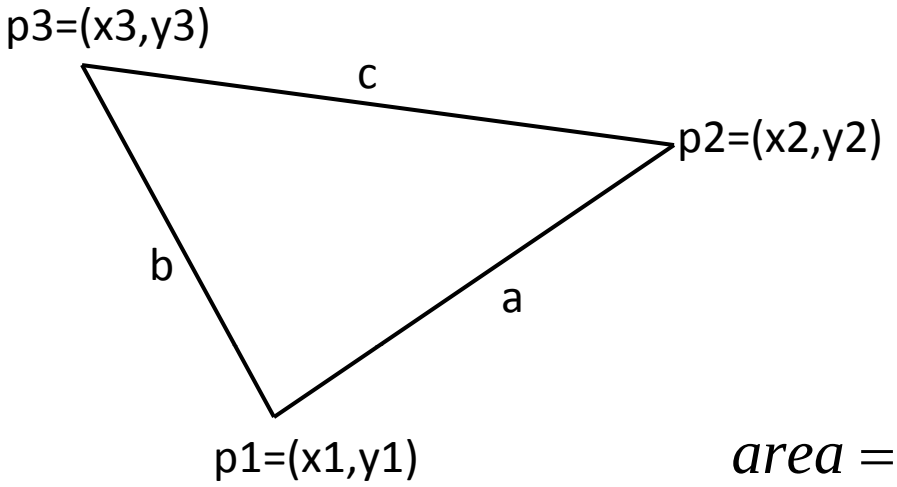
Functions

Moon Landings

	Time	Fuel	Velocity
Will Cyr	13	86.20	-0.49
Yongjiao Yu	13	86.00	-1.82
Bin Tian	13	87.00	-1.69
Nan Xia	13	87.00	-1.69
Chenli Yuan	13	87.00	-1.69
Scott Oliver	13	87.70	-2.74
Mike Robell	13	87.88	-3.00

Triangle Area Computation



$$a = |p2 - p1|$$

$$b = |p3 - p1|$$

$$c = |p3 - p2|$$

$$a = \sqrt{(x2 - x1)^2 + (y2 - y1)^2}$$

$$area = \sqrt{p(p-a)(p-b)(p-c)}$$

$$p = \frac{a+b+c}{2}$$

How would you write this program?

Variables

```
int main()
{
    double x1=0, y1=0;
    double x2=17, y2=10.3;
    double x3=-5.2, y3=5.1;

    double a, b, c;     /* Triangle side lengths */
    double p;           /* For Heron's formula */
    double area;
```

$$a = |p2 - p1|$$

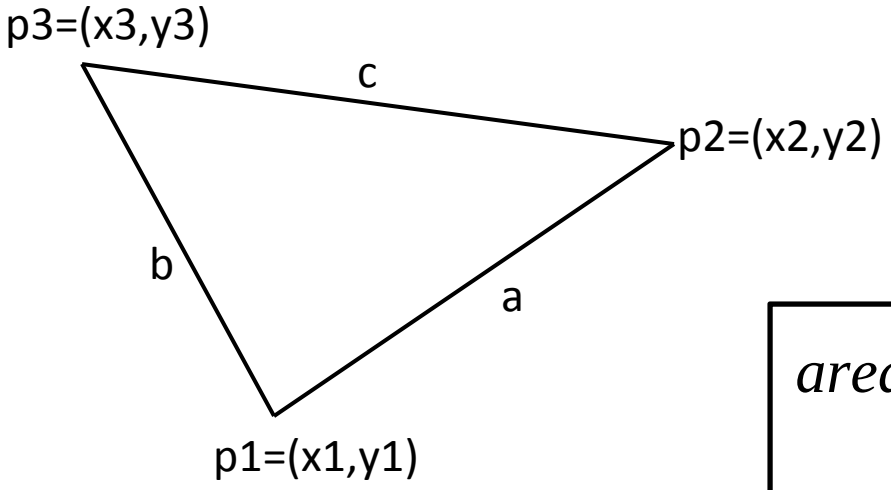
$$b = |p3 - p1|$$

$$c = |p3 - p2|$$

$$a = \sqrt{(x2 - x1)^2 + (y2 - y1)^2}$$

Lengths of Edges

```
a = sqrt((x1 - x2) * (x1 - x2) + (y1 - y2) * (y1 - y2));
b = sqrt((x1 - x3) * (x1 - x3) + (y1 - y3) * (y1 - y3));
c = sqrt((x2 - x3) * (x2 - x3) + (y2 - y3) * (y2 - y3));
```



