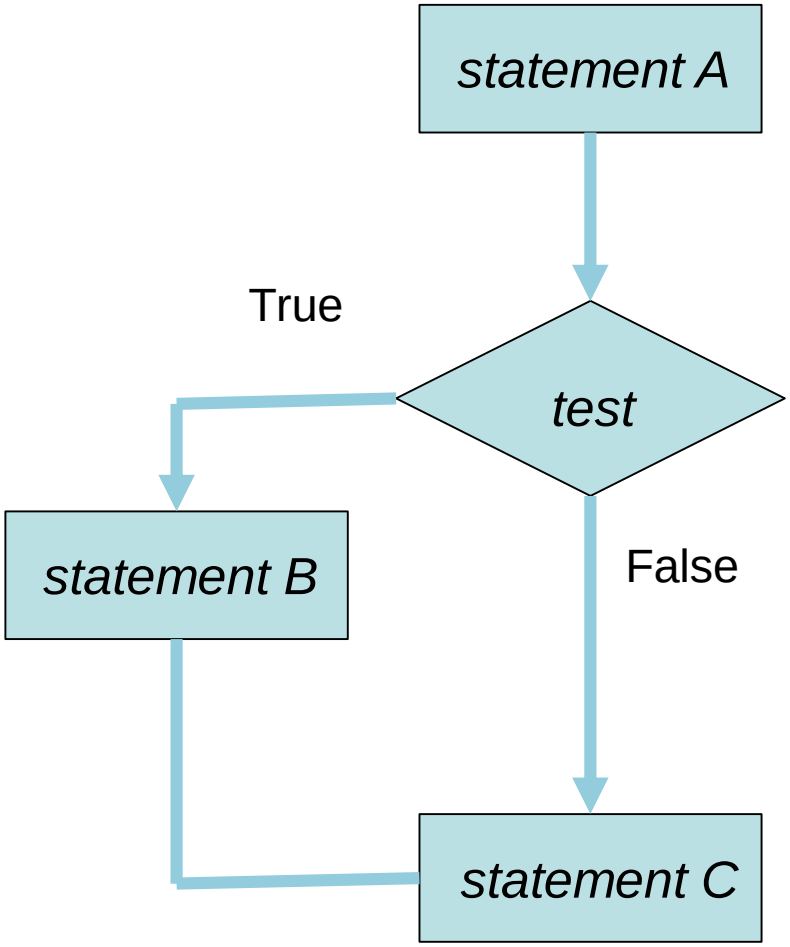
- An **expression** in your code is something that ends in a semicolon ‘;’. For example x=0;
- **Do we need a semicolon after squiggly brackets {}?**

Statements and Blocks

- An **expression** in your code is something that ends in a semicolon ‘;’. For example x=0;
- **Do we need a semicolon after squiggly brackets {}?**
- **No, these brackets denote a functional block or a “compound statement”.**
- **Example main() {….} No semicolon**
- **if, else, while, for … {} we will see the brackets are used to group multiple statements together.**

Choices…the **if**() statement

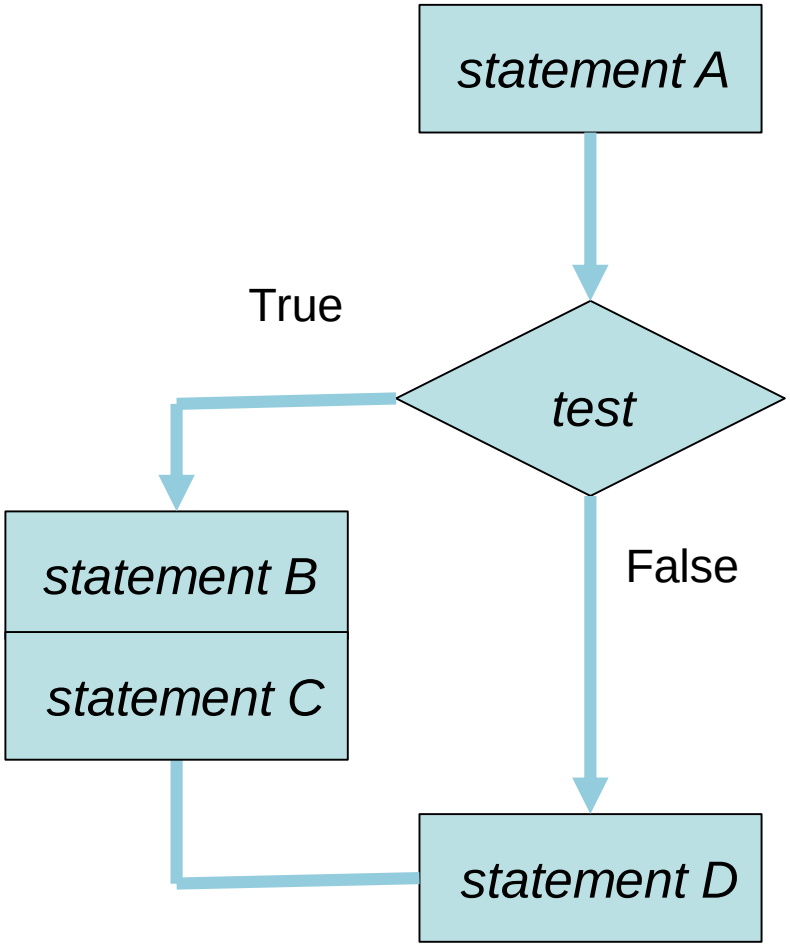
Choosing **to execute** a statement or **not**




```
statement A;
if (test)
      statement B;
statement C;
```

