DATA TYPES AND EXPRESSIONS

CS10003 PROGRAMMING AND DATA STRUCTURES

Data Types in C

int :: integer quantity

Typically occupies 4 bytes (32 bits) in memory.

char :: single character

Typically occupies 1 byte (8 bits) in memory.

float :: floating-point number (a number with a decimal point)

Typically occupies 4 bytes (32 bits) in memory.

double :: double-precision floating-point number

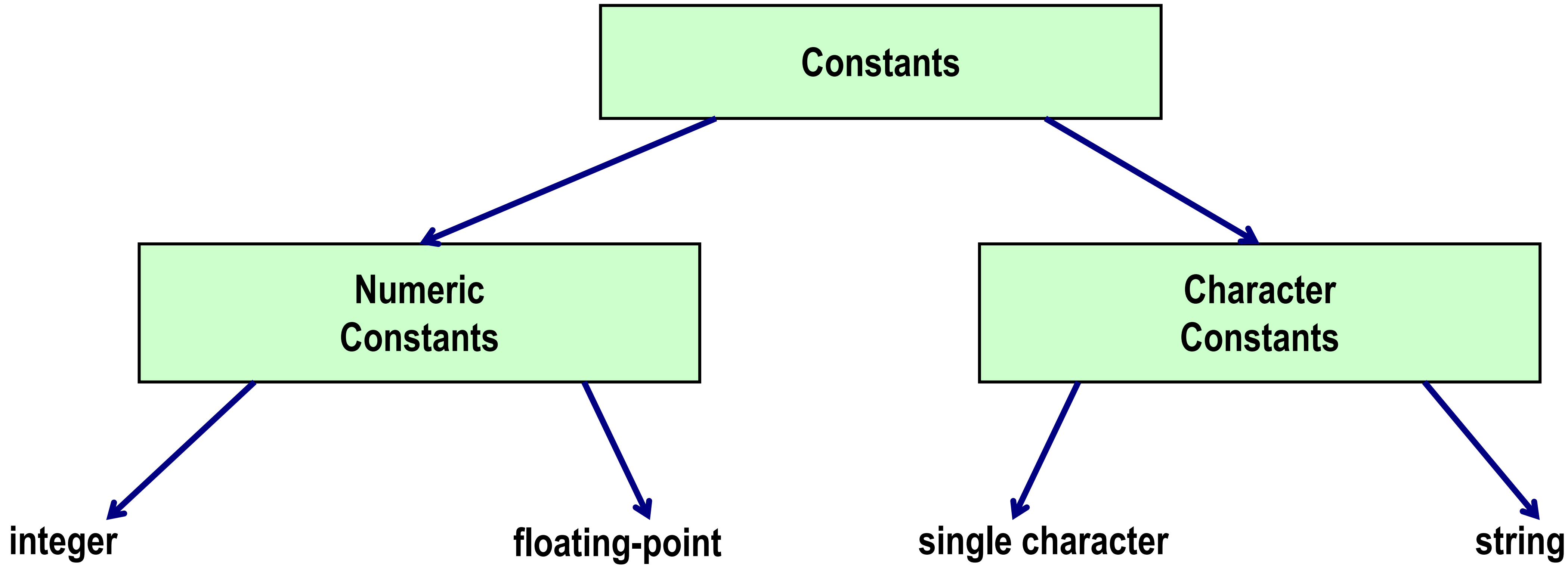
Some of the basic data types can be augmented by using certain data type qualifiers:

- short
- long
- signed
- unsigned

Typical examples:

- short int
- long int
- unsigned int
- unsigned char

Constants



We have studied integer, floating-point, and single character constants earlier

Integer and Floating-point Constants

- **Integer constants:**
  - Consists of a sequence of digits, with possibly a plus or a minus sign before it
  - Embedded spaces, commas and non-digit characters are not permitted between digits
  - Examples: 10, 39994, -765

- **Floating point constants – Two different notations:**
  - Decimal notation:
    - 25.0, 0.0034, .84, -2.234
  - Exponential (scientific) notation:
    - 3.45e23, 0.123e-12, 123e2

Single Character and String Constants

SINGLE CHARACTER CONSTANTS

Contains a single character enclosed within a pair of single quote marks.

