Eclipse

- Using Eclipse to write and run programs
  - See Sakai Eclipse page for Setup
  - Make sure you can write and execute a program before next class

CS111
Introduction to Computer Science

- Building Blocks of a Program
- Programming Process
- Printing Statements
- Fahrenheit to Celsius

Programming Languages

Programming languages differ from human languages because they have to be completely unambiguous

- The rules to determined what is allowed is called the *syntax* of the language
- The meaning of the program is called the *semantics*, which is a set of syntactically correct rules that specify meaning the program

Building Blocks of Programs

- Data: Variables and Types
  - a *variable* is just a memory location to hold data
  - a variable has a *type* to indicate what sort of data it can hold
- Instructions: Control Structures and Subroutines
  - *control structures* can change the flow of control
    - branches and loops
  - *subroutines* are a group of instructions that together perform some task

Primitive Data Types

A variable in Java can hold only one type of data

Data Type	Bytes	Range	Example
byte	1	-128 to 127	byte a = 10;
short	2	-32768 to 32767	short a = 1230;
int	4	-2147483648 to 2147483647	int a = 331;
long	8	-92233720368547758O8 to 92233720368547758O7	long a = 23;
float	4	10^{38}	float a = 23.1f;
double	8	10^{308}	double a = 26.2;
char	2		char a = 'A';
boolean	1	true or false	boolean a = true;

See Types.java

Arithmetic Operators +, -, *, /

- Can be used on values of byte, short, int, long, float, double or char.
- When used on char the values are treated as integers (char is converted to its Unicode number)
- The two values must be of the same type. If the program tells the computer to combine two values of different types, the computer will convert one of the values from one type to another:

  56.3 + 10 => 56.3 + 10.0 = 66.3

Increment and Decrement

Adding or subtracting 1 to and from a variable is extremely common

Increment / Decrement	Equivalent expression
counter = counter + 1;	counter++;
counter = counter – 1;	counter--;

Expression	Result		
	x	y	z
x = 6;	6		
x = x++;	6		
y = x++;	7	6	
y = ++x;	8	8	
y = --x;	7	7	
z = (++x) * (y--);	7	6	49

The Programming Process

1. Problem Statement
2. Problem Analysis: understand what the program should do
   - Inputs, outputs, error conditions
3. Program Design: what operations are necessary?
4. Algorithm Construction: choose a sequence of actions to achieve the goal
   - We'll use pseudocode
5. Coding
   - Use a programming language (Java) to express the actions
6. Testing: does the program work correctly?
   - Test case constructions, debugging

Program: Printing Data

1. Problem Statement: printing welcoming CS111 note
2. Analysis
   - No inputs, outputs, errors
3. Program Design
   - Printing
4. Algorithm Construction

```
print "CS111 Introduction to Computer Science"
print "Are you ready to learn how to program?"
```

5. Coding: Let's do our first program!!!
6. Testing: only one test case needed, check if output matches expected

Statements in double quotes printed verbatim

Statements in Java have different syntax

See Announcement.java

IO Module

A module written by us to help you read user input and display the output of your programs

You are to use the only the IO Module on your assignments for input and output

Codelab does not use the IO Module

Program: summing apples

1. Statement: summing apples of two people
2. Analysis
   - Input: Jane and John's number of apples
   - Output: Total number of apples
   - No errors
3. Program Design
   - Request input, read input, sum, print to screen
4. Algorithm Construction

```
print "Enter how many apples Jane has: "
janeApples ← read number
print "Enter how many apples John has: "
johnApples ← read number
total ←janeApples + johnApples
print total
```

5. Coding: Let's code!!!
6. Testing: only one test case needed, check if the total amount is correct

Relational Operators

Relational operators are: ==, !=, <, >, <=, and >=

Operator	Meaning
A == B	Is A equal to B?
A != B	Is A not equal to B?
A < B	Is A less than B?
A > B	Is A greater than B?
A <= B	Is A less or equal to B?
A >= B	Is A greater than or equal to B?

Program: Fahrenheit To Celsius Conversion

2. Analysis
   - Input: temperature in Fahrenheit
   - Output: temperature in Celsius
   - Error conditions: input less than -459.67 (absolute zero)
3. Program Design
   - Request input, read input, do conversion, display answer
4. Algorithm Construction

```
print "Please, enter the temperature in Fahrenheit"
tempF ⟵ read number
tempC ⟵ (tempF – 32) * 5 / 9
print tempC
```

When execution gets here, it waits for user to enter data, then reads the value entered, and stores it into a memory location called tempF

The value in the memory location tempC is retrieved and printed. Retrieval does NOT wipe out the values – they are still there, and can be reused as many times as needed.

The right hand side is computed, using the value retrieved from the memory location tempF, the result is stored in a memory location called tempC

Program: Fahrenheit To Celsius Conversion

2. Analysis
   - Input: temperature in Fahrenheit
   - Output: temperature in Celsius
   - Error conditions: input less than -459.67 (absolute zero)
3. Program Design
   - Request input, read input, do conversion, display answer
4. Algorithm Construction

```
print "Please, enter the temperature in Fahrenheit"
tempF ← read number
tempC ← (tempF – 32) * 5 / 9
print tempC
```

5. Coding
6. Testing

Input	Expected Output	Output
32	0	0
100	37.78	37.78
-600	error	-351.11

Program: Fahrenheit To Celsius Conversion with Error Checking

2. Analysis: same as before
3. Program Design: same as before
4. Algorithm Construction

```
print "Please, enter the temperature in Fahrenheit"
tempF ← read number
if tempF < -459.67
    print "Not a valid temperature"
    halt
tempC ← (tempF – 32) * 5 / 9
print tempC
```

In pseudocode indentation expresses conditionality

6. Testing

Input	Expected Output	Output
32	0	0
100	37.78	37.78
-600	error	error

When making a code change, run all tests again.

Same Problem, Different Solutions

```
print "Please, enter the temperature in Fahrenheit"
tempF ← read number
if tempF < -459.67
    print "Not a valid temperature"
    halt
tempC ← (tempF – 32) * 5 / 9
print tempC
```

1-way decision

See F2C.java

```
print "Please, enter the temperature in Fahrenheit"
tempF ← read number
if tempF < -459.67
    print "Not a valid temperature"
else
    tempC ← (tempF – 32) * 5 / 9
    print tempC
```

2-way decision

See F2C_v2.java

Multi-way decisions

- 1-way
  - `if…`
- 2-way
  - `if… else…`
- 3-way (cascaded)
  - `if… else {if… else…}`
- 4-way (nested)
  - `if… {if… else…} else… {if… else…}`

```
if true
   - operation
```

```
if true
   - operation
else
   -operation
```

```
if true
   - operation
else
   if true
      -operation
   else
      -operation
```

```
if true
   if true
      -operation
   else
      -operation
else
   if true
      -operation
   else
      -operation
```

CS111
Introduction to Computer Science

- Booleans
- Calculator
- Letter Grade
- Amount of Daylight
- Testing

Booleans

- Like other data booleans are stored as variables
  - there are only two values: true or false
- The result of a comparison is a boolean value
  - if temperature in Fahrenheit < -459.67
  - Can be used for combining tests
    - Hour value is invalid if hour < 0 or hour > 12

Boolean values as data

- Since true and false are data values, we can:
  - Store them in variables: xBig ← x > y
  - Read them from input and print them as output
  - Create them with operations

    x<y x>y x<=y x>=y x==y x!=y
  - Use them as operand for boolean operators

    xBig || yBig xBig && yBig !xBig

Boolean Operators: not, and, or

NOT

A	!A
false	true
true	false

AND

A	B	A && B
false	false	false
false	true	false
true	false	false
true	true	true

OR

A	B	A || B
false	false	false
false	true	true
true	false	true
true	true	true

Boolean examples

x ← 10, y ← 20

What are the boolean values of the following:

```
x < y
x >= y
x >= 10
x == 9 || x == 10
x == 9 && x == 10
x > y || (x == 10 && y < 7)
```

Precedence Rules

Order of evaluation from highest to lowest precedence

Unary operators	++, --, !, unary -, unary +, type cast
Multiplication and division	*, /, %
Addition and subtraction	+, -
Relational operators	<, >, <=, >=
Equality and inequality	==, !=
Boolean and	&&
Boolean or	||
Conditional operator	?:
Assignment operators	=, +=, -=, *=, /=, %=

Precedence Rules

When operators of the same precedence are strung together in the absence of parentheses, unary operators and assignment operators are evaluated right-to-left, while the remaining operators are evaluated left-to-right.

A*B/C means (A*B)/C evaluated left-to-right

A=B=C means A=(B=C) evaluated right-to-left

Evaluate Expressions

Expression	Result
1 <= 1 && 5 <= 8	true
!(6 – 2 != 12 - 10)	false
4.2 + 3	7.2
(int) 34.2	34
(double) 10	10.0
5 % 2	1
50/15	3
6 = 7	Compiler error

Program: Calculator

Should do 4 basic arithmetic operations.

- Example of program interaction:

  Enter first number: 2

  Enter second number: 3

  Enter [1]addition, [2]subtraction, [3]multiplication, [4]division: 3

  Result: 2*3 = 6

See Calculator.java, Calculator_v2.java

Program: Calculator

1. Analysis
   - inputs: operand1 and operand2 (real numbers), operator (integer, choice from menu)
   - outputs: result (real number)
   - errors: invalid operation, divide by 0
2. Program Design
   - Prompt for input
   - Read input
   - Do calculation
   - Display result

Program: Calculator

3. Algorithm

```
print “Enter first number:”
op1 = read number
print “Enter second number:”
op2 = read number
print “Enter [1]addition, [2]subtraction,
        [3]multiplication, [4]division:”
choice = read integer
...
```

algorithm cont.

```
...
if choice == 1
        print op1 + op2
        halt
if choice == 2
        print op1 – op2
        halt
if choice == 3
        print op1 * op2
        halt
if choice == 4
        if op2 != 0
                print op1/op2
        else
                print “can’t divide by zero”
        halt
print “invalid menu selection”
```

4. Coding

Program: Calculator

5. Testing

First Number	Second Number	Operation	Expected Output
2	4	1	6
2	4	2	-2
2	4	3	8
2	4	4	0.5
2	0	4	Error
2	4	7	Error

Program: Letter Grade

Assigning a letter grade to a student

- Example of program interaction

  Enter score: 98.2

  Letter grade is A

See LetterGrade.java

Letter Grade: analysis

- Inputs: student score
- Outputs:
  - Letter grade
- Errors: score less than 0 or grater than 100
- Test data

- Each part of the program must be executed by some set of test data
- Each if condition (decision) should be made both true and false at different times

Input	Expected output
80	B
40	F
109	Error
-4	Error

Letter Grade: algorithm

```
print “Enter student grade:”
grade = read number
if (grade < 0 or grade > 100)
    print “Error”
    halt
if (grade >= 90)
    print “A”
   halt
if (grade >= 80)
    print “B”
   halt
if (grade >= 70)
   print “C”
   halt
if (grade >= 60)
    print “D”
   halt
if (grade >= 50)
    print “F”
```

What is the output?

```
public class Test {

   public static main void (String[] args) {
      System.out.println("Enter an integer: ");
      int a = IO.readInt();
      if (a = 4) {
        System.out.println("User entered the number 4");
      } else {
        System.out.println("User entered another value");
      }
   }
}
```

Program: Amount of daylight

Computes the amount of daylight from sunrise to sunset

- Example of program interaction:

  Enter sunrise hour: 6
  Enter sunrise minute: 30
  Enter true for morning sunrise, false otherwise: true
  Enter sunset hour: 8
  Enter sunset minute: 45
  Enter true for morning sunset, false otherwise: false

  Amount of daylight is 14 hours and 15 minutes.