Choices…the if() statement

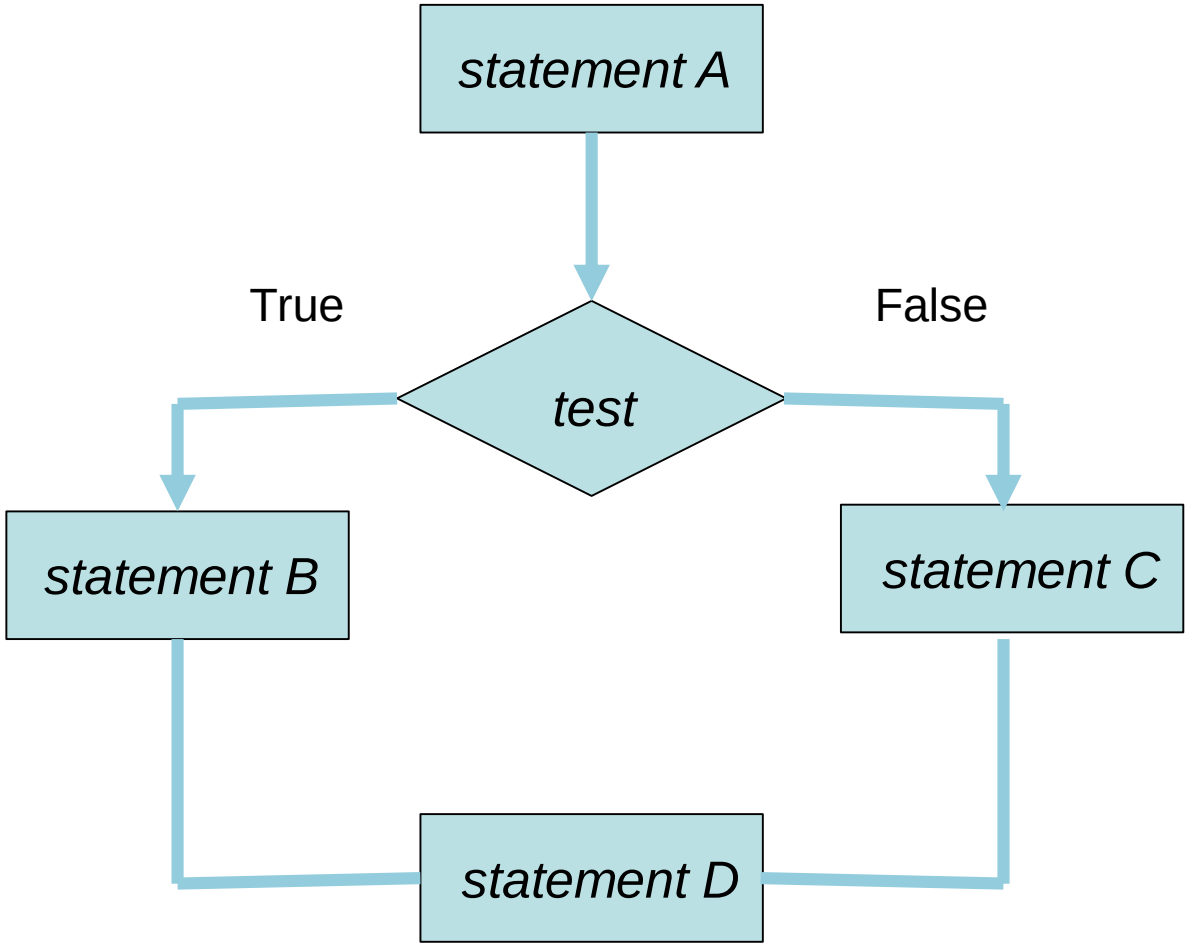
Choosing **to execute** a BLOCK of statements or **not**




```
statement A;
if (test)
      {
       statement B;
       statement C;
      }
statement D;
```