- Examples :: ‘2’, ‘+’, ‘Z’

Some special backslash characters

‘\n’ new line
‘\t’ horizontal tab
‘\’’ single quote
‘\”’ double quote
‘\\’ backslash
‘\0’ null

STRING CONSTANTS

Sequence of characters enclosed in double quotes.

- The characters may be letters, numbers, special characters and blank spaces.

Examples:

“nice”, “Good Morning”, “3+6”, “3”, “C”

Differences from character constants:

- ‘C’ and “C” are not equivalent.
- ‘C’ has an equivalent integer value while “C” does not.

More about Character Constants and Variables

In C language, a character constant is actually a small integer (1 byte)

The character constant 'A' is internally an integer value 65

Character constants mapped to integers via ASCII codes (American Standard Code for Information Interchange)

'A': 65 'B': 66 … 'Z': 90

'a': 97 'b': 98 … 'z': 122

'0': 48 '1': 49 … '9': 57

An example:

```
char cvar = 'A';
printf ("%c %d", cvar, cvar);  /* Print the same value twice, once as character, second time as integer */
```

Variable Values and Variable Addresses

In C terminology, in an expression

speed (a variable name) refers to the contents of the memory location where the variable is stored.

&speed refers to the address of the memory location where the variable is stored.

Examples:

```
printf ("%f %f %f", speed, time, distance);     /* We need only the values of the vars to print them */
scanf ("%f %f", &speed, &time);                 /* We need the address of the vars to store the values read */
```

Assignment Statement

Used to assign values to variables, using the assignment operator (=).

General syntax:

```
variable_name  =  expression;
```

Left of = is called l-value, must be a modifiable variable

Right of = is called r-value, can be any expression

Examples:

```
velocity = 20;
b = 15;  temp = 12.5;
A = A + 10;
v = u + f * t;
s = u * t + 0.5 * f * t * t;
```

A value can be assigned to a variable at the time the variable is declared.

```
int   speed = 30;
char  flag = 'y';
```

Several variables can be assigned the same value using multiple assignment operators.

```
a = b = c = 5;
flag1 = flag2 = 'y';
speed = flow = 0.0;
```

Types of l-value and r-value

- Usually should be the same
- If not, the type of the r-value will be internally converted to the type of the l-value, and then assigned to it
- Example:

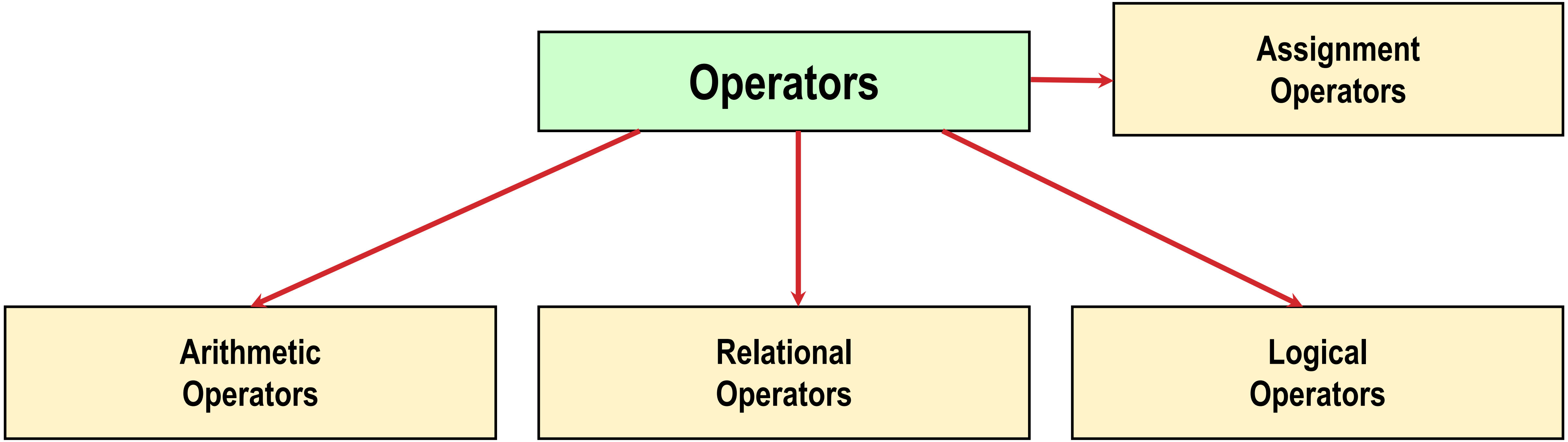
```
double a;
a = 2*3;
```

  - Type of r-value is int and the value is 6
  - Type of l-value is double, so stores 6.0

```
int a;
a = 2*3.2;
```