Program: Amount of daylight

1. Analysis
   - Input: sunrise hour (integer), sunrise minute (integer), am/pm (boolean), sunset hour (integer), sunset minute (integer), am/pm (boolean)
   - Output: amount of daylight in hours (integer), minutes (integer)
   - Error conditions: input out of range 1-12 or 0-59
2. Algorithm Construction

cont.

```
print “Enter sunrise hour:”
riseHour = read integer
if riseHour < 1 or riseHour > 12
   print "sunrise hour not valid"
   halt
print “Enter sunrise minute:”
riseMinute = read integer
if riseMinute < 0 or riseMinute > 59
   print "sunrise minute not valid"
   halt
print “Enter sunrise am/pm”
riseAm = read boolean
```

```
print “Enter sunset hour:”
if setHour < 1 or setHour > 12
   print "sunset hour not valid"
   halt
print “Enter sunset minute:”
setMinute <- read integer
if setMinute < 0 or setMinute > 59
   print "sunset minute not valid"
   halt
print “Enter sunset am/pm”
setAm = read boolean
```

Program: Amount of daylight

cont.

```
if riseAm is true and riseHour is 12
     riseHour = 0
if riseAm is false and riseHour is not 12
     riseHour = riseHour + 12

if setAm is true and setHour is 12
     setHour = 0
if setAm is false and setHour is not 12
     setHour = setHour + 12

if setHour < riseHour or (setHour == riseHour and setMin < riseMin)
     print "sunrise must be before sunset"
     halt

dayHour = setHour - riseHour
dayMin = setMin - riseMin
if dayMin < 0
     dayHour = dayHour - 1
     dayMin = dayMin + 60
print dayHour
print dayMin
```

Convert sunrise hour to 24 hour time

Convert sunset hour to 24 hour time

See DaylightTime.java

Program: Amount of daylight

4. Testing

riseHour	riseMin	am	setHour	setMin	am	Expected output dayHour	dayMin
-1						error	
24						error	
6	-1					error	
6	60					error	
6	30	1	-1			error	
6	30	1	24			error	
6	30	1	5	-1		error	
6	30	1	6	60		error	
6	30	0	7	30	1	error	
6	30	1	8	45	0	14	15
6	30	1	8	20	0	13	50
6	30	1	6	20	1	error	
3	00	0	5	45	0	2	45

Testing Data

- Each part of the program must be executed by some set of test data
- Each if condition (decision) should be made both true and false at different times

CS111
Introduction to Computer Science

- Loops
- Letter Grade
- Add Numbers
- Averaging Numbers
- Maximum of a Sequence of Numbers

Loops: Repeating things

- Loops allows repetition inside a program

```
loop condition
    operations
```

- Test the condition
  - if false, go to the end of the loop and continue on
  - otherwise, do the operations and go back to the start of the loop (do the test again)
- Repeatedly ask for good input using the *while* loop

```
riseHour = read integer
while riseHour < 1 or riseHour > 12
    print "invalid hour,  enter again:"
    riseHour = read integer
```


See DaylightTime_v2.java

Program: Adding numbers

Adding numbers until a terminating value is seen

- Example interaction

  Enter terminating value: -1

  Enter next number: 3

  Enter next number: 5

  Enter next number: -1

  Sum is: 8

See SequenceSum.java

Adding numbers: analysis

- Inputs: terminator, the sequence of numbers
  - terminator, number, number, ..., terminator
- Outputs:
  - Sum of numbers (not the terminator)
- Errors: none
- Test data
  - blackbox: enumerate before writing the code
  - coverage: enumerate after writing the code

Input	Expected output	
-1 -1	0	blackbox
-1 3 -1	3	blackbox
-1 8 15 3 -1	26	blackbox

Adding numbers: algorithm

```
print "Enter terminating value:"
terminator = read number
sum = 0
do
    print "Enter next number:"
    num = read number
    if num != terminator
        sum = sum + num
while num != terminator
print sum
```

Only one value is entered at a time, how can we add them all? Summary variable to hold a running total.

Summary variable: initialized before loop

Summary variable: Updated inside the loop

Program: Averaging numbers

Average of input values

- Example interaction

  Enter terminating value: -1

  Enter next number: 3

  Enter next number: 5

  Enter next number: -1

  Average is: 4

See SequenceAverage.java

Averaging numbers: analysis

- Inputs: terminator, the sequence of numbers
  - terminator, number, number, ..., terminator
- Outputs:
  - Average of numbers (not the terminator)
- Errors: zero length sequence
- Test data

Input	Expected output	
-1 -1	Error	blackbox
-1 3 -1	3	blackbox
-1 8 4 3 -1	5	blackbox

Averaging numbers: algorithm

```
print “Enter terminating value:”
terminator = read number
sum = 0
count = 0
do
    print “Enter next number:”
    num = read number
    if num != terminator
        sum = sum + num
        count = count + 1
while num != terminator
if count == 0
    print “Zero length sequence”
else
    print sum/count
```

Now we need both sum and a count of the numbers to average.

Program: Maximum of a Sequence

Find the maximum value of a sequence of numbers

- Example interaction

  Enter terminating value: -1

  Enter next number: 3

  Enter next number: 5

  Enter next number: -1

  Maximum is: 5

See SequenceMax.java

Maximum of a Sequence: analysis

- Inputs: terminator, the sequence of numbers
  - terminator, number, number, ..., terminator
- Outputs:
  - Maximum number (not the terminator)
- Errors: zero length sequence
- Test data

Input	Expected output	
-1 -1	Error	blackbox
-1 20 10 -1	20	blackbox

Maximum of a Sequence: algorithm

```
print "Enter terminating value:"
terminator = read number
print "Enter next number: "
num = read number
if num == terminator
    print "no maximum"
    halt
max = num
do
    print "Enter next number:"
    num = read number
    if num != terminator and num > max
            max = num
while num != terminator
print max
```

Input	Expected output
-1 -1	No maximum
-1 20 10 -1	20
-1 5 30 -1	30

coverage

Makes num > max true

CS111
Introduction to Computer Science

- Counted Loops
- Nested Loops
- Break and Continue

Counted Loops

An alternative to marking the end of the input

- How many numbers are in sequence?
  - input length of sequence of numbers to read
  - count the numbers as you read them
  - repeat as long as you have not read enough
- Example Interaction:

  How many numbers to sum: 2

  Enter next number: 5

  Enter next number: 1

  Sum is: 6

See CountedSum.java

Adding numbers: analysis

- Inputs: sequence size (integer), sequence of number
  - n, $number_0$, $number_1$, ..., $number_n$
- Outputs:
  - Sum of numbers
- Errors: negative sequence size
- Test data

Size	Sequence	Expected output	
3	5, 8, 12	25	blackbox
-1		error	blackbox

Adding numbers: algorithm

```
print "How many numbers to sum:"
size = read number
if size < 0
    print "sequence size cannot be negative
    halt
count = 0
sum = 0
while count < size
    print "Enter next number:"
    num = read number
    sum = sum + num
    count = count + 1
print sum
```

count will store how many numbers we have read

Repeat as long as you have not read enough

Increment count by 1 when you read a number

Size	Sequence	Expected output	
3	5, 8, 12	25	blackbox
-1		error	blackbox
0		0	coverage

Program: Letter Grade for Multiple Students

Assigning a letter grade for more than one student

- Example of program interaction

  Enter number of students: 2

  Enter grade: 98.2

  Letter grade is A

  Enter grade: 32

  Letter grade is F

See LetterGrade.java, LetterGrade_v2.java

Letter Grade for Multiple Students: analysis

- Inputs: number of students, students grade
- Outputs:
  - Letter grade for each student
- Errors: grade less than 0 or grater than 100
- Test data
  - blackbox: enumerate before writing the code
  - coverage: enumerate after writing the code

Input	Expected output	
1 80	B	blackbox
2 40 67	F D	blackbox
1 109	Error	blackbox

Letter Grade for Multiple Students: algorithm

```
print “Enter number of students:”
students = read number
while (students > 0) do
    print “Enter student grade:”
    grade = read number
    if (grade < 0 or grade > 100)
        print “Error”
        halt
    if (grade >= 90)
        print “A”
    else if (grade >= 80)
        print “B”
    else if (grade >= 70)
        print “C”
    else if (grade >= 60)
        print “D”
    else
        print “F”
    students = student – 1;
```

Input	Expected output	
1 80	B	blackbox
2 40 67	F D	blackbox
1 109	Error	blackbox
2 94.3 74.1	A C	coverage

Counting *n* numbers

0, 1, 2, …, n-1

```
int n = IO.readInt();
count = 0;
while (count < n) {
   count = count+1;
}
```

1, 2, 3, …, n

```
int n = IO.readInt();
count = 1;
while (count <= n) {
   count = count+1;
}
```

Loops so far

- do...while
  - operations are executed at least once
  - then the condition is tested

```
do
    operations
while condition
```

- while...
  - operations are only executed if condition is true

```
while condition
    operations
```

Another kind of Loop: for

- The for loop can be used when the number of iterations is known before entering the loop.

```
for ( ⟨initialization ⟩; ⟨continuation-condition ⟩; ⟨update ⟩ ) {
        ⟨statements ⟩
}
```

- How would our Adding Numbers look like with a `for` loop?

See CountedSum_v2.java

`for` loop

```
for (int count = 0; count < 5; count = count + 1) {
    IO.outputIntAnswer(count);
}
```

```
int count = 0;
while (count < 5) {
    IO.outputIntAnswer(count);
    count = count + 1;
}
```

Factorial

Compute the factorial of a number

- Example Interaction:

  Enter number: 3

  The factorial of 3 is 6

See Factorial.java

Nested Loops

- When the operations of a loop contain another loop

```
loop condition 1
    operations
    loop condition 2
        operations
```

Print Triangle

Print a triangle of stars of *n* lines.

Example Interaction:

Enter the number of lines: 5

```
*
**
***
****
*****
```

See Shapes.java

Problem: Build a multiplication table

- Build a multiplication table of n x m
- Example Interaction:

Enter number of rows = 3

Enter number of columns = 5

Result:

	1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15

See MultiplicationTable.java
MultiplicationTable_v2.java

Build multiplication table: analysis

- Inputs: number of rows (integer), number of columns (integer)
- Output: table (text)
- Errors: negative/zero number of rows or columns

Build multiplication table: algorithm

```
print “Enter number of columns:”
numCols= read number
if numCols <= 0
    print “Invalid number of columns”
    halt
print “Enter number of rows:”
numRows= read number
if numRows <= 0
    print “Invalid number of rows”
    halt
row = 1
while row <= numRows
    col = 1
    while col <= numCols
        print row * col
        col = col + 1
    print new line
    row = row + 1
```

Outer Loop

For each iteration of the outer loop all iterations of the inner loop are executed.

Build multiplication table: algorithm

- Suppose we want to compute only the values bellow the diagonal

	1	2	3	4	5
1					
2	2				
3	3	6			

```
row = 1
while row <= numRows
    col = 1
    while col < row
        print row * col
        col = col + 1
    print new line
    row = row + 1
```

Outer Loop: walks over the rows.

Inner loop: walks over columns.
Restrict inner loop!

What does this print?

```
for(int j = 1; j <= 3; j++) {
   System.out.println(j);
   for(int k = 11; k<=12; k++) {
      System.out.println(k);
   }
}
```

Result

```
1
11
12
2
11
12
3
11
12
```

Break and Continue

- Break
  - exit current loop
- Continue
  - skip the rest of current iteration
  - go directly to test

What does this print?

```
for(int j = 1; j <= 3; j++) {
   if (j == 1) {
      continue;
   }
   System.out.println(j);
   for(int k = 11; k<=12; k++) {
      System.out.println(k);
   }
}
```

Result

2
11
12
3
11
12

What does this print?

```
for(int j = 1; j <= 3; j++) {
   if (j == 2) {
      break;
   }
   System.out.println(j);
   for(int k = 11; k<=12; k++) {
      System.out.println(k);
   }
}
```

Result

1
11
12

What does this print?

```
for(int j = 1; j <= 3; j++) {
   System.out.println(j);
   for(int k = 11; k<=12; k++) {
      if (k==11) {
         break;
      }
      System.out.println(k);
   }
}
```

Result

1
2
3

Increment/Decrement

Very Common	Shorthand
foo = foo + x;	foo += x;
foo = foo + 1;	foo++;
foo = foo – x;	foo -= x;
foo = foo – 1;	foo--;

Scope of Variables

- A variable lives
  - from its declaration
  - to the end of the innermost block the declaration is in

```
if(...) {
    if (...) {
        int x;
        while (...) {
        ...
        }
    }
}
```

See Scope.java

CS111
Introduction to Computer Science

- Switch
- Methods

Switch Statement

- Tests the value of an expression, and depending on that value, jumps directly to some location within the switch statement.

```
switch expression
    case constant-1:
        operations
        break;
    case constant-2:
        operations
        break;
    ...
    case constant-2:
        operations;
        break;
    default:
        operations;
```

See Calculator_v3.java

Subroutines

A way to break a complex program into smaller pieces.