Choices…the if() else statement

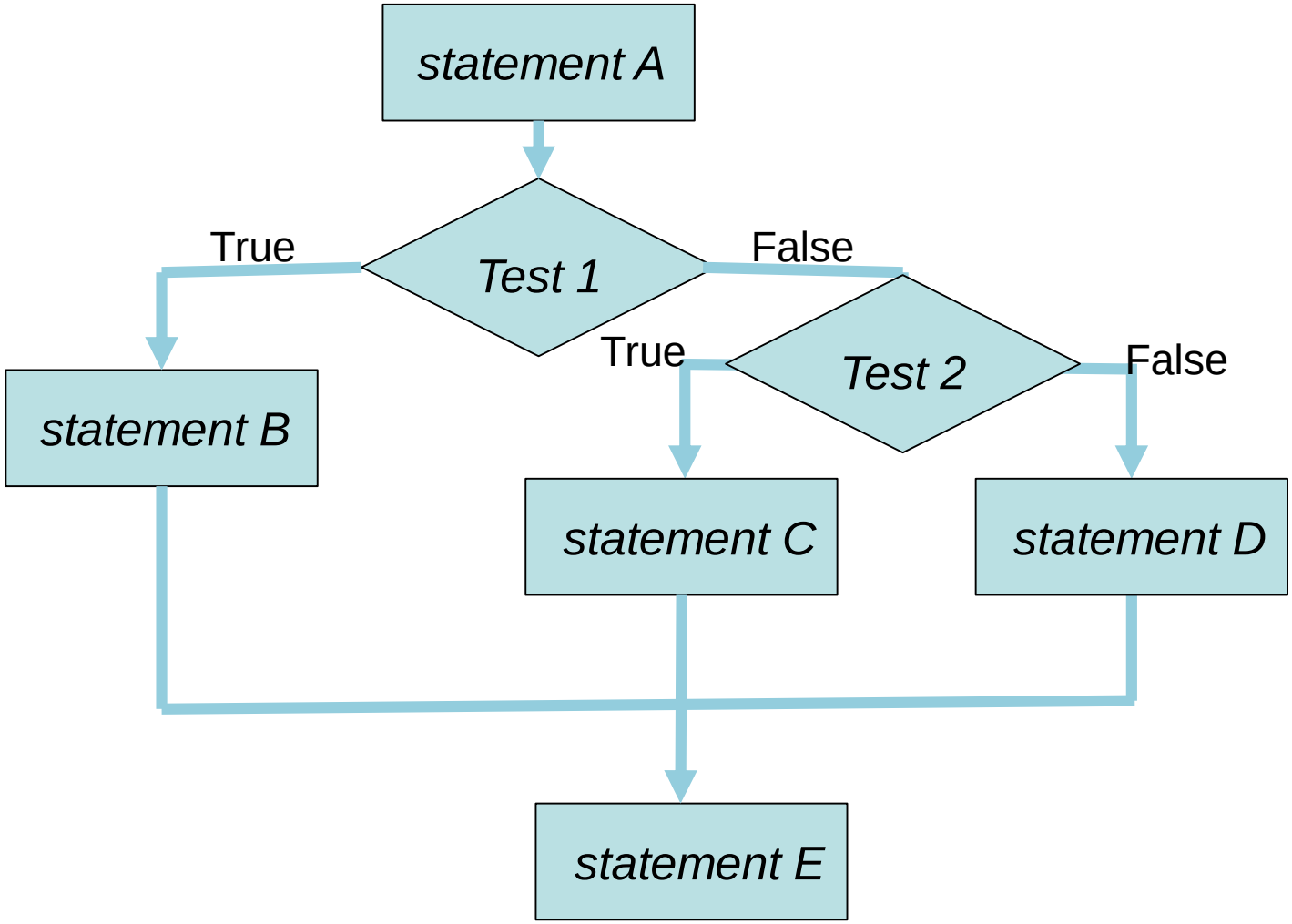
Choosing **between two statements or blocks**




```
statement A;
if (test)
        statement B;
else
        statement C;
statement D;
```

the if() else if() … statements

Choosing **between two statements or blocks**




```
statement A;
if(test1)
   statement B;
else if(test2)
   statement C;
else
   statement D;

Statement E;
```

Pairs of if() and else

```
if ( number > 6 )
   if ( number < 12 )
    printf("You are close!");
else
    printf("You Lose!");
```

How does this work? (which if does else belong to)?

'number'	*output*
5	
7	
14	

Pairs of if() and else

```
if ( number > 6 )
  if ( number < 12 )
    printf("You are close!");
  else
     printf("You Lose!");
```

else pairs with the most recent **if** unless braces are used

'number'	*output*
5	*none*
7	You are close!
14	You loose!

