2.1 Functions
A Foundation for Programming

objects  functions and modules  graphics, sound, and image I/O  arrays  conditionals and loops  Math  text I/O  primitive data types  assignment statements

any program you might want to write

build bigger programs and reuse code
Functions

• Take in input arguments (zero or more)
• Perform some computation
  - May have side-effects (such as drawing)
• Return one output value

Input Arguments

\[ f(x, y, z) \]
Functions (Static Methods)

• Applications:
  - Use mathematical functions to calculate formulas
  - Use functions to build modular programs

• Examples:
  - Built-in functions:
    Math.random(), Math.abs(), Integer.parseInt()
  - I/O libraries:
    PennDraw.circle, PennDraw.
  - User-defined functions:
    main()
Why do we need functions?

• Break code down into logical sub-steps
• Readability of the code improves
• Testability - focus on getting each individual function correct
Anatomy of a Java Function

• Java functions – It is easy to write your own
  - Example: `double sqrt(double c)`

```
public static double sqrt(double c) {
...
}
```

Please note that the method signature is defined incorrectly in the figure on pg 188 of your textbook.
Anatomy of a Java Function

• Java functions – It is easy to write your own
  - Example: `double sqrt(double c)`

\[
\text{sqrt}(c) = \sqrt{c}
\]

Example:

\[
\begin{align*}
\text{input} & : 2.0 \\
\text{output} & : 1.414213...
\end{align*}
\]

```java
public static double sqrt(double c) {
    if (c < 0) return Double.NaN;
    double err = 1e-15;
    double t = c;
    while (Math.abs(t - c/t) > err * t)
        t = (c/t + t) / 2.0;
    return t;
}
```
Flow of Control

Functions provide a **new way** to control the flow of execution

```java
public class Newton {
    public static double sqrt(double c) {
        if (c < 0) return Double.NaN;
        double err = 1e-15;
        double t = c;
        while (Math.abs(t - c/t) > err * t)
            t = (c/t + t) / 2.0;
        return t;
    }

    public static void main(String[] args) {
        int N = args.length;
        double[] a = new double[N];
        for (int i = 0; i < N; i++)
            a[i] = Double.parseDouble(args[i]);
        for (int i = 0; i < N; i++)
            double x = sqrt(a[i]);
        StdOut.println(x);
    }
}
```

Implicit return statement at end of void function
Flow of Control

What happens when a function is called:
- Control transfers to the function
- Argument variables are assigned the values given in the call
- Function code is executed
- Return value is substituted in place of the function call in the calling code
- Control transfers back to the calling code

Note: This is known as "pass by value"
Example

• Function to reverse a word

• Apply this word reversal function to reverse a sentence that is entered via command line arguments.

Live coding time .....
Organizing Your Program

• Functions help you organize your program by breaking it down into a series of steps
  - Each function represents some abstract step or calculation
  - Arguments let you make the function have different behaviors

• **Key Idea**: write something ONCE as a function then reuse it many times
Scope

Scope: the code that can refer to a particular variable
  - A variable's scope is the entire code block (any any nested blocks) after its declaration

Simple example:

```java
int count = 1;
for (int i = 0; i < 10; i++) {
    count *= 2;
}
// using 'i' here generates
// a compiler error
```

Best practice: declare variables to limit their scope
Q. What happens when you compile and run the following code?

```java
public class Cubes1 {
    public static int cube(int i) {
        int j = i * i * i;
        return j;
    }
    public static void main(String[] args) {
        int N = Integer.parseInt(args[0]);
        for (int i = 1; i <= N; i++)
            System.out.println(i + " " + cube(i));
    }
}
```
Scope with Functions

```java
public class Newton {
    public static double sqrt(double c) {
        if (c < 0) return Double.NaN;
        double err = 1e-15;
        double t = c;
        while (Math.abs(t - c/t) > err * t) {
            t = (c/t + t) / 2.0;
        }
        return t;
    }

    public static void main(String[] args) {
        int N = args.length;
        double[] a = new double[N];
        for (int i = 0; i < N; i++) {
            a[i] = Double.parseDouble(args[i]);
        }
        for (int i = 0; i < N; i++) {
            double x = sqrt(a[i]);
            StdOut.println(x);
        }
    }
}
```