- Type of r-value is float/double and the value is 6.4
- Type of l-value is int, so internally converted to 6
- So a stores 6, and not 6.4

Operators in Expressions



Arithmetic Operators

Addition ::	+
Subtraction ::	–
Division ::	/
Multiplication ::	*
Modulus ::	% (remainder of division)

Examples:

```
distance = rate * time ;
netIncome = income - tax ;
speed = distance / time ;
area = PI * radius * radius;
y = a * x * x + b*x + c;
quotient = dividend / divisor;
remainder = dividend % divisor;
```

EXAMPLE: Suppose x and y are two integer variables, whose values are 13 and 5 respectively.

x + y	18
x – y	8
x * y	65
x / y	2
x % y	3

Operator Precedence of Arithmetic Operators

In decreasing order of priority

1. Parentheses :: ( )
2. Unary minus :: –5
3. Multiplication, Division, and Modulus
4. Addition and Subtraction

For operators of the *same priority*, evaluation is from *left to right* as they appear.

Parenthesis may be used to change the precedence of operator evaluation.

EXAMPLES:

a + b * c – d / e	a + (b * c) – (d / e)
a * – b + d % e – f	a * (– b) + (d % e) – f
a – b + c + d	(((a – b) + c) + d)
x * y * z	((x * y) * z)
a + b + c * d * e	(a + b) + ((c * d) * e)

Integer, Real, and Mixed-mode Arithmetic

INTEGER ARITHMETIC

- When the operands in an arithmetic expression are integers, the expression is called *integer expression*, and the operation is called *integer arithmetic*.
- Integer arithmetic always yields integer values.

For example:

25 / 10 evaluates to 2

REAL ARITHMETIC

- Arithmetic operations involving only real or floating-point operands.
- Since floating-point values are rounded to the number of significant digits permissible, the final value is an approximation of the final result.

1.0 / 3.0 * 3.0 will have the value 0.99999 and not 1.0

- The modulus operator cannot be used with real operands.

MIXED-MODE ARITHMETIC

- When one of the operands is integer and the other is real, the expression is called a *mixed-mode* arithmetic expression.
- If either operand is of the real type, then only real arithmetic is performed, and the result is a real number.

25 / 10 evaluates to 2

25 / 10.0 evaluates to 2.5

Similar code – different results !!

```
int a=10, b=4, c;
float x;
c = a / b;
x = a / b;
```

The value of c will be 2

The value of x will be 2.0

But we want 2.5 to be stored in x

Solution: Typecasting

```
int a=10, b=4, c;
float x;
c = a / b;
x = ((float) a) / b;
```

- Changing the type of a variable during its use
- General form

  (type_name) variable_name
- Example:

  x = ((float) a) / b;
- Now x will store 2.5 (type of a is considered to be float for this operation only, now it is a mixed-mode expression, so real values are generated)

Restrictions on Typecasting

- Not everything can be typecast to anything
  - float/double should not be typecast to int (as an int cannot store everything a float/double can store)
  - int should not be typecast to char (same reason)

Example: Finding Average of 2 Integers

Wrong program !! Why?

```
int a, b;
float avg;
scanf("%d%d", &a, &b);
avg = (a + b)/2;
printf("%f\n", avg);
```

```
int a, b;
float avg;
scanf("%d%d", &a, &b);
avg = ((float) (a + b))/2;
printf("%f\n", avg);
```

Correct programs

```
int a, b;
float avg;
scanf("%d%d", &a, &b);
avg = (a + b) / 2.0;
printf("%f\n", avg);
```