$$a = |p2 - p1|$$

$$b = |p3 - p1|$$

$$c = |p3 - p2|$$

$$a = \sqrt{(x2 - x1)^2 + (y2 - y1)^2}$$

$$area = \sqrt{p(p-a)(p-b)(p-c)}$$

$$p = \frac{a+b+c}{2}$$

Area

```
p = (a + b + c) / 2;
area = sqrt(p * (p - a) * (p - b) * (p - c));

printf("%f\n", area);
```

$$area = \sqrt{p(p-a)(p-b)(p-c)}$$

$$p = \frac{a+b+c}{2}$$

Whole Program

What if I made a mistake on the edge length equation?

```
int main()
{
    double x1=0, y1=0;
    double x2=17, y2=10.3;
    double x3=-5.2, y3=5.1;

    double a, b, c;     /* Triangle side lengths */
    double p;           /* For Heron's formula */
    double area;

    a = sqrt((x1 - x2) * (x1 - x2) + (y1 - y2) * (y1 - y2));
    b = sqrt((x1 - x3) * (x1 - x3) + (y1 - y3) * (y1 - y3));
    c = sqrt((x2 - x3) * (x2 - x3) + (y2 - y3) * (y2 - y3));

    p = (a + b + c) / 2;
    area = sqrt(p * (p - a) * (p - b) * (p - c));

    printf("%f\n", area);
}
```

Functions

- Functions are subprograms that perform some operation and return one value
- They “encapsulate” some particular operation, so it can be re-used by others (for example, the abs() or sqrt() function)

Characteristics

- Reusable code
  - code in sqrt() is reused often
- Encapsulated code
  - implementation of sqrt() is hidden
- Can be stored in libraries
  - sqrt() is a built-in function found in the math library

Writing Your Own Functions

- Consider a function that converts temperatures in Celsius to temperatures in Fahrenheit.
  - Mathematical Formula:

$$F = C * 1.8 + 32.0$$

  - We want to write a C function called CtoF

Convert Function in C

```
double CtoF ( double paramCel )
{
        return paramCel*1.8 + 32.0;
}
```

- This function takes an input parameter called paramCel (temp in degree Celsius) and returns a value that corresponds to the temp in degree Fahrenheit

How to use a function?

```
#include <stdio.h>

double CtoF( double );

/*****************************************************************
* Purpose: to convert temperature from Celsius to Fahrenheit
*****************************************************************/
int main()
{
    double c, f;
    printf("Enter the degree (in Celsius): ");
    scanf("%lf", &c);

    f = CtoF(c);
    printf("Temperature (in Fahrenheit) is %lf\n", f);
}

double CtoF ( double paramCel)
{
    return paramCel * 1.8 + 32.0;
}
```

Terminology

- Declaration: double CtoF(double);

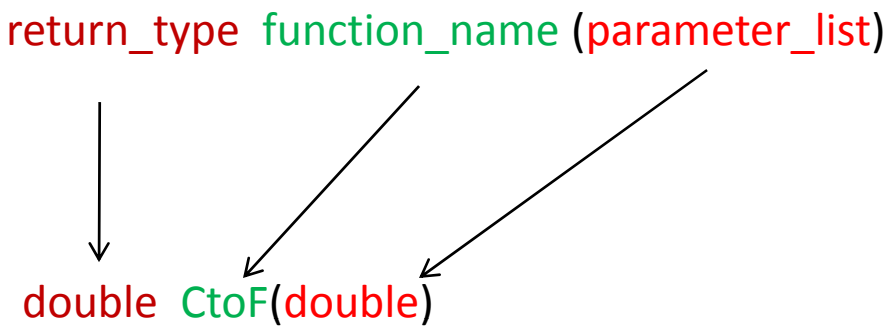
- Invocation (Call): Fahr = CtoF(Cel);