- A subroutine consists of:
  - a set of operations for carrying out a certain task that can be called from different places in the program
  - name (how the subroutine is known)
  - arguments (data for each call)
  - return value (result computed by the subroutine)

Subroutines

A subroutine is sometimes called a black box because we don't need to see what's inside to interact with it. All we need is to know is its specification (interface):

- arguments it expects and the type of value it returns

```
double pow(double base, double exponent);
```

Java Subroutines: Methods

In Java every subroutine must be declared inside a some class. *That is the reason we always create a class to write our main method.*

Static and non-static subroutines

- static: belongs to the class
- non-static: belong to the object (we'll learn later)

From now on we'll refer to subroutines as Methods

Method Definition

- Every method must be defined somewhere (inside a class in Java)

```
<modifiers><return-type><name>(<parameters>)
{
   <statements>
}
```

```
public static double pow(double base, double
exponent){}
```

```
public static int readInt(){}
```

```
public static void outputIntAnswer(int i){}
```

Method Definition

- Define a static method called *factorial* that receives an integer value as argument. It computes and returns the factorial of that value.

```
public static int factorial(int n){
   int result = 1;
   for (int count = 1; count <=n; count++){
      result *= count;
    }
   return result;
}
```

See the factorial method in Methods.java

Calling Static Methods

- When it returns a value

```
double x = Math . pow (2,3);
```

What class to look for definition in

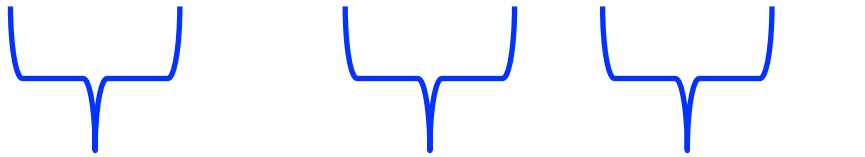
Method name

Argument list

Calling Static Methods

- When it returns a value

```
double x =          pow (2,3);
```



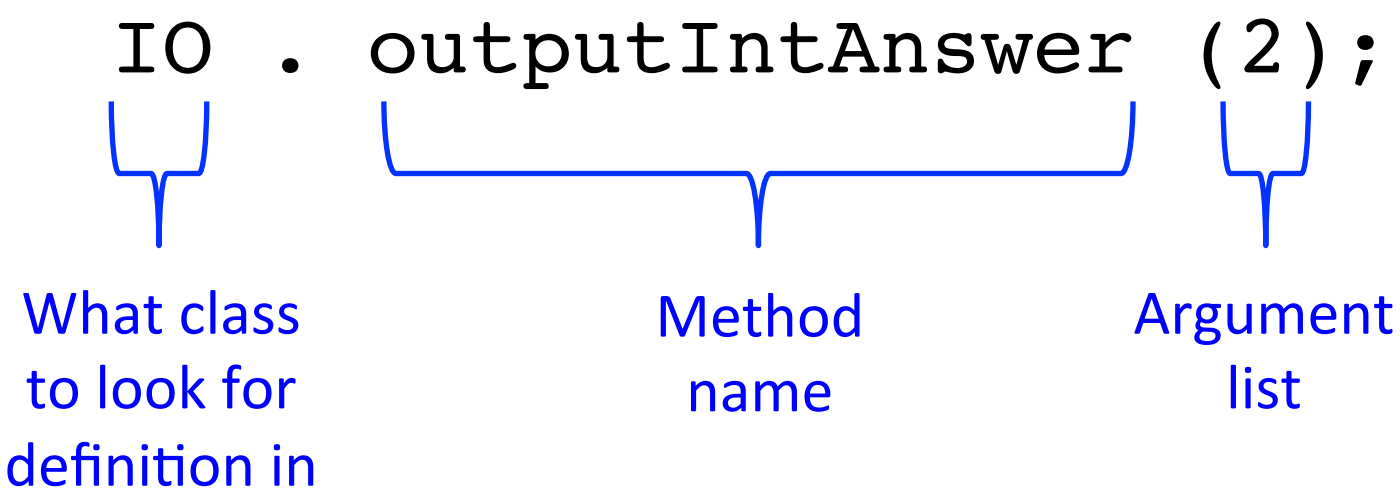
Look in current class for definition

Method name

Argument list

Calling Static Methods

- When it does NOT return a value (void)



Calling Static Methods

```
int x = factorial (3);
```

See the factorial method in Methods.java

Return Statement

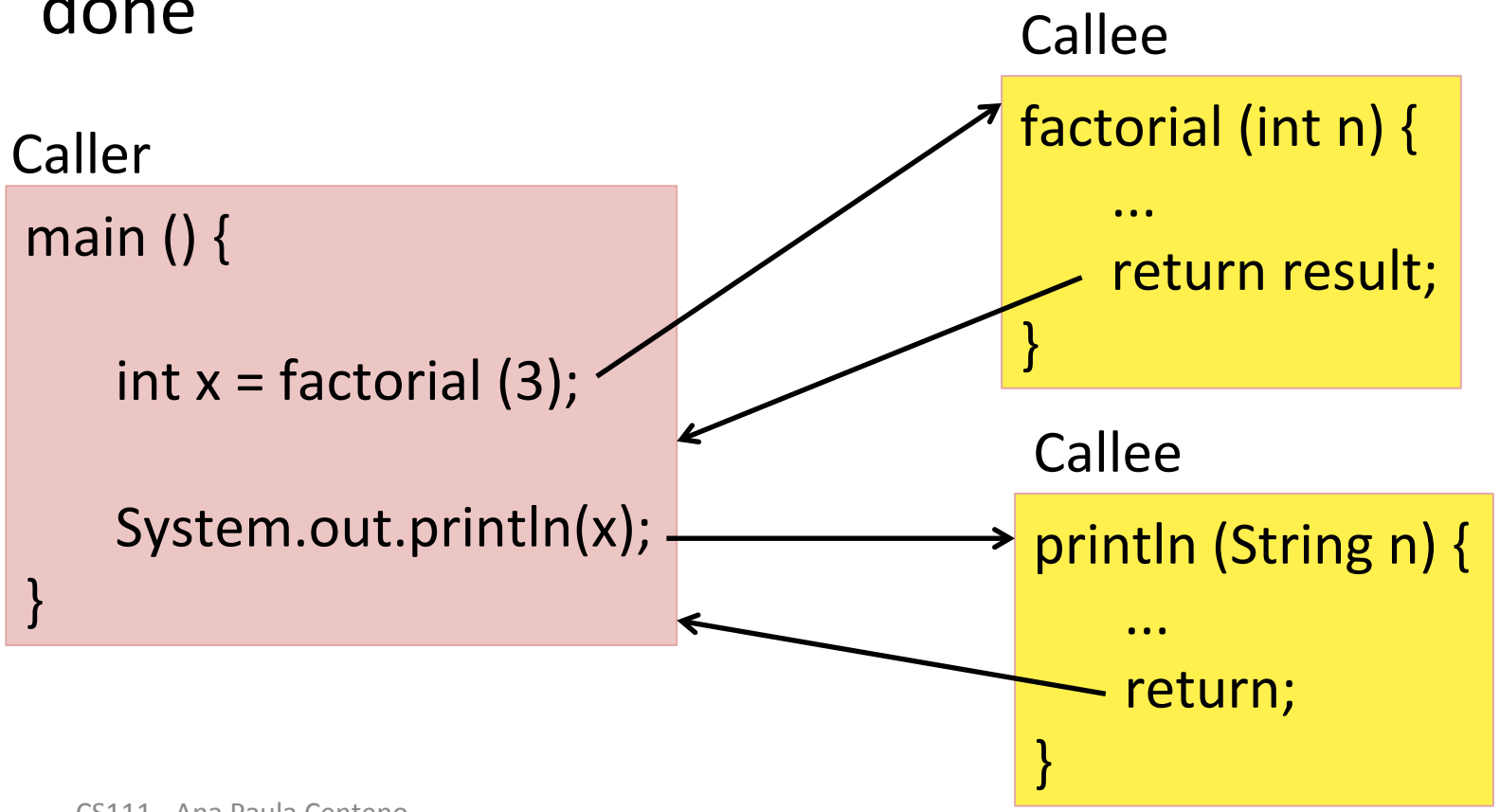
- Returns to the caller
  - returns to where it was called from
- `return <expression>;`
  - the type of `<expression>` must match the return type specified in the definition of the function

```
return result;
```

- `return;`
  - `void return type`

Caller and Callee

- Caller calls the callee
- Callee returns to the caller once its execution is done



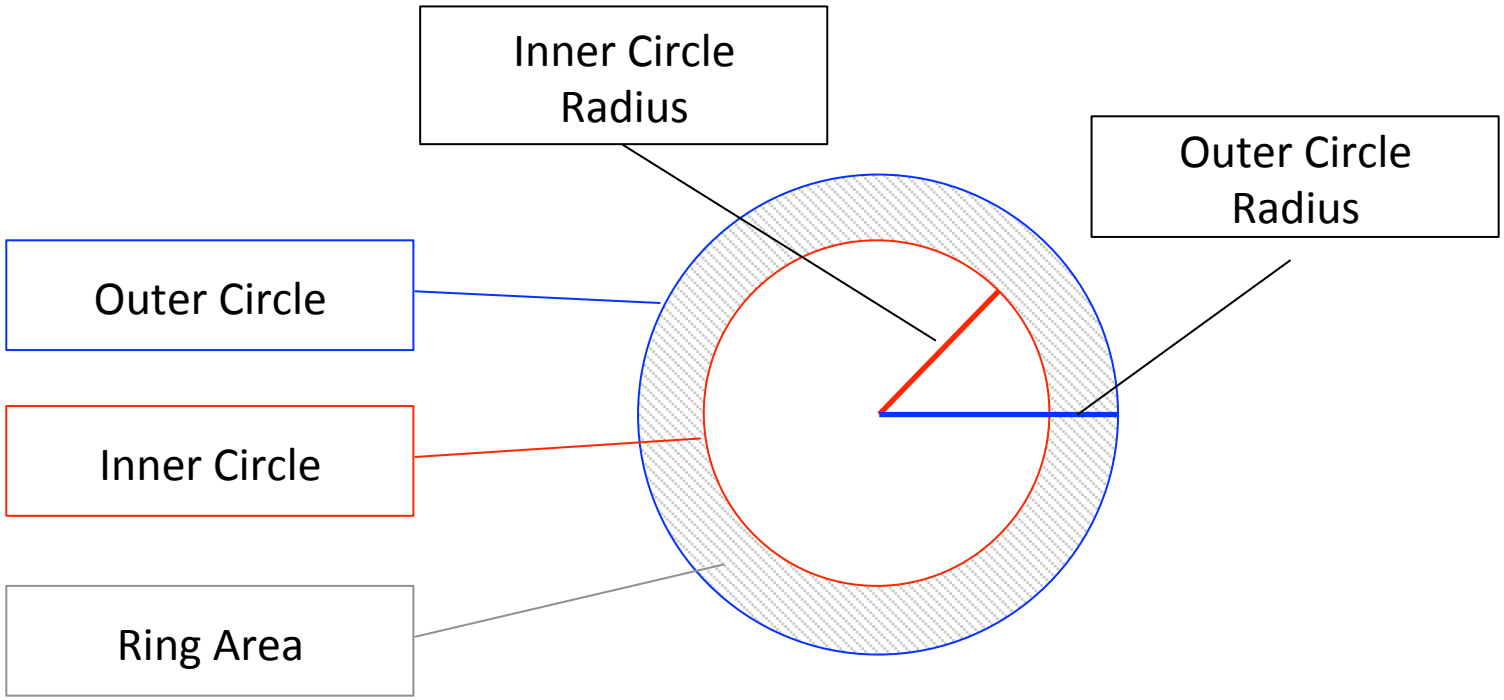
Frames

- When a method is called (invoked), the JVM creates a frame to store information about that method call. The frame is stored into the JVM execution stack (call stack).
- When a method returns, the frame for that call is destroyed.
- Also called invocation or activation records.