More Assignment Operators

`+=,  -=,  *=,  /=,  %=`

Operators for special type of assignments

a += b is the same as a = a + b

Same for -=, *=, /=, and %=

Exact same rules apply for multiple assignment operators

Suppose x and y are two integer variables, whose values are 5 and 10 respectively.

x += y	Stores 15 in x Evaluates to 15
x –= y	Stores -5 in x Evaluates to -5
x *= y	Stores 50 in x Evaluates to 50
x /= y	Stores 0 in x Evaluates to 0

Increment (++) and Decrement (--) Operators

- Both of these are unary operators; they operate on a single operand.
- The increment operator causes its operand to be increased by 1.
  - Example: a++, ++count
- The decrement operator causes its operand to be decreased by 1.
  - Example: i--, --distance

Pre-increment versus Post-increment

Operator written before the operand (++i, --i))

- Called pre-increment operator.
- Operator will be altered in value ***before*** it is utilized for its intended purpose in the statement.

Operator written after the operand (i++, i--)

- Called post-increment operator.
- Operator will be altered in value ***after*** it is utilized for its intended purpose in the statement.

EXAMPLES:

<u>Initial values :: a = 10; b = 20;</u>

x = 50 + ++a;	a = 11, x = 61
x = 50 + a++;	x = 60, a = 11
x = a++ + --b;	b = 19, x = 29, a = 11
x = a++ – ++a;	??

*Called **side effects**:: while calculating some values, something else get changed.*

Best to avoid such complicated statements

Relational Operators

Used to compare two quantities.

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

10 > 20	is false, so value is 0
25 < 35.5	is true, so value is non-zero
12 > (7 + 5)	is false, so value is 0
32 != 21	is true, so value is non-zero

- **Note:** The value corresponding to TRUE can be any non-zero value, not necessarily 1; FALSE is 0

- When arithmetic expressions are used on either side of a relational operator, the arithmetic expressions will be evaluated first and then the results compared

  a + b > c – d   is the same as   (a + b) > (c – d)

Logical Operators

There are three logical operators in C (also called logical connectives).

- ! : Unary negation (NOT)
- && : Logical AND
- || : Logical OR

What do these operators do?

- They act upon operands that are themselves logical expressions.
- The individual logical expressions get combined into more complex conditions that are true or false.

Unary negation operator (!)

- Single operand
- Value is 0 if operand is non-zero
- Value is 1 if operand is 0

Example: ! (grade == 'A')

Logical Operators

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What do these operators do?

- They act upon operands that are themselves logical expressions.
- The individual logical expressions get combined into more complex conditions that are true or false.

- Logical AND
  - Result is true if both the operands are true.
- Logical OR
  - Result is true if at least one of the operands are true.

X	Y	X && Y	X || Y
FALSE	FALSE	FALSE	FALSE
FALSE	TRUE	FALSE	TRUE
TRUE	FALSE	FALSE	TRUE
TRUE	TRUE	TRUE	TRUE

Examples of Logical Expressions

(count <= 100)

((math+phys+chem)/3 >= 60)

((sex == ‘M’) && (age >= 21))

((marks >= 80) && (marks < 90))

((balance > 5000) | | (no_of_trans > 25))

(! (grade == ‘A’))

Suppose we wish to express that *a should not have the value of 2 or 3.* Does the following expression capture this requirement?

((a != 2) || (a != 3))

Ans: No

Example: AND and OR

```
#include <stdio.h>
int main ()
{
        int i, j;
        scanf("%d%d", &i, &j);
        printf ( "%d AND %d = %d, %d OR %d=%d\n", i, j, i&&j, i, j, i||j ) ;
         return 0;

}
```

Output

```
3 0
3 AND 0 = 0, 3 OR 0 = 1
```

Precedence among different operators (there are many other operators in C, some of which we will see later)

Operator Class	Operators	Associativity
Unary	postfix ++, --	Left to Right
Unary	prefix ++, -- — ! &	Right to Left
Binary	* / %	Left to Right
Binary	+ —	Left to Right
Binary	< <= > >=	Left to Right
Binary	== !=	Left to Right
Binary	&&	Left to Right
Binary	||	Left to Right
Assignment	= += —= *= /= %=	Right to Left