- Definition:

```
double CtoF( double paramCel )
{
   return paramCel*1.8 + 32.0;
}
```

Function Declaration

- Also called function prototype:



- Declarations describe the function:
  - the return type and function name
  - the type and number of parameters

Function Definition

```
return_type  function_name (parameter_list)
{
        ….
      function body
        ….
}
```

```
double  CtoF(double paramCel)
{
      return paramCel*1.8 + 32.0;
}
```

Function Invocation

```
int main()
{ ...
  f = CtoF(c);
}
```

1. Call copies argument *c* to parameter *paramCel*

2. Control transfers to function "CtoF"

```
double CtoF ( double paramCel )
{
      return paramCel*1.8 + 32.0;
}
```

Invocation (cont)

```
int main()
{ …
   f = CtoF(c);
}
```

3. Expression in "CtoF" is evaluated

```
double CtoF ( double paramCel )
{
      return paramCel*1.8 + 32.0;
}
```

4. Value of expression is returned to "main"

Local Objects

- The parameter “paramCel” is a local object which is defined only while the function is executing. Any attempt to use “paramCel” outside the function is an error.

- The name of the parameter need not be the same as the name of the argument. Types must agree.

```
int main()
{
   double x1=0, y1=0;
   double x2=17, y2=10.3;
   double x3=-5.2, y3=5.1;

   double a, b, c;     /* Triangle side lengths */
   double p;           /* For Heron's formula */
   double area;

   a = sqrt((x1 - x2) * (x1 - x2) + (y1 - y2) * (y1 - y2));
   b = sqrt((x1 - x3) * (x1 - x3) + (y1 - y3) * (y1 - y3));
   c = sqrt((x2 - x3) * (x2 - x3) + (y2 - y3) * (y2 - y3));

   p = (a + b + c) / 2;
   area = sqrt(p * (p - a) * (p - b) * (p - c));

   printf("%f\n", area);
}
```

Can we do better than this?

What should we name our function?

```
a = sqrt((x1 - x2) * (x1 - x2) + (y1 - y2) * (y1 - y2));
```

"Length" sounds like a good idea.

```
???   Length(   ???   )
{
}
```

What does our function need to know?

```
a = sqrt((x1 - x2) * (x1 - x2) + (y1 - y2) * (y1 - y2));
```

(x, y) for two different points:

```
???   Length(double x1, double y1,
             double x2, double y2)
{
}
```

What does our function *return*?

```
a = sqrt((x1 - x2) * (x1 - x2) + (y1 - y2) * (y1 - y2));
```

A computed value which is of type *double*

```
double Length(double x1, double y1,
              double x2, double y2)
{
}
```

How does it compute it?

```
a = sqrt((x1 - x2) * (x1 - x2) + (y1 - y2) * (y1 - y2));
```

A computed value which is of type *double*

```
double Length(double x1, double y1,
              double x2, double y2)
{
    double len;
    len = sqrt((x1 - x2) * (x1 - x2) + (y1 - y2) * (y1 - y2));
    return(len);
}
```

Using This

```c
#include <stdio.h>
#include <math.h>

/* Declaration */
double Length(double x1, double y1, double x2, double y2);

/*
 * Program to determine the area of a triangle
 */

int main()
{
    double x1=0, y1=0;
    double x2=17, y2=10.3;
    double x3=-5.2, y3=5.1;

    double a, b, c;     /* Triangle side lengths */
    double p;           /* For Heron's formula */
    double area;

    a = Length(x1, y1, x2, y2);
    b = Length(x1, y1, x3, y3);
    c = Length(x2, y2, x3, y3);

    p = (a + b + c) / 2;
    area = sqrt(p * (p - a) * (p - b) * (p - c));

    printf("%f\n", area);
}

/* Definition */
double Length(double x1, double y1, double x2, double y2)
{
    double len;
    len = sqrt((x1 - x2) * (x1 - x2) + (y1 - y2) * (y1 - y2));
    return(len);
}
```