Pairs of if() and else

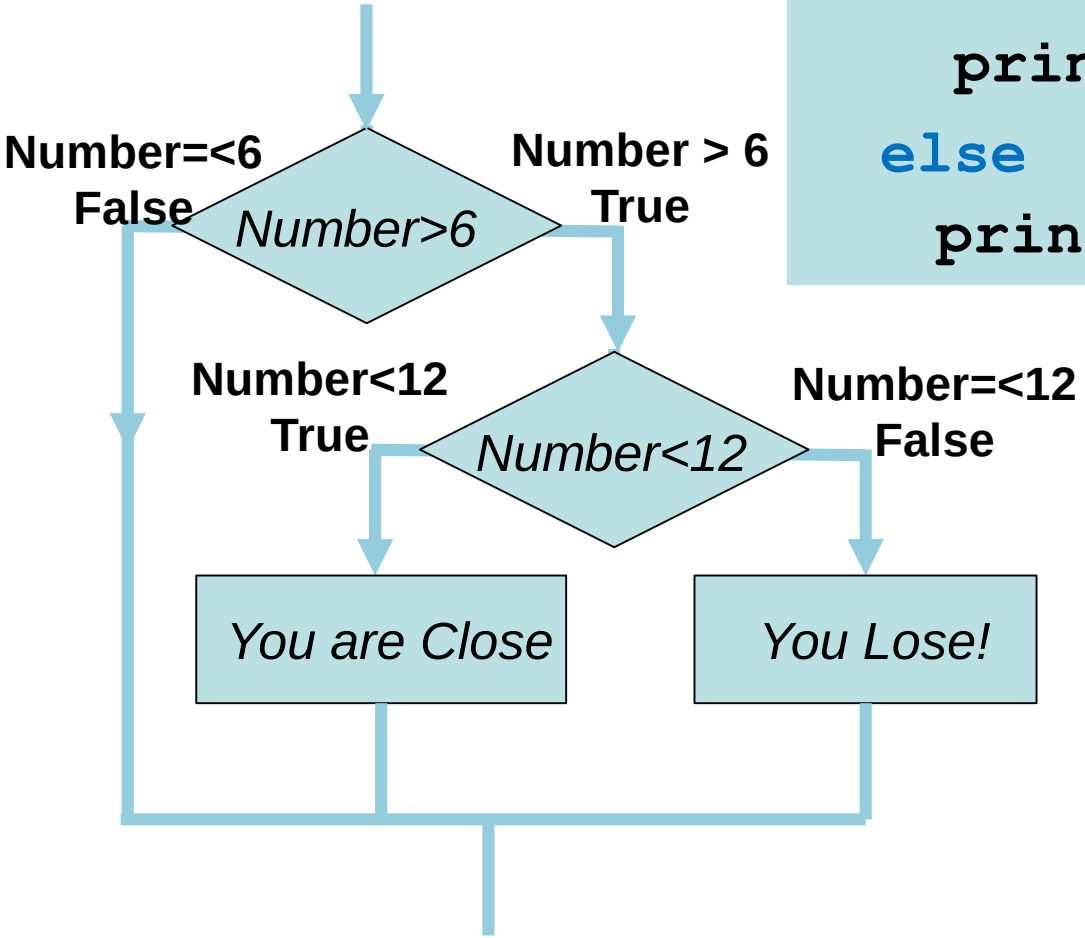
```
if ( number > 6 )
   if ( number < 12 )
      printf("You are close!");
   else
      printf("You Lose!");
```

else pairs with the most recent **if** unless braces are used

'number'	*output*
5	*none*
7	You are close!
14	You loose!

Pairs of if() and else…flow chart

```
if ( number > 6 )
  if ( number < 12 )
     printf("You are close!");
  else
    printf("You Lose!");
```



Quick Quiz 1

What is the value of z?

```
int x = 5, y = 2, z = 0;
if(x>3)
   if(y>2)
      z=1;
   else if(x<10)
      z=2;
   else
      z=3;
```

a) 0

b) 1

c) 2

d) 3

Quick Quiz 1

What is the value of z?

```
int x = 5, y = 2, z = 0;
if(x>3)
        if(y>2)
                z=1;
        else if(x<10)
                z=2;
        else
                z=3;
```

a) 0

b) 1

c) 2

d) 3

Logic

The Grim Reasoner

- Logic is all about reasoning with statements
- Statements can be either true or false
- Logic can be used to deduce new or simpler statements

Logic and Common Sense

- So far, we have taken a procedural view of logic:

```
if (x is true) do y
else           do z
```

- Common sense tells us we can re-write this as:

```
if (x is false) do z
else            do y
```

But sometimes, common sense isn't reliable…

If your logic is wrong, the program will do the wrong thing!