Frames

- A frame contains the following Information about a method call:
  - parameters
  - local variables: declared inside the method
  - temporary variables
  - where to return to

RingArea

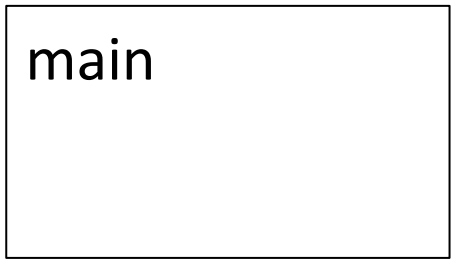

Inner Circle Radius
Outer Circle Radius
Outer Circle
Inner Circle
Ring Area

Frames and The Call Stack

- RingArea.java

Call Sequence

Call Stack



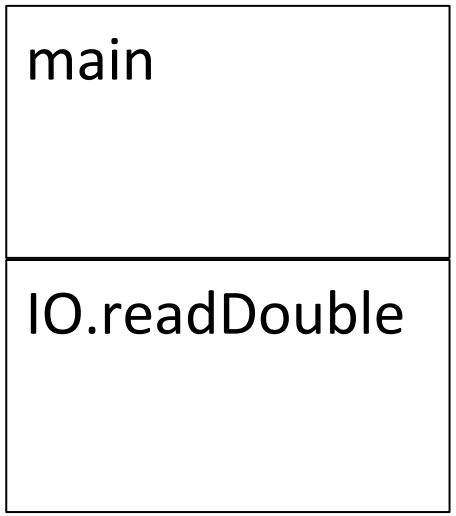
Frames and The Call Stack

- RingArea.java

Call Sequence

```
IO.readDouble();
```

Call Stack

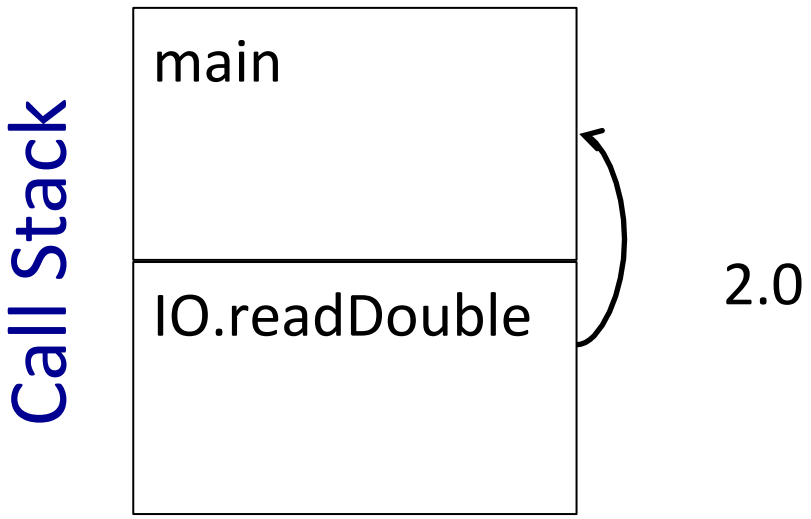


Frames and The Call Stack

- RingArea.java

Call Sequence

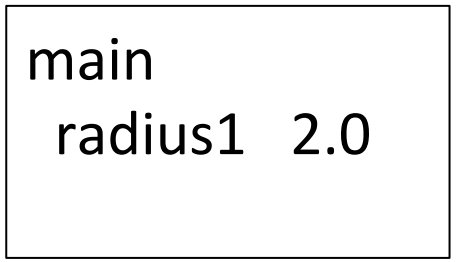
```
IO.readDouble();
```



Frames and The Call Stack

- RingArea.java

Call Stack



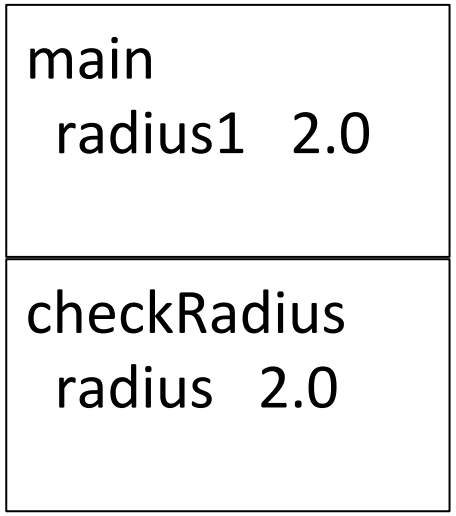
Call Sequence

```
IO.readDouble();
```

Frames and The Call Stack

- RingArea.java

Call Stack

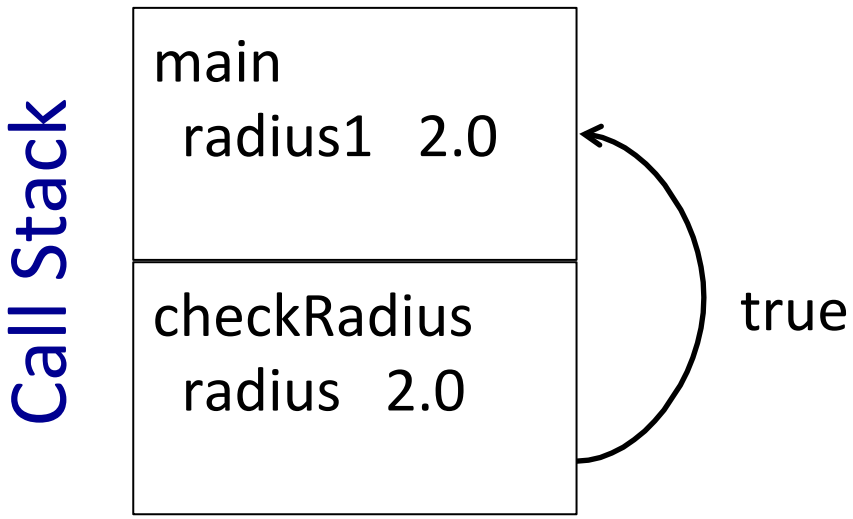


Call Sequence

```
IO.readDouble();
checkRadius(2.0);
```

Frames and The Call Stack

- RingArea.java



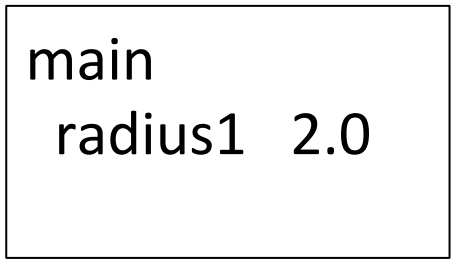
Call Sequence

```
IO.readDouble();
checkRadius(2.0);
```

Frames and The Call Stack

- RingArea.java

Call Stack



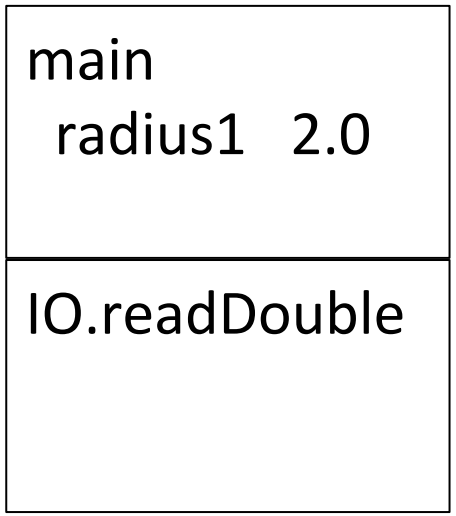
Call Sequence

```
IO.readDouble();
checkRadius(2.0);
```

Frames and The Call Stack

- RingArea.java

Call Stack

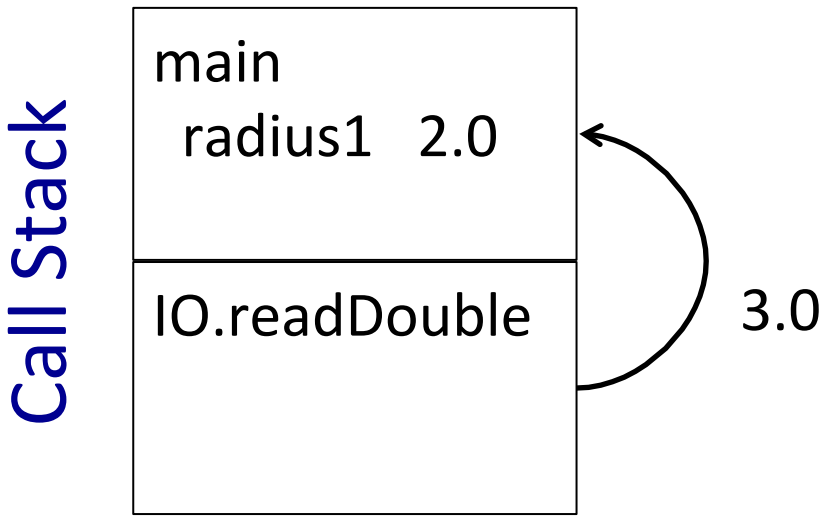


Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
```

Frames and The Call Stack

- RingArea.java



Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
```

Frames and The Call Stack

- RingArea.java

Call Stack

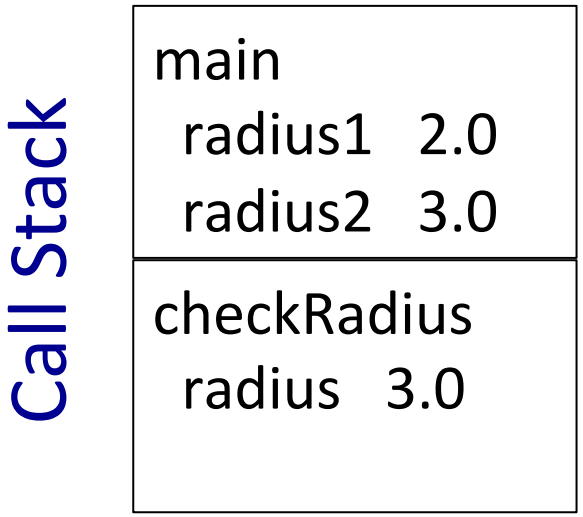
main
radius1 2.0
radius2 3.0

Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
```

Frames and The Call Stack

- RingArea.java

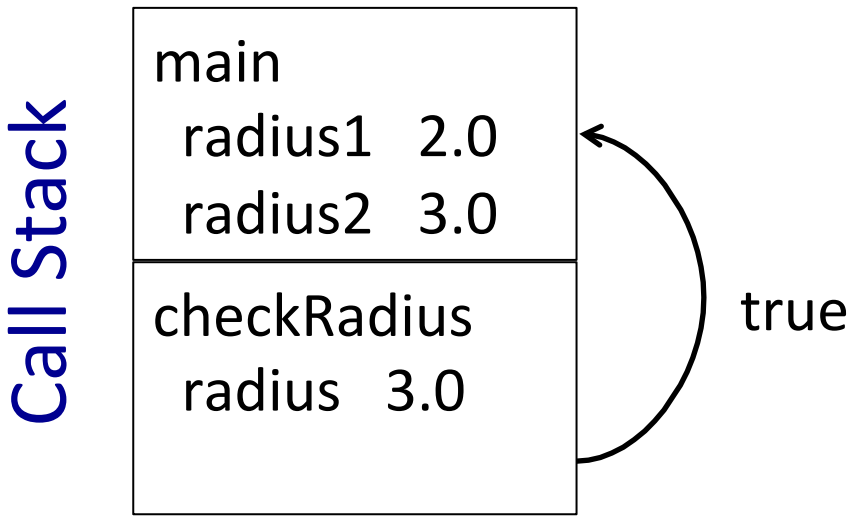


Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
```

Frames and The Call Stack

- RingArea.java



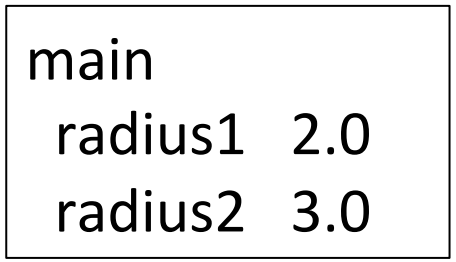
Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
```

Frames and The Call Stack

- RingArea.java

Call Stack



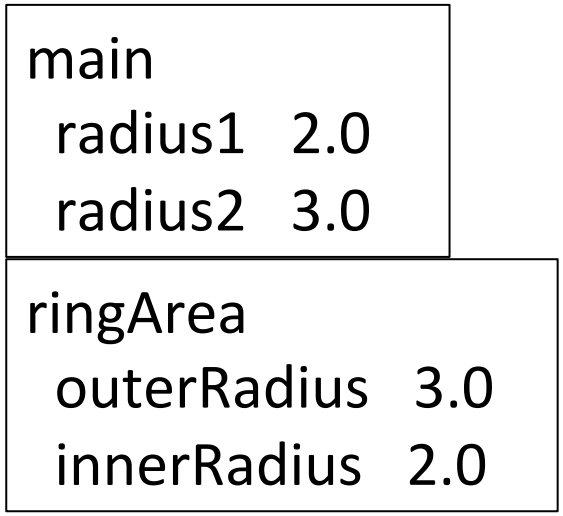
Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
```

Frames and The Call Stack

- RingArea.java

Call Stack



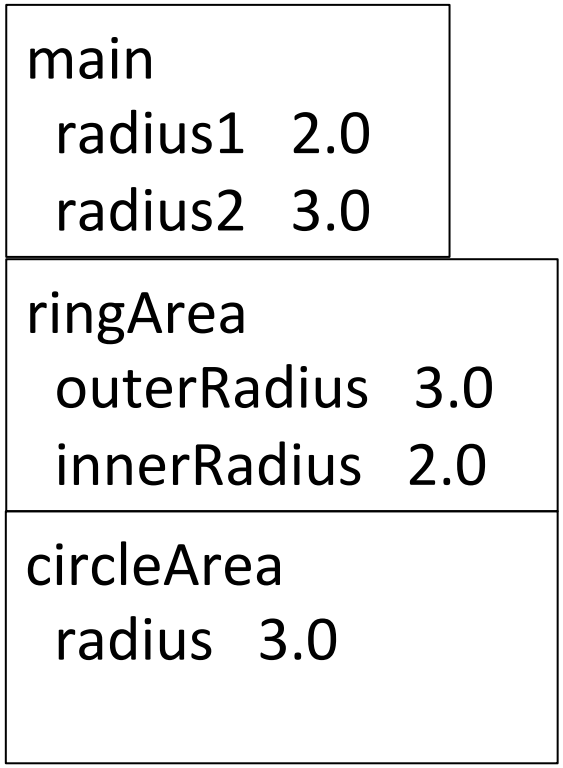
Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
```

Frames and The Call Stack

- RingArea.java

Call Stack



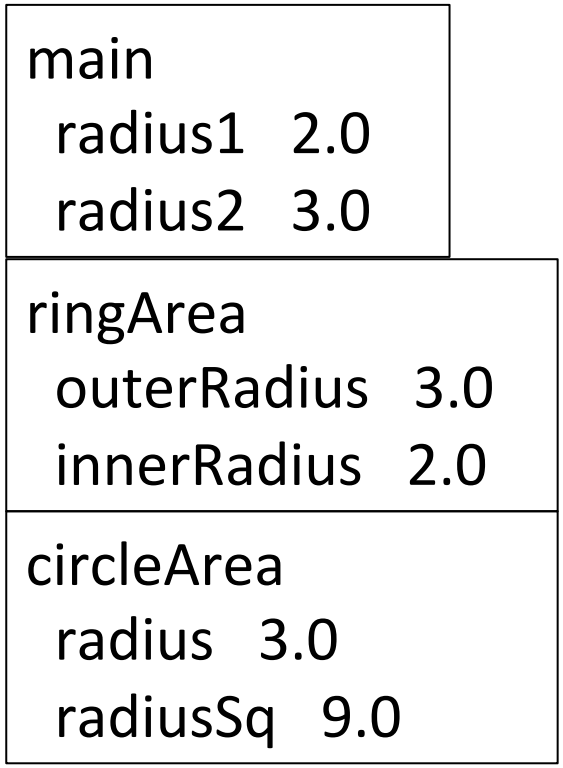
Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
circleArea(3.0);
```