Declaration

Invocations

Definition

Potential Errors

```
#include <stdio.h>
double convert( double );

int main()
{
      double c, f;
      printf("Enter the degree (in Celsius): ");
      scanf("%lf", &c);
      f= convert(c);
      printf("Temp (in Fahrenheit) for %lf Celsius is %lf", paramCel, f);
}

double CtoF( double paramCel)
{
      return c * 1.8 + 32.0;
}
```

Error! paramCel is not defined

Error! C is not defined

Scope – Where a variable is known to exist.

No variable is known outside of the curly braces that contain it, even if the same name is used!

Another Example

```
#include <stdio.h>

double GetTemperature();
double CelsiusToFahrenheit( double );
void DisplayResult( double, double );

int main()
{
  double
    TempC,                    // Temperature in degrees Celsius
    TempF;                    // Temperature in degrees Fahrenheit

  TempC = GetTemperature();
  TempF = CelsiusToFahrenheit(TempC);
  DisplayResult(TempC, TempF);

  return 0;
}
```

Function: GetTemperature

```
double GetTemperature()
{
  double Temp;

  printf("\nPlease enter a temperature in degrees Celsius: ");
  scanf("%lf", &Temp);
  return Temp;
}
```

Function: CelsiusToFahrenheit

```
double CelsiusToFahrenheit(double Temp)
{
  return (Temp * 1.8 + 32.0);
}
```

Function: DisplayResult

```
void DisplayResult(double CTemp, double FTemp)
{
  printf("Original: %5.2f C\n", CTemp);
  printf("Equivalent: %5.2f F\n", FTemp);

  return;
}
```

Declarations (Prototypes)

```
double GetTemp( );
double CelsiusToFahrenheit( double );
void Display( double, double );
```

- *void* means “nothing”. If a function doesn’t return a value, its return type is void

Abstraction

1. Get Temperature
2. Convert Temperature
3. Display Temperature

```
int main()
{
  double
    TempC,          // Temperature in degrees Celsius
    TempF;          // Temperature in degrees Fahrenheit

  TempC = GetTemperature();
  TempF = CelsiusToFahrenheit(TempC);
  DisplayResult(TempC, TempF);

  return 0;
}
```

We are hiding details on *how* something is done in the function implementation.

Another Way to Compute Factorial

Pseudocode for factorial(n)

```
if n == 0 then
    result = 1
else
    result = n * factorial(n – 1)
```

After all, 5! = 5 * 4 * 3 * 2 * 1 = 5 * 4!

Recursive Functions

```
int Factorial(int n)
{
    if(n == 0)
        return 1;
    else
        return n * Factorial(n-1);
}
```

Factorial function contains an invocation of itself.

We call this a: *recursive call*.

This works much like proof by induction.

Recursive functions must have a *base case* (if n == 0): why?

```
if n == 0 then
   result = 1
else
   result = n * factorial(n – 1)
```

Infinite Recursion

What if I omit the “base case”?

This leads to *infinite recursion*!

```
int Factorial(int n)
{
    return n * Factorial(n-1);
}
```

```
cbowen@ubuntu:~/cse251$ ./combi1
Input n: 5
Input k: 3
Segmentation fault
```

Factorial(3)=
3 * Factorial(2) =
3 * 2 * Factorial(1) =
3 * 2 * 1 * Factorial(0) =
3 * 2 * 1 * 0 * Factorial(-1) =
…

Psuedocode and Function

```
if n == 0 then
   result = 1
else
   result = n * factorial(n – 1)
```

```
int Factorial(int n)
{
    if(n == 0)
        return 1;
    else
        return n * Factorial(n-1);
}
```

Base Case

Declaration:

```
int Factorial(int n);
```

Invocation:

```
f = Factorial(7);
```

Definition:

```
int Factorial(int n)
{
    if(n == 0)
        return 1;
    else
        return n * Factorial(n-1);
}
```