Expression Evaluation

An assignment expression evaluates to a value

Value of an assignment expression is the value assigned to the l-value

Example: value of

- a = 3 is 3
- b = 2*4 – 6 is 2
- n = 2*u + 3*v – w is whatever the arithmetic expression 2*u + 3*v – w evaluates to given the current values stored in variables u, v, w

Consider a = b = c = 5

- Three assignment operators
- Rightmost assignment expression is c=5, evaluates to value 5
- Now you have a = b = 5
- Rightmost assignment expression is b=5, evaluates to value 5
- Now you have a = 5
- Evaluates to value 5
- So all three variables store 5, the final value the assignment expression evaluates to is 5

A more non-trivial example:

a = 3 && (b = 4)

- b = 4 is an assignment expression, evaluates to 4
- && has higher precedence than =
- 3 && (b = 4) evaluates to true as both operands of && are non-0, so final value of the logical expression is true
- a = 3 && (b = 4) is an assignment expression, evaluates to 1 (true)

Note that changing to b = 0 would have made the final value 0

Statements and Blocks

An expression followed by a semicolon becomes a statement.

```
x = 5;
i++;
printf ("The sum is %d\n", sum") ;
```

Braces { and } are used to group declarations and statements together into a compound statement, or block.

```
{
      sum = sum + count;
      count++;
      printf ("sum = %d\n", sum) ;
}
```

Doing More Complex Mathematical Operations

- C provides some mathematical functions to use in the math library
  - Can be used to perform common mathematical calculations
  - Two steps needed:

    (1) Must include a special header file

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

    (2) Must tell the compiler to link the math library: gcc <program name> –lm

- Example

  ```
  printf ("%f", sqrt(900.0));
  ```

  - Calls function sqrt, which returns the square root of its argument

- Return values of math functions are of type double
- Arguments may be constants, variables, or expressions

Math Library Functions

double acos(double x)	– Compute arc cosine of x.
double asin(double x)	– Compute arc sine of x.
double atan(double x)	– Compute arc tangent of x.
double atan2(double y, double x)	– Compute arc tangent of y/x.
double cos(double x)	– Compute cosine of angle in radians.
double cosh(double x)	– Compute the hyperbolic cosine of x.
double sin(double x)	– Compute sine of angle in radians.
double sinh(double x)	– Compute the hyperbolic sine of x.
double tan(double x)	– Compute tangent of angle in radians.
double tanh(double x)	– Compute the hyperbolic tangent of x.

Math Library Functions

double ceil(double x)	– Get smallest integral value that exceeds x.
double floor(double x)	– Get largest integral value less than x.
double exp(double x)	– Compute exponential of x.
double fabs (double x)	– Compute absolute value of x.
double log(double x)	– Compute log to the base e of x.
double log10 (double x)	– Compute log to the base 10 of x.
double pow (double x, double y)	– Compute x raised to the power y.
double sqrt(double x)	– Compute the square root of x.

Computing distance between two points

```
#include <stdio.h>
#include <math.h>
int main()
{
        int x1, y1, x2, y2;
        double dist;
        printf("Enter coordinates of first point: ");
        scanf("%d%d", &x1, &y1);
        printf("Enter coordinates of second point: ");
        scanf("%d%d", &x2, &y2);
        dist = sqrt(pow(x1 – x2, 2) + pow(y1 – y2, 2));
        printf("Distance = %lf\n", dist);
        return 0;
}
```

Output

```
Enter coordinates of first point: 3  4
Enter coordinates of second point: 2  7
Distance = 3.162278
```

Practice Problems

1. Read in three integers and print their average
2. Read in four integers a, b, c, d. Compute and print the value of the expression

   a+b/c/d*10*5-b+20*d/c

   - Explain to yourself the value printed based on precedence of operators taught
   - Repeat by putting parentheses around different parts (you choose) and first do by hand what should be printed, and then run the program to verify if you got it right
   - Repeat similar thing for the expression a&&b||c&&d>a||c<=b
3. Read in the coordinates (real numbers) of three points in 2-d plane, and print the area of the triangle formed by them
4. Read in the principal amount P, interest rate I, and number of years N, and print the compound interest (compounded annually) earned by P after N years