Frames and The Call Stack

- RingArea.java

Call Stack



Call Sequence

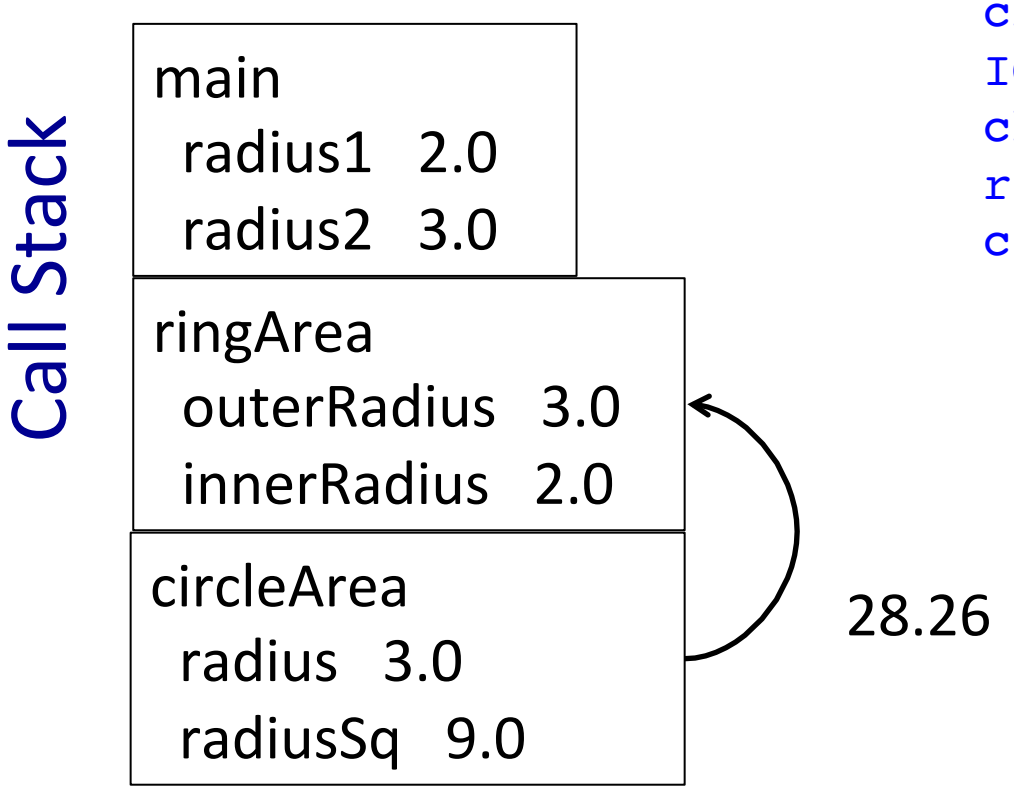
```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
circleArea(3.0);
```

Frames and The Call Stack

- RingArea.java

Call Sequence

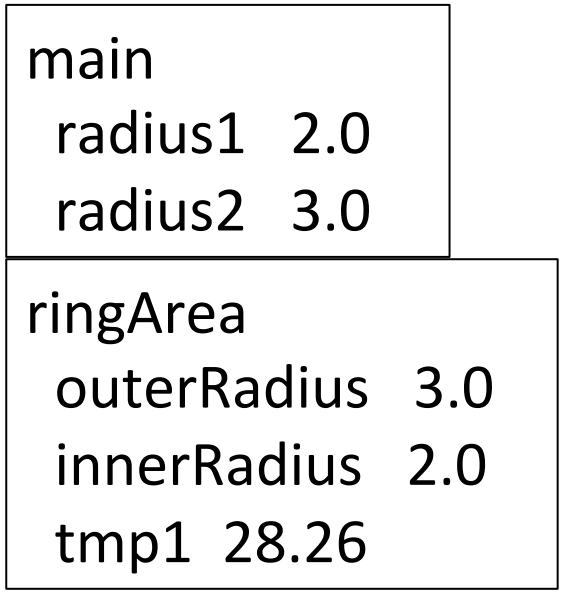
```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
circleArea(3.0);
```



Frames and The Call Stack

- RingArea.java

Call Stack



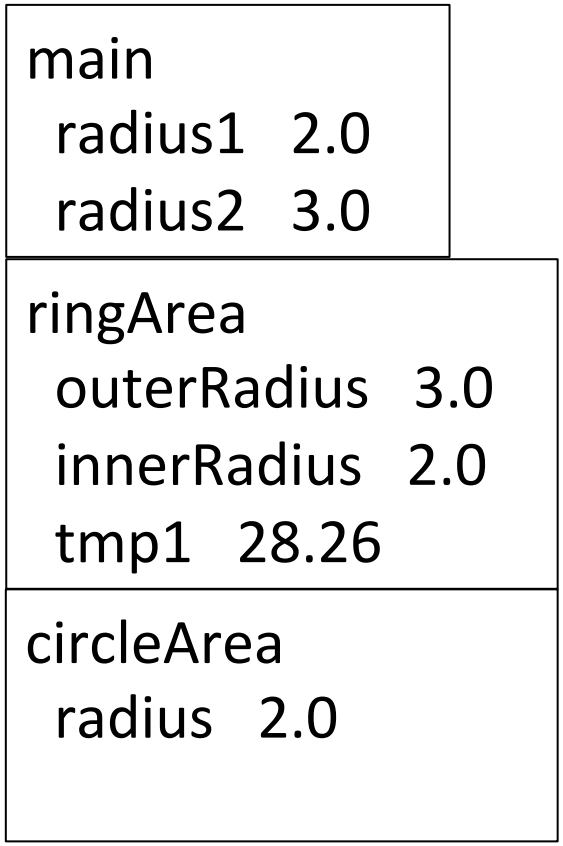
Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
circleArea(3.0);
```

Frames and The Call Stack

- RingArea.java

Call Stack



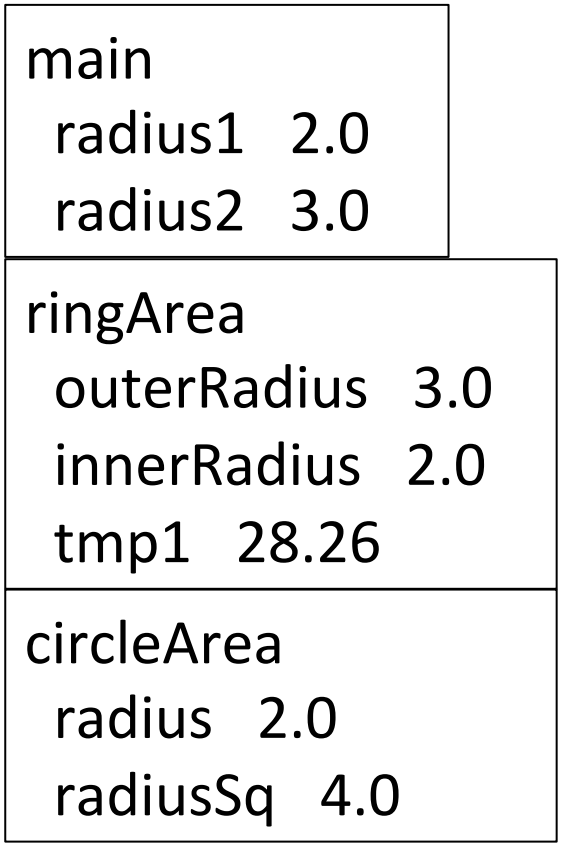
Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
circleArea(3.0);
circleAread(2.0);
```

Frames and The Call Stack

- RingArea.java

Call Stack

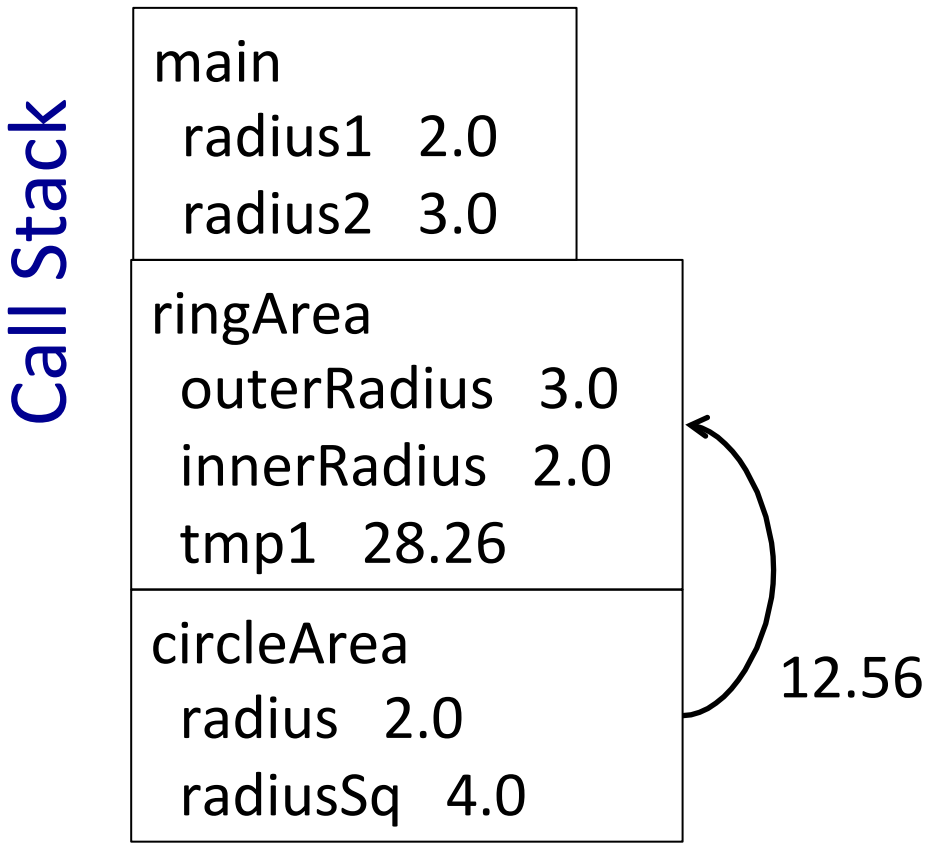


Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
circleArea(3.0);
circleAread(2.0);
```

Frames and The Call Stack

- RingArea.java



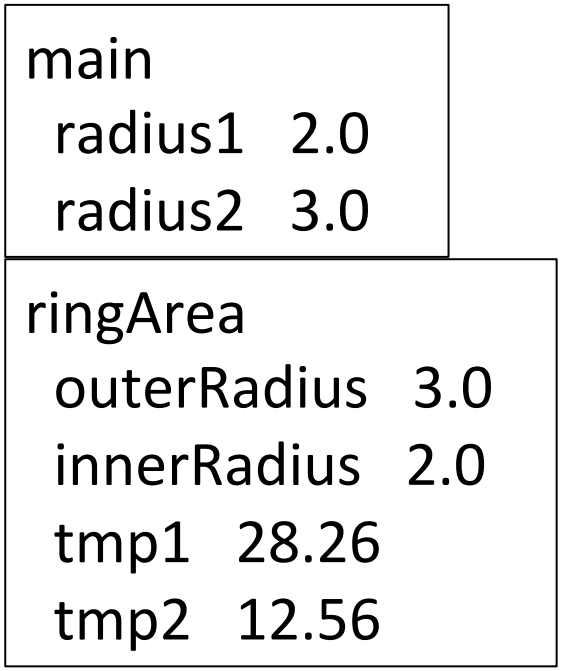
Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
circleArea(3.0);
circleAread(2.0);
```