Negating Logic – De Morgans Rules

Negation rule can be proved using De-Morgans Rules

$!(P \&\& Q) \equiv !P \,||\, !Q$

P	Q	P &&Q	!(P &&Q)	!P	!Q	!P || !Q
T	T	T	F	F	F	F
T	F	F	T	F	T	T
F	T	F	T	T	F	T
F	F	F	T	T	T	T

- Similarly, it can be shown that: $!(P \,||\, Q) \equiv !P \,\&\&\, !Q$

Simplifying C Conditionals

- When programming, it is usually easier to understand what conditional statements will do if they are expressed in a **positive** sense

- Example: Use De-Morgans rules to re-write

```
if(!(w<50 || h<50))
if(!(P || Q))          /*subs P = w<50,Q=h<50*/
if(!P && !Q)           /*apply DeMorgan's*/
if(w>=50 && h>=50)     /*subs !P = w>=50,etc*/
```

Quick Quiz 2

- **Simplify the following:**

```
if (!(p>=200 && p<0) && q>0)
```

1) `if (p<200 && p>=0 && q>0)`
2) `if (p<200 || (p>=0 || q<=0))`
3) `if ((p<200 || p<0) || q<=0)`
4) `if (p>=0 || p<200 && q>0)`
5) `if ((p>=0 || p<200) && q>0)`

Quick Quiz 2

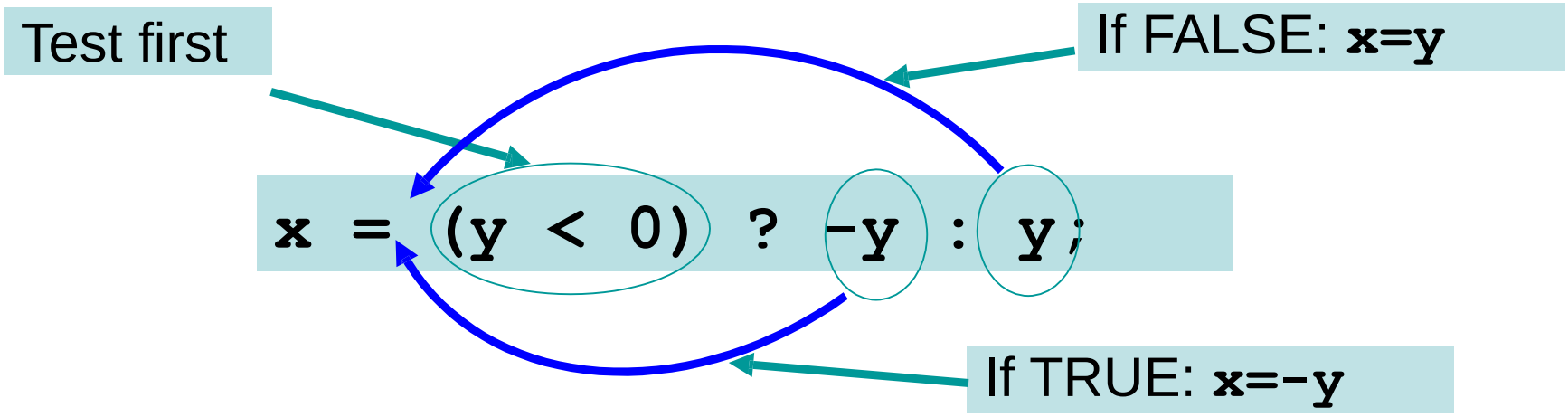
- **Simplify the following:**

```
if (!(p>=200 && p<0) && q>0)
```

1) `if (p<200 && p>=0 && q>0)`
2) `if (p<200 || (p>=0 || q<=0))`
3) `if ((p<200 || p<0) || q<=0)`
4) `if (p>=0 || p<200 && q>0)`
5) `if ((p>=0 || p<200) && q>0)`

More Shorthand (Laziness!)