This code cannot refer to `args[]`, `N`, or `a[]`

Scope of `c`, `err`, and `t`

Scope of `args[]`, `N`, and `a[]`

This code cannot refer to `c[]`, `err`, or `t`

Scope of `i` and `x`

Scope of `i`

Two different variables
public class Cubes1 {
    
    public static int cube(int i) {
        int j = i * i * i;
        return j;
    }

    public static void main(String[] args) {
        int N = Integer.parseInt(args[0]);
        for (int i = 1; i <= N; i++)
            System.out.println(i + " " + cube(i));
    }
}
Last In First Out (LIFO) Stack of Plates
Method Overloading

• Two or more methods \textit{in the same class} may also have the same name

• This is called \textit{method overloading}

\begin{verbatim}
public static int abs(int x)
{
    if (x < 0) return -x;
    else return x;
}

public static double abs(double x)
{
    if (x < 0.0) return -x;
    else return x;
}
\end{verbatim}
A method is uniquely identified by
- its name and
- its parameter list (parameter types and their order)

This is known as its signature

Examples:

```java
static int min(int a, int b)
static double min(double a, double b)
static float min(float a, float b)
```
Return Type is Not Enough

• Suppose we attempt to create an overloaded `circle(double x, double y, double r)` method by using different return types:

```java
static void circle(double x, double y, double r) {...}
//returns true if circle is entirely onscreen, false otherwise
static boolean circle(double x, double y, double r) {...}
```

• This is NOT valid method overloading because the code that calls the function can ignore the return value
  `circle(50, 50, 10);`
  - The compiler can’t tell which `circle()` method to invoke
  - Just because a method returns a value doesn’t mean the calling code has to use it
Automatic type promotion and overloading can sometimes interact in ways that confuse the compiler. For example:

```java
// version 1
static void printAverage(int a, double b) {
    ...
}

// version 2
static void printAverage(double a, int b) {
    ...
}
```

Why might this be problematic?
• Consider if we do this

    public static void main (String[] args) {
        ...
        average(4, 8);
        ...
    }

• The Java compiler can’t decide whether to:
  - promote 7 to 7.0 and invoke the first version of `average()`, or
  - promote 5 to 5.0 and invoke the second version

• Take-home lesson: don’t be too clever with method overloading
### Function Examples

#### absolute value of an int value

```java
public static int abs(int x) {
    if (x < 0) return -x;
    else return x;
}
```

#### absolute value of a double value

```java
public static double abs(double x) {
    if (x < 0.0) return -x;
    else return x;
}
```

#### primality test

```java
public static boolean isPrime(int N) {
    if (N < 2) return false;
    for (int i = 2; i <= N/i; i++)
        if (N % i == 0) return false;
    return true;
}
```

#### hypotenuse of a right triangle

```java
public static double hypotenuse(double a, double b) {
    return Math.sqrt(a*a + b*b);
}
```
Q. What happens when you compile and run the following code?

```java
public class Cubes2 {
    public static int cube(int i) {
        int i = i * i * i;
        return i;
    }

    public static void main(String[] args) {
        int N = Integer.parseInt(args[0]);
        for (int i = 1; i <= N; i++)
            System.out.println(i + " " + cube(i));
    }
}
```
Q. What happens when you compile and run the following code?

```java
public class Cubes3 {

    public static int cube(int i) {
        i = i * i * i;
    }

    public static void main(String[] args) {
        int N = Integer.parseInt(args[0]);
        for (int i = 1; i <= N; i++)
            System.out.println(i + " " + cube(i));
    }
}
```
Q. What happens when you compile and run the following code?

```java
public class Cubes4 {
    public static int cube(int i) {
        i = i * i * i;
        return i;
    }

    public static void main(String[] args) {
        int N = Integer.parseInt(args[0]);
        for (int i = 1; i <= N; i++)
            System.out.println(i + " " + cube(i));
    }
}
```
Q. What happens when you compile and run the following code?

```java
public class Cubes5 {
    public static int cube(int i) {
        return i * i * i;
    }
    public static void main(String[] args) {
        int N = Integer.parseInt(args[0]);
        for (int i = 1; i <= N; i++)
            System.out.println(i + " " + cube(i));
    }
}
```