Frames and The Call Stack

- RingArea.java

Call Stack

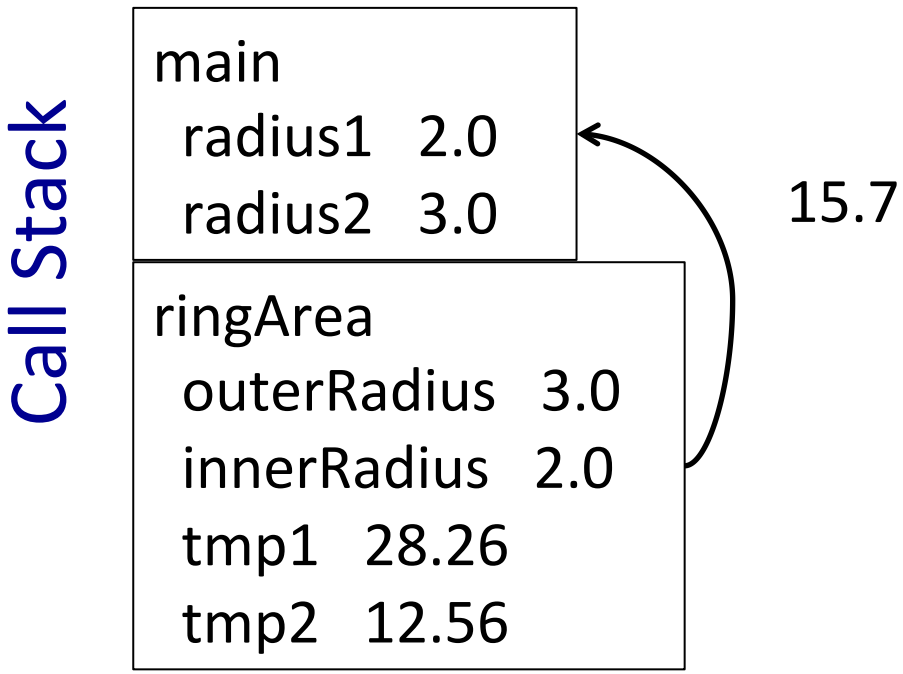


Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
circleArea(3.0);
circleAread(2.0);
```

Frames and The Call Stack

- RingArea.java



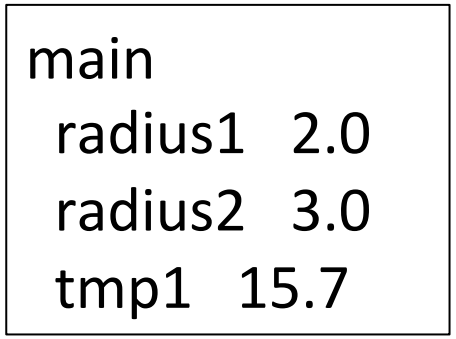
Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
circleArea(3.0);
circleAread(2.0);
```

Frames and The Call Stack

- RingArea.java

Call Stack

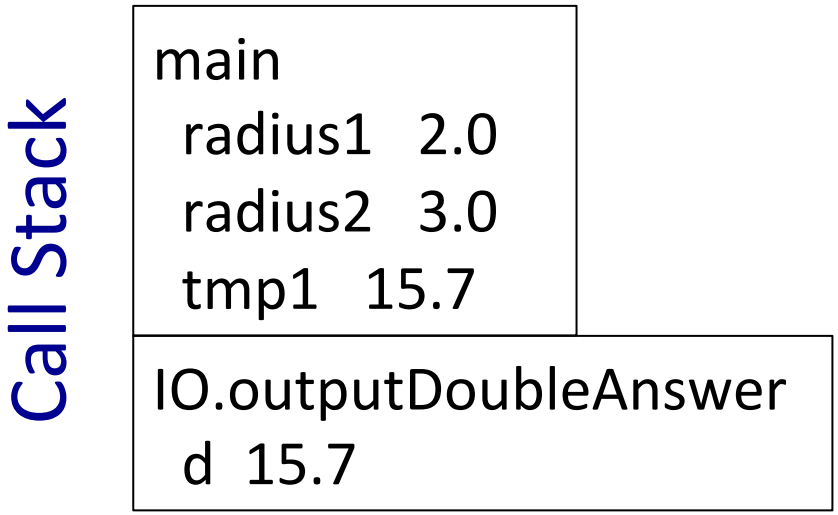


Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
circleArea(3.0);
circleAread(2.0);
```

Frames and The Call Stack

- RingArea.java



Call Sequence

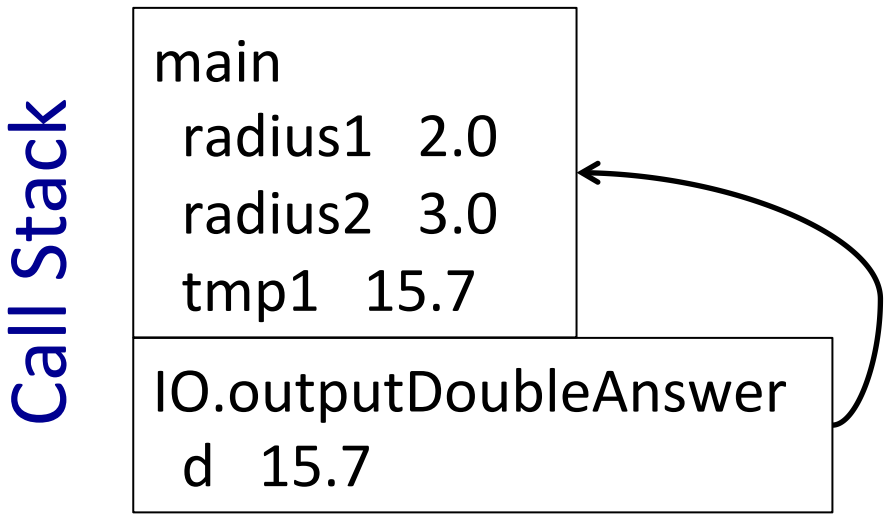
```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
circleArea(3.0);
circleAread(2.0);
IO.outputDoubleAnswer(15.7);
```

Output

15.7

Frames and The Call Stack

- RingArea.java



Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
circleArea(3.0);
circleAread(2.0);
IO.outputDoubleAnswer(15.7);
```

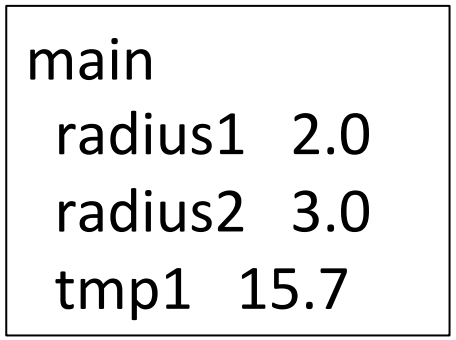
Output

15.7

Frames and The Call Stack

- RingArea.java

Call Stack



Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
circleArea(3.0);
circleAread(2.0);
IO.outputDoubleAnswer(15.7);
```

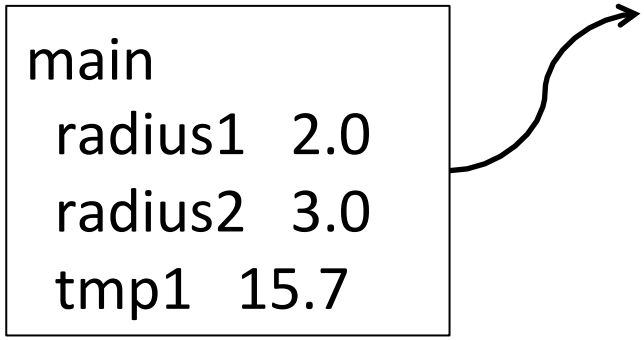
Output

15.7

Frames and The Call Stack

- RingArea.java

Call Stack



Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
circleArea(3.0);
circleAread(2.0);
IO.outputDoubleAnswer(15.7);
```

Output

15.7

Frames and The Call Stack

- RingArea.java

Call Stack

Call Sequence

```
IO.readDouble();
checkRadius(2.0);
IO.readDouble();
checkRadius(3.0);
ringArea(3.0, 2.0);
circleArea(3.0);
circleAread(2.0);
IO.outputDoubleAnswer(15.7);
```

Output

15.7

Frames and The Call Stack

- Frames are stored in the call stack
- When a method is called, it starts up from the beginning of its execution with a new Frame
- When a call returns to a waiting Frame, that waiting Frame re-activates and continues from where it has left off.
- When a method calls a method, the method doing the call waits, and its Frame is saved

CS111
Introduction to Computer Science

- Characters and Strings
- More frames and Call Stack
- Classes, objects and references

Characters

- A character is any single character
  - letters ‘A’ and ‘b’
  - digit ‘0’ and ‘9’
  - punctuation ‘#’ ‘.’
  - special characters ‘\t’ – tab character
    ‘\n’ – newline character
- Multiple characters are not legal
  - ‘ru’

Operations on Characters

char c = IO.readChar();

Character.isLetter(c);

true if c is a letter

Character.isDigit(c)

true if c is a digit

Character.toUpperCase(c)

value is upper case version of c

Character.toLowerCase(c)

– value is lower case version of c

String

- A string is a sequence of characters
  - "cs111"
  - ""
  - "Are you listening?"
- Position of a character in the String: *index*
  - "now and then"

```
|   |  |  |   |
0   3  5  7   11
```

  - length of the String: 12 characters
    - last index = length - 1

Concatenating Strings

- For Strings, + means concatenate
  - “ab” + “cd” -> “abcd”
- If one operand is a String and the other is not, Java converts the non-String into a String
  - “cs” + 111 -> “cs111”
  - 111 + “cs” -> “111cs”
  - “abcd” + ‘e’ -> “abcde”
  - (“ab” + ‘c’) + ‘d’ -> “abcd”
  - “ab” + (3+1) -> “ab4”

See the captalize method in Methods.java

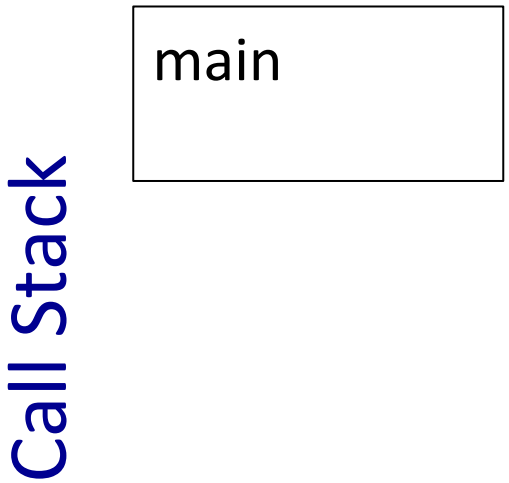
Frames

- Stars.java

```
public static void main(String[] args) {
    for (int i = 1; i <= 3; i++) {
        printNStars(i);
    }
}
public static void printNStars (int n) {
    System.out.println(nTimesChar(n, '*'));
}
public static String nTimesChar (int n, char c) {
    String result = "";
    for (int i = 1; i <= n; i++) {
        result = result + c;
    }
    return result;
}
```

Frames

- Stars.java



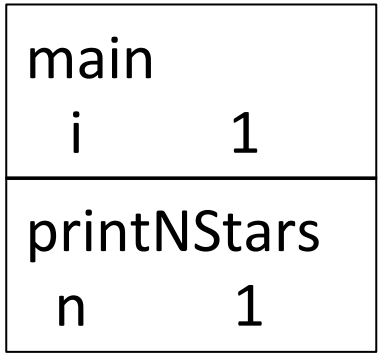
Call Sequence

Output

Frames

- Stars.java

Call Stack



Call Sequence

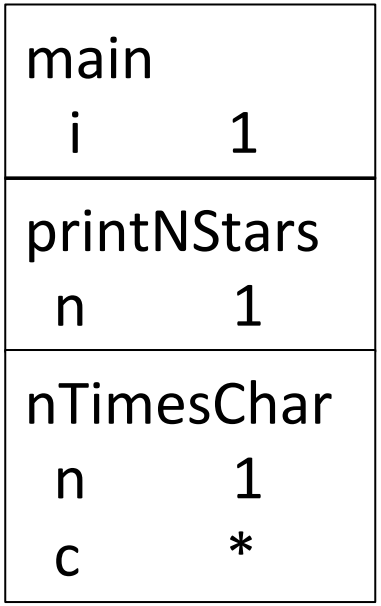
```
printNStars(1);
```

Output

Frames

- Stars.java

Call Stack



Call Sequence

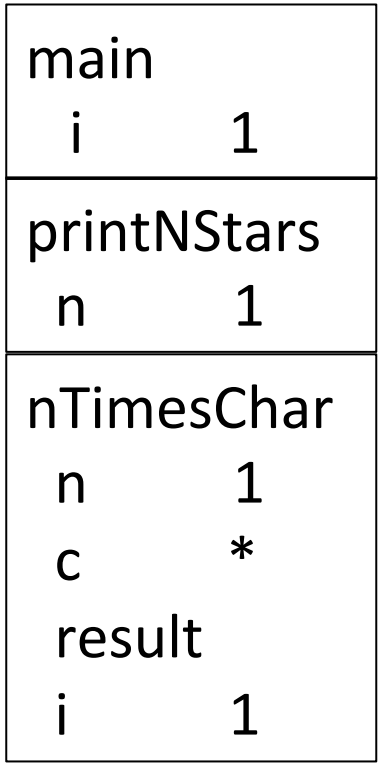
```
printNStars(1);
nTimesChar(1, '*');
```