- **if else** has a shorthand form



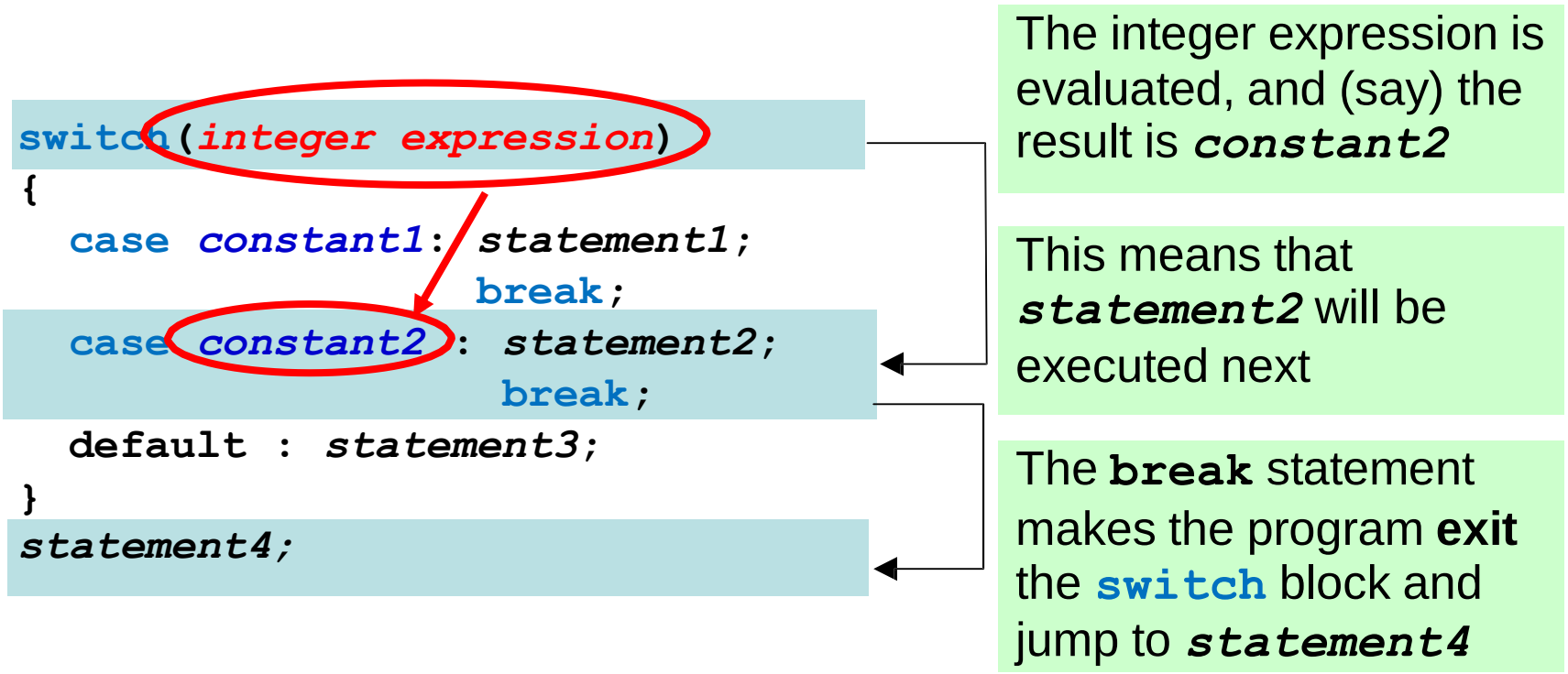
This is equivalent to

```
if ( y < 0 )
   x = -y;
else
   x = y;
```

test expression ? expression2 : expression3

Multiple Choice...**switch** and **break**

- **switch** is used to provide multiple choices



- **switch** test expression must have **integer** value
- **case** labels must be **integer-type**

  (constant, variable or expressions)

switch without break

- **break** ends the code block. It is good practice to include it in all cases…including the default.

```
switch(integer expression)
{
case constant1 : statement1;
case constant2 : statement2;
case constant3 : statement3;
default        : statement4;
}
statement5;
```

The integer expression is evaluated and the result is ***constant2***

This means that ***statement2*** will be executed next…

…then ***statement3*** is executed next…

… then ***statement4*** is executed next

switch and break example

```
#include <stdio.h>
#include <simpio.h>

main()
{
   int day;
   scanf("%d", &day);

   switch(day)
   {
      case 0 : printf("Sunday");
               break;
      case 6 : printf("Saturday");
               break;
      default: printf("Weekday");
               break;
   }
}
```