Output

Frames

- Stars.java

Call Stack



Call Sequence

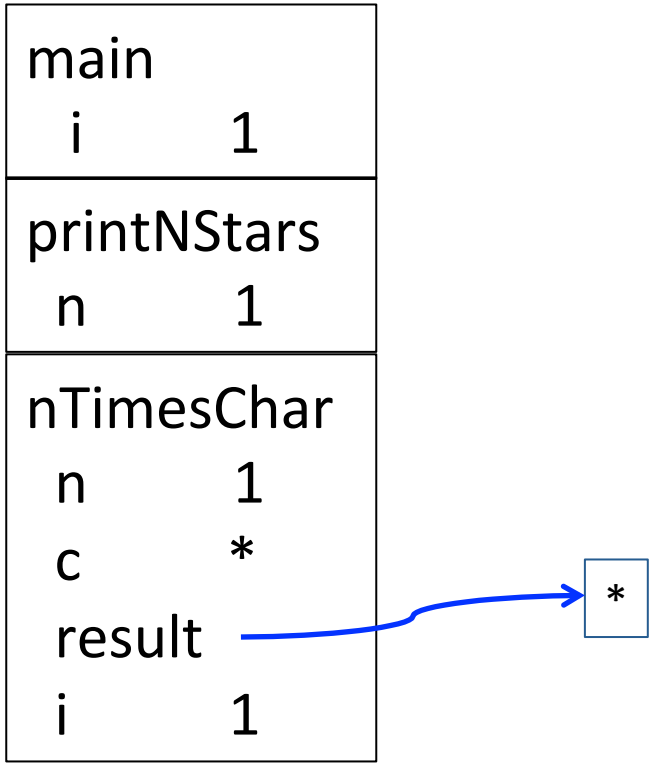
```
printNStars(1);
nTimesChar(1, '*');
```

Output

Frames

- Stars.java

Call Stack



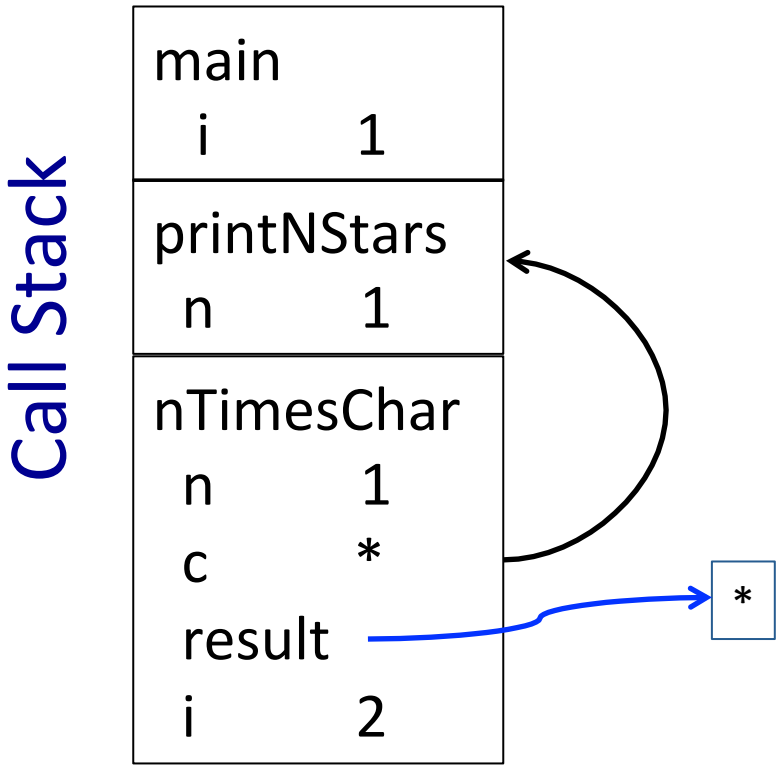
Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
```

Output

Frames

- Stars.java



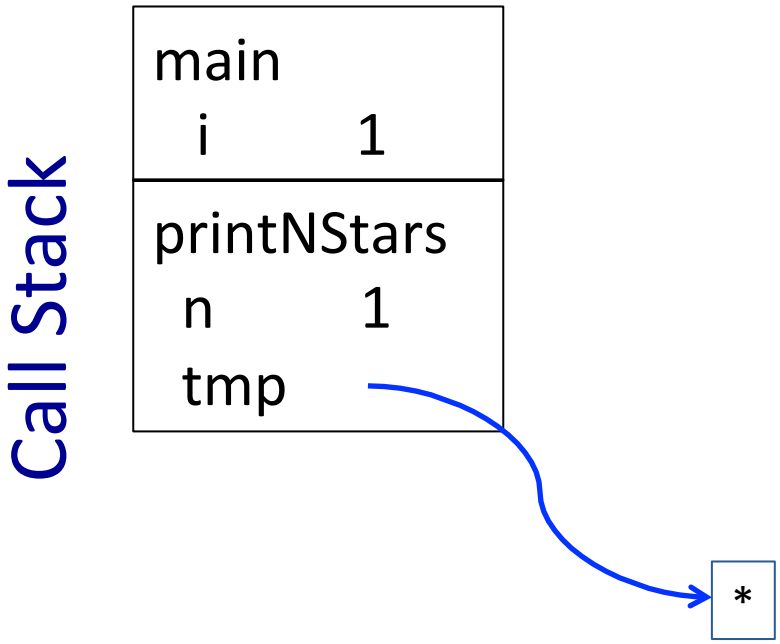
Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
```

Output

Frames

- Stars.java



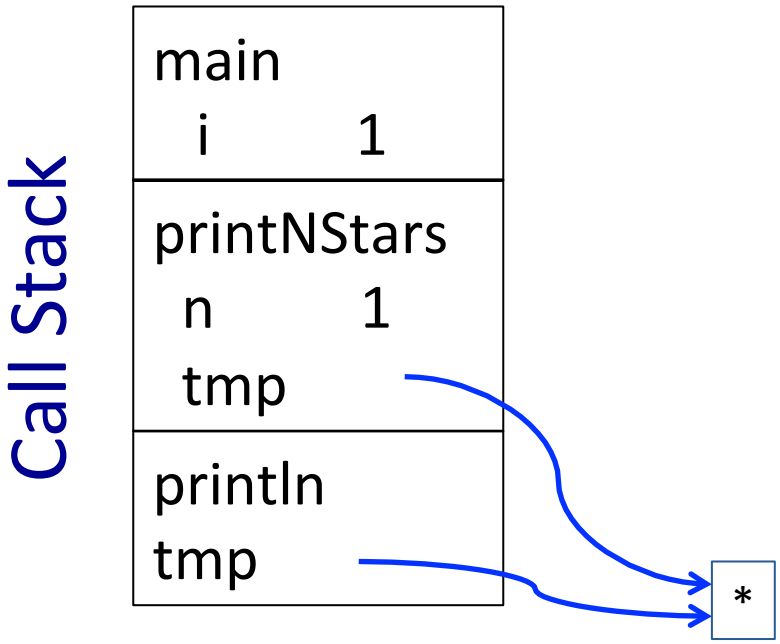
Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
```

Output

Frames

- Stars.java



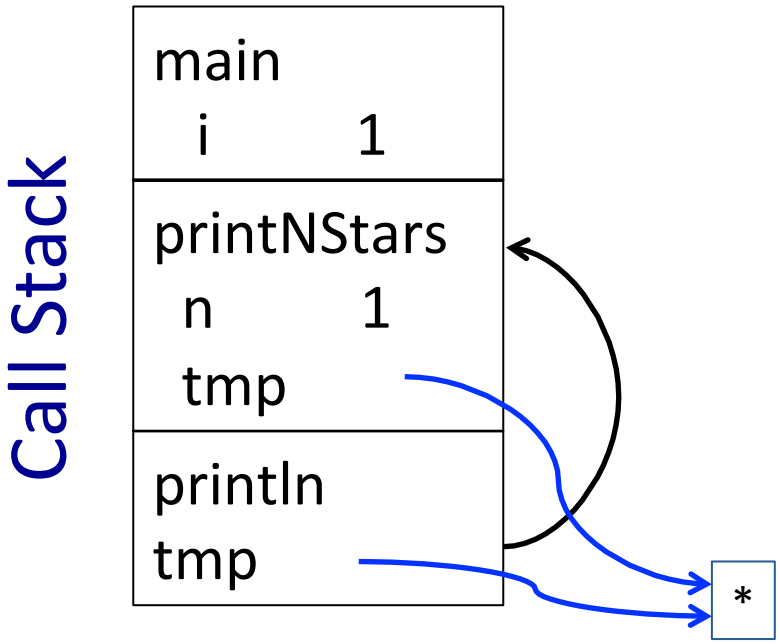
Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
```

Output

Frames

- Stars.java



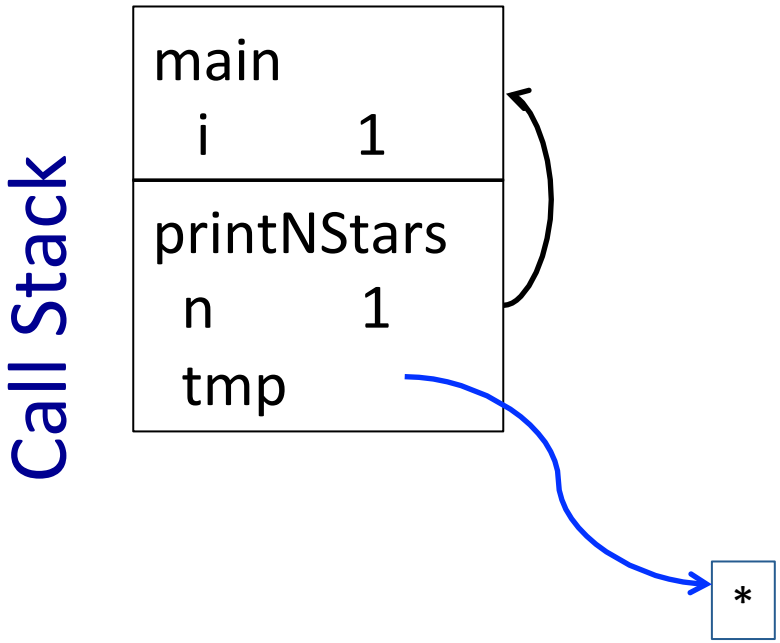
Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
```

Output *

Frames

- Stars.java



Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
```