Read integer value - store it in **day**

If **day** is 0 print **Sunday**

If **day** is 6 print **Saturday**

The **break** statements make the program **exit** the **switch** block

For any other number print **Weekday**

Flow Control - Looping

Looping…the **while** loop

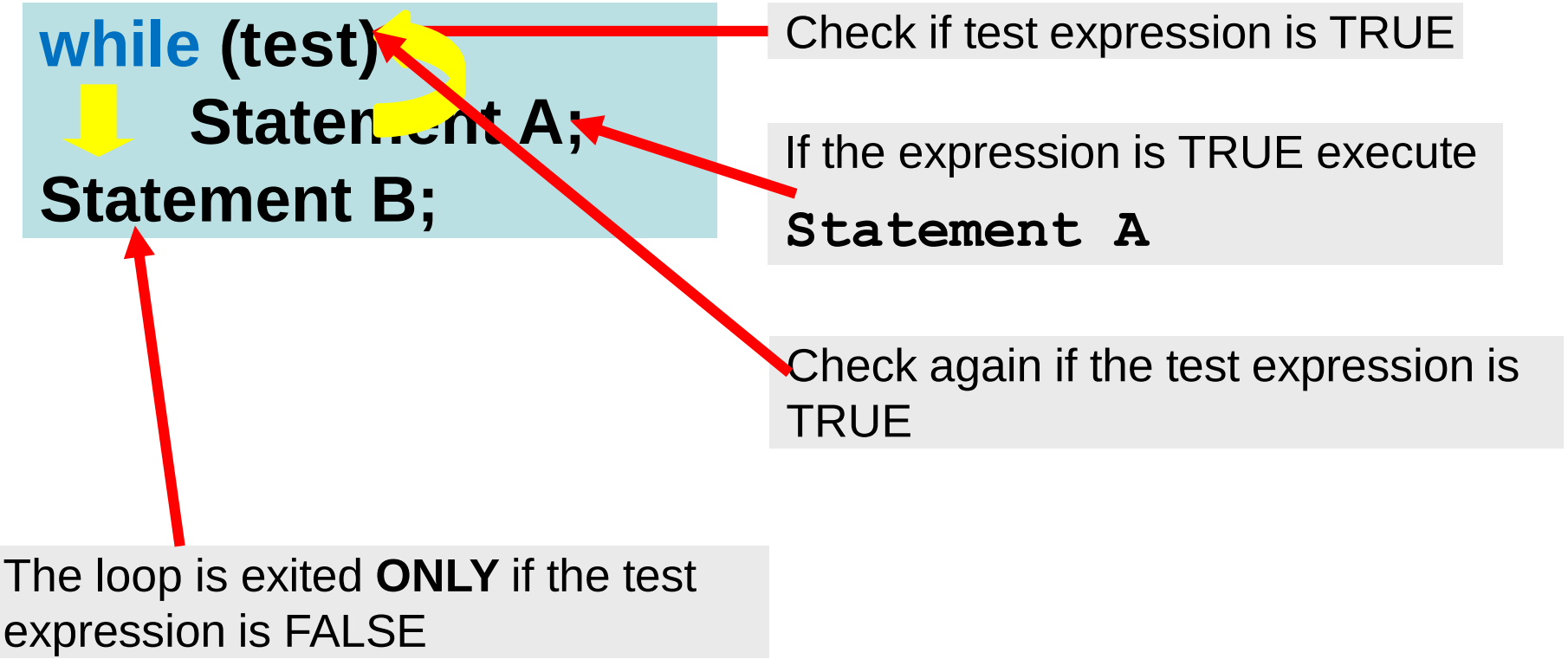
- In C, the syntax for a **while** loop looks like an **if** statement without **else**.

```
while (whileCondition) {
  /* do something */
}
```

- The body of the while statement is executed **repeatedly** as long as the condition is true.

the **while** loop

- Conditional loop with an entry condition



The **while** loop

```
while(test)
        {
        statement1;
        statement2;
        . . .
        }
int i=0,n,sum=0;
long factorial=1;
scanf("%d",&n);
while(i<n)
      {
      i = i+1;
      factorial *= i;
      sum += i;
      }
```

If the test expression is TRUE execute the **loop body** (the block of statements in between the set of squiggly brackets **{ }**)

- Note that part of the loop body relates to the loop condition
- It is **good style** to indent the loop body statements

The **do while** loop

What if you want to make sure the loop content executes once, whatever the test result?

The **do while** loop

What if you want to make sure the loop content executes once, whatever the test result?

The **do while** loop allows for this (**while** becomes an **exit** condition)

```
do
   statement;
while(test);
```

Use the test to decide if you want to have another go … execute the **statement** or **block of statements** again

```
count = 1;
do
{
   prinf("La,la,la!\n");
   count ++;
}
while(count < 5);
```

The do while or while loop?

Decide if you need an **entry** or an **exit** condition

Entry condition loops are preferred

Better to look before leaping

Entry condition loops make programs easier to read

while is ideal for conditions like:

```
while ( scanf("%d", &num) != 1 )
```

Quick Quiz 3

What number is printed after the loop?

```
float fac = 1.0;
int n = 0;
while (1){
   n++;
   if (fac*n > 50)
         break;
   fac = fac * n;
}
printf("Factorial = %f ", fac);
```

a) 1
b) 2
c) 6
d) 24
e) 120

Quick Quiz 3

What number is printed after the loop?

```
float fac = 1.0;
int n = 0;
while (1){
   n++;
   if (fac*n > 50)
         break;
   fac = fac * n;
}
printf("Factorial = %f ", fac);
```

a) 1
b) 2
c) 6
d) 24
e) 120

The for Loop

- Combines 3 actions in one place:

```
for(init;test;step)
        statement;
next statement;
```

```
for( i=1;i<=10;i++ )
    factorial*=i;
printf("%d",factorial);
```

- ***init*** **– initialise counter variable**
- ***test*** **– logical condition**
- ***step*** **– modify counter variable**

The for Loop

- Combines 3 actions in one place:

```
for(init;test;step)
        statement;
next statement;
```

```
for( i=1;i<=10;i++ )
    factorial*=i;
printf("%d",factorial);
```

Equivalent to

```
init;
while(test)
{
        statement;
        step;
}
next statement;
```

```
i=1;
while( i<=10)
{
        factorial*=i;
        i++;
}
printf("%d",factorial);
```

Quick Quiz 4

What number is printed after the loop?

```
int n, total=0;
for (n=1; n<5; n++)
      total = total + n*n;

printf("Total: %d\n", total);
```

a) 5
b) 10
c) 16
d) 25
e) 30

Quick Quiz 4

What number is printed after the loop?

```
int n, total=0;
for (n=1; n<5; n++)
      total = total + n*n;

printf("Total: %d\n", total);
```

a) 5
b) 10
c) 16
d) 25
e) <u>30</u>

Indefinite (**while**) vs. Counting (**for**)

- Indefinite loops – do not know in advance how many times the loop will be executed.
- Counting loops – the loop is executed a fixed (known) number of times.