Output *

Frames

- Stars.java

Call Stack

Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
```

Output *

Frames

- Stars.java

Call Stack

Call Sequence

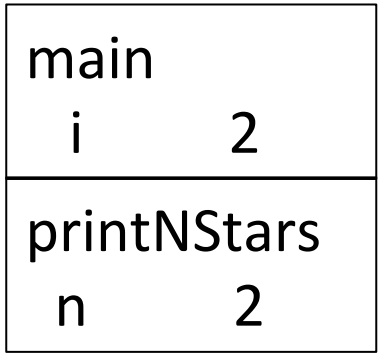
```
printNStars(1);
nTimesChar(1, '*');
println("*");
```

Output *

Frames

- Stars.java

Call Stack



Call Sequence

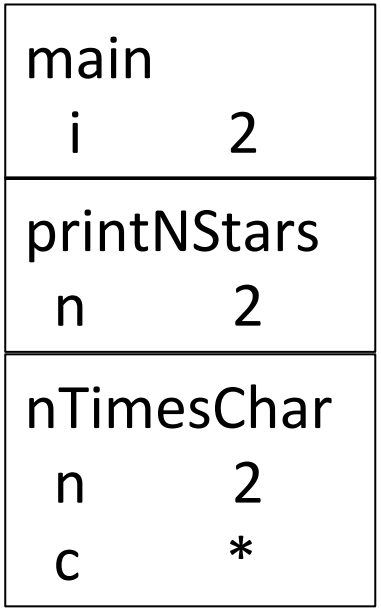
```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
```

Output *

Frames

- Stars.java

Call Stack



Call Sequence

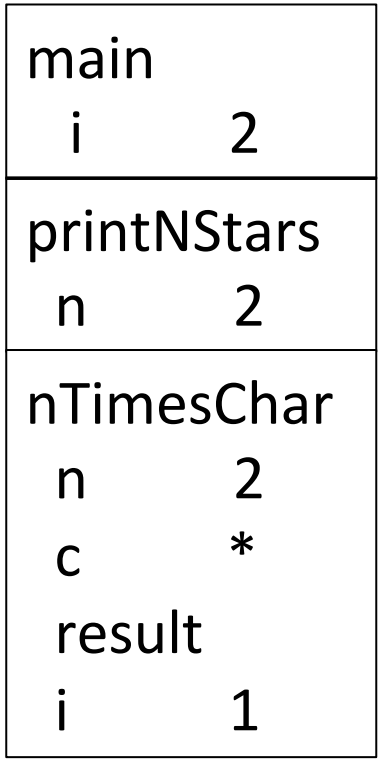
```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
```

Output *

Frames

- Stars.java

Call Stack



Call Sequence

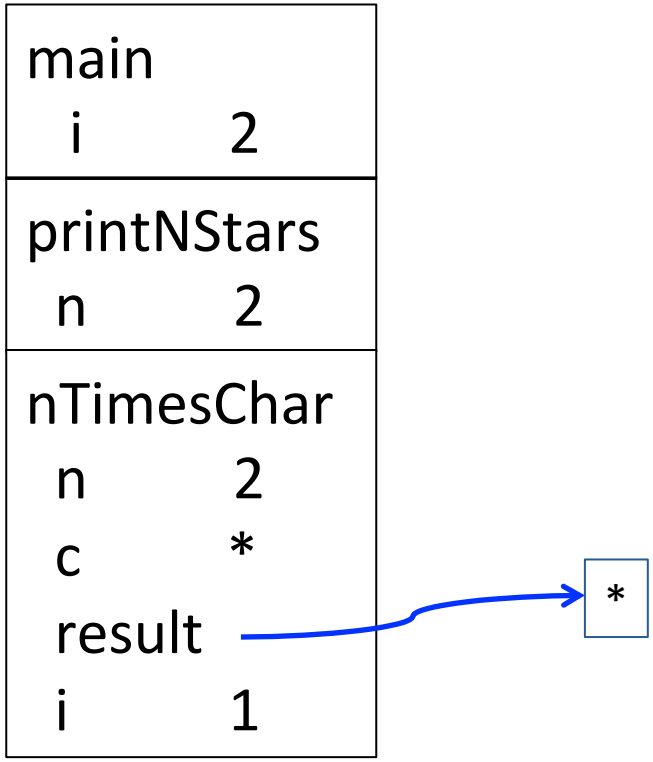
```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
```

Output *

Frames

- Stars.java

Call Stack



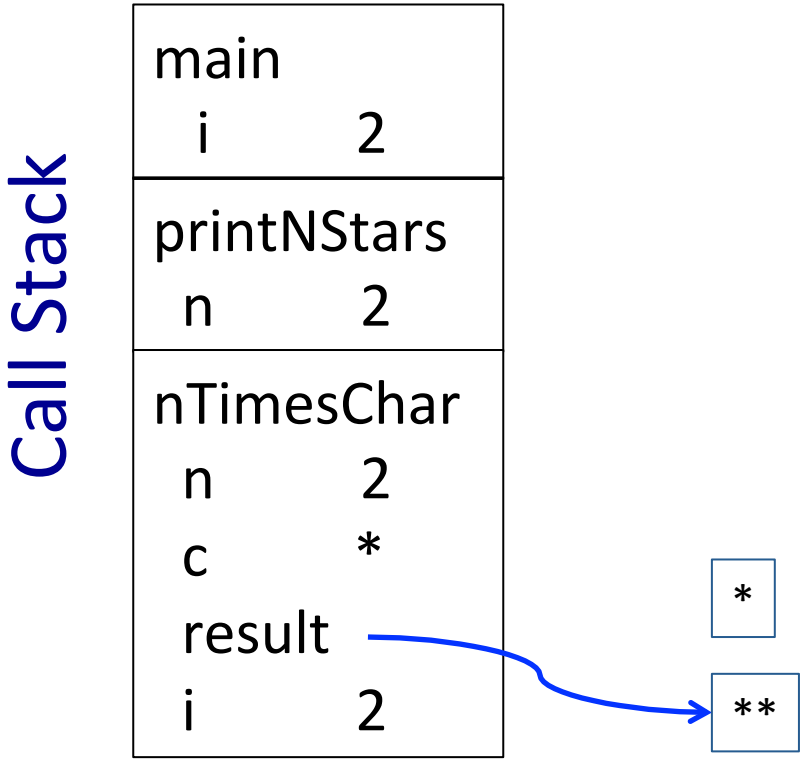
Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
```

Output *

Frames

- Stars.java



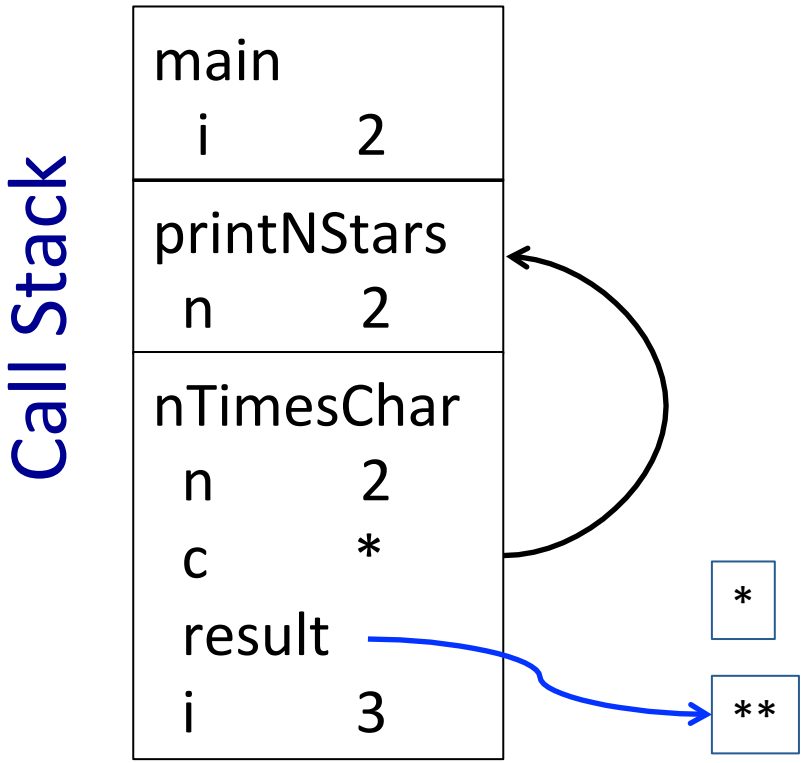
Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
```

Output *

Frames

- Stars.java



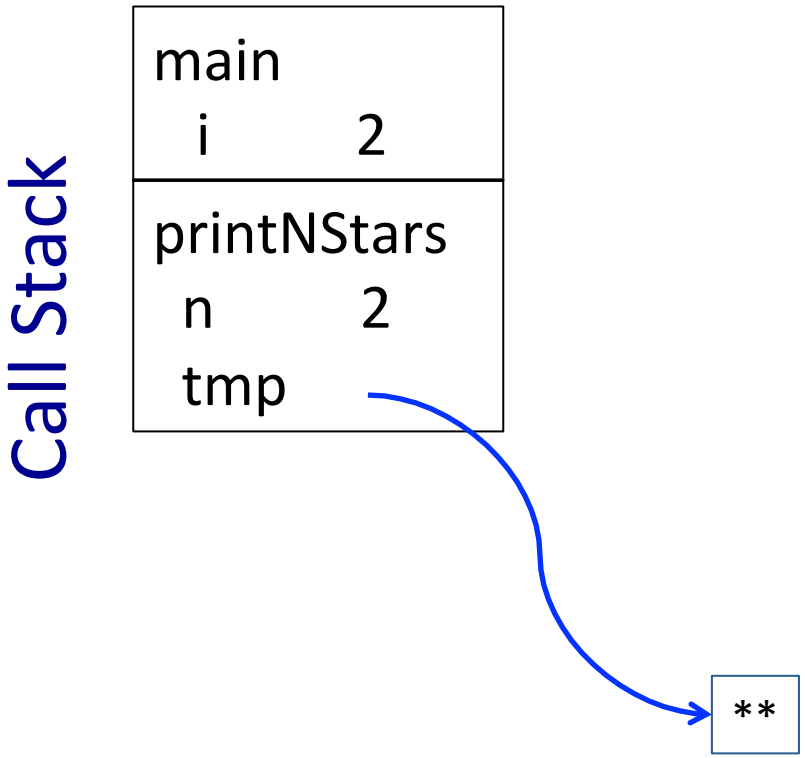
Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
```

Output *

Frames

- Stars.java



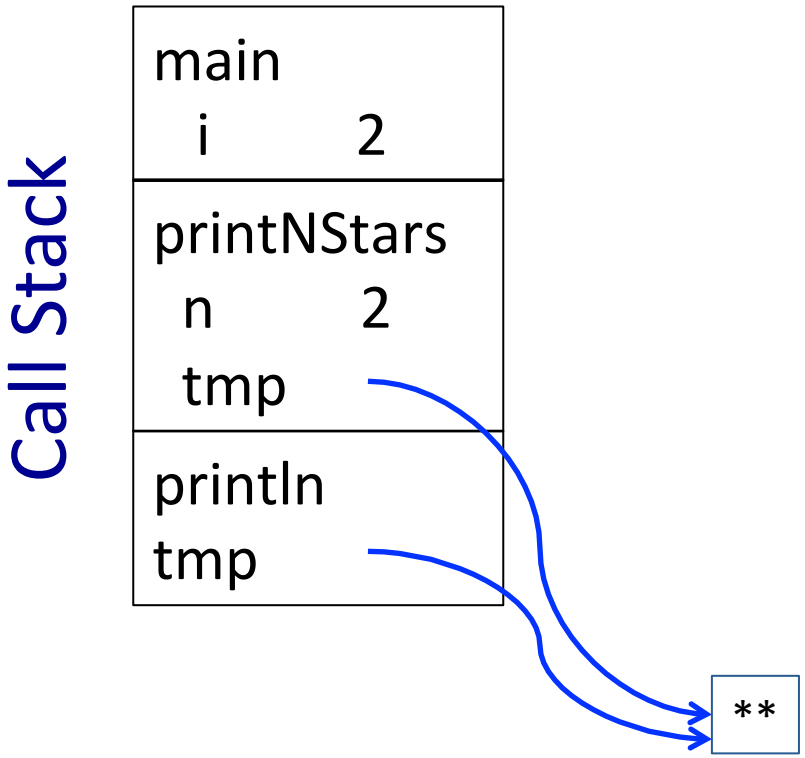
Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
```

Output *

Frames

- Stars.java



Call Sequence

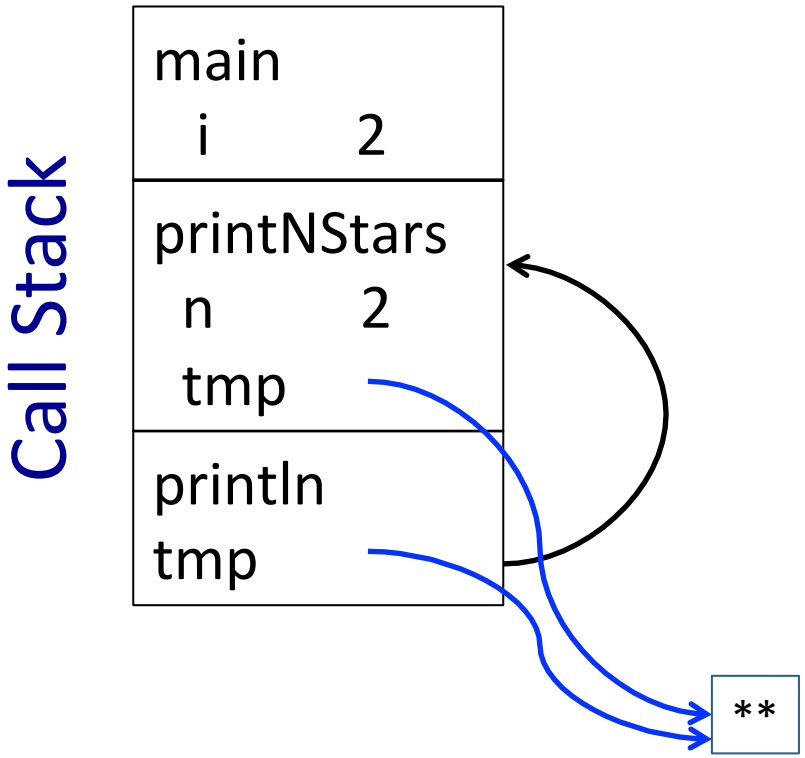
```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
```

Output

```
*
```

Frames

- Stars.java



Call Sequence