- **A counter should be initialised**
- **The counter is compared with a limiting value**
- **The counter is incremented each time the loop is completed.**

The for Loop

```
#include <stdio.h>
main()
{
 double debt;

  for (debt=100.0; debt< 150; debt*=1.1)

  printf ("Your debt is now %.2f\n", debt);
}
```

This time the **update expression** involves some extra arithmetic calculations.

Program output

```
Your debt is now 100.00
Your debt is now 110.00
Your debt is now 121.00
Your debt is now 133.10
Your debt is now 146.41
```

The for Loop…counting down

In this example our counting variable is **decremented** every time the loop is executed

```
#include <stdio.h>
main()
{
 int secs;
 for(secs=5;secs>0;secs--)
   printf("%d seconds\n",secs);
 printf("We have ignition!");
 return 0;
}
```

Program output

```
5 seconds
4 seconds
3 seconds
2 seconds
1 seconds
We have ignition!
```

The for Loop…increment options

In this example our counter variable is **increased by 12** every time the loop is executed

```
#include <stdio.h>
main()
{
   int n;
   for(n=0;n<55;n=n+12)
       printf("%d \n", n);

}
```

Program output

```
0
12
24
48
```

The for Loop…by character

Remember that characters are just numbers

ASCII code . . .

```
#include <stdio.h>
main()
{
 char ch;
 for (ch='a'; ch<='z'; ch++)
   printf("ASCII value of %c is %d\n", ch, ch);
}
```

Here we compare and increment the numeric code for the character stored in **ch** variable

The **for** Loop…changing conditions

```
#include <stdio.h>
main()
{
 int n;
 for (n=0;n*n < 12; n++)
   printf ("%d \n", n);
}
```

Our **test expression** involves some extra arithmetic calculations. Do you remember which operator is **evaluated first** – has the **higher precedence?**

Program output

```
0
1
2
3
```

The **for** Loop…omitting expressions

- Any of the 3 expressions in the **for** statement can be left out.
- **If expression 1 (init) or 3 (step) are omitted then they just don't happen**
- **If expression 2 (test) is omitted then the loop appears permanently true.**

Here we have omitted the expression that **tests** the condition, **the loop will never be terminated!**

```
#include <stdio.h>
main()
{
 int time = 5;
 for (n=2;; time = time*n)
  printf("n=%d;time is %d.",n,time);
}
```

The for Loop…nested loops

- A loop inside another loop
- **Used to display data as rows and columns**

```
#include <stdio.h>
#define ROWS 4
#define CHARS 4

main ()
{
 int row; char ch;
 for (row = 0;row <ROWS; row++)
 {
  for (ch=('A'+row);ch<('A'+CHARS);ch++)
    printf ("%c",ch);
  printf("\n");
 }
}
```

Program output

```
ABCD
BCD
CD
D
```

Mid-Test Loops (1/2)

- Sometimes it is useful to use an infinite loop and make the termination test inside the loop using **break** or **continue**
- Try not to use **goto** or **label**, it is poor practice
- Example: find the first prime number>1000000

```
int p = 1000000;
while (1){                    / *  could also use: for (; ;) */
   p++;                        /* 1st  attempt is 1000001 */
   if (P>20)
      break;                 /* break when P is greater than 20 */
 }
```

Mid-Test Loops (2/2)

- **break** – exit the loop immediately (what about nested loops)
- **Continue** – skip the rest of the current cycle and start a new iteration

```
for(i=1;i<=10;i++)
{
    ch = getchar();
    if ( ch == '\n' )
        continue;
    putchar(ch);
}
```

```
for(i=1;i<=10;i++)
{
    ch = getchar();
    if ( ch == 'q' )
        break;
    putchar(ch);
}
```

Quick Quiz 5

The loop should print all numbers between 1 and 100. What is wrong with it?

```
int k;
for (k=1; k!=100; k=k+2)
{     printf ("Odd: %d \n", k);
      printf ("Even: %d \n", (k+1));
}
```

a) k=1;
b) k!=100
c) k=k+2
d) "Odd: %d \n",
e) (k+1)

Quick Quiz 5

The loop should print all numbers between 1 and 100. What is wrong with it?

```
int k;
for (k=1; k!=100; k=k+2)
{     printf ("Odd: %d \n", k);
      printf ("Even: %d \n", (k+1));
}
```

a) k=1;
b) k!=100
c) k=k+2
d) "Odd: %d \n",
e) (k+1)

As always…

Thank you for your attention

See you in the lab sessions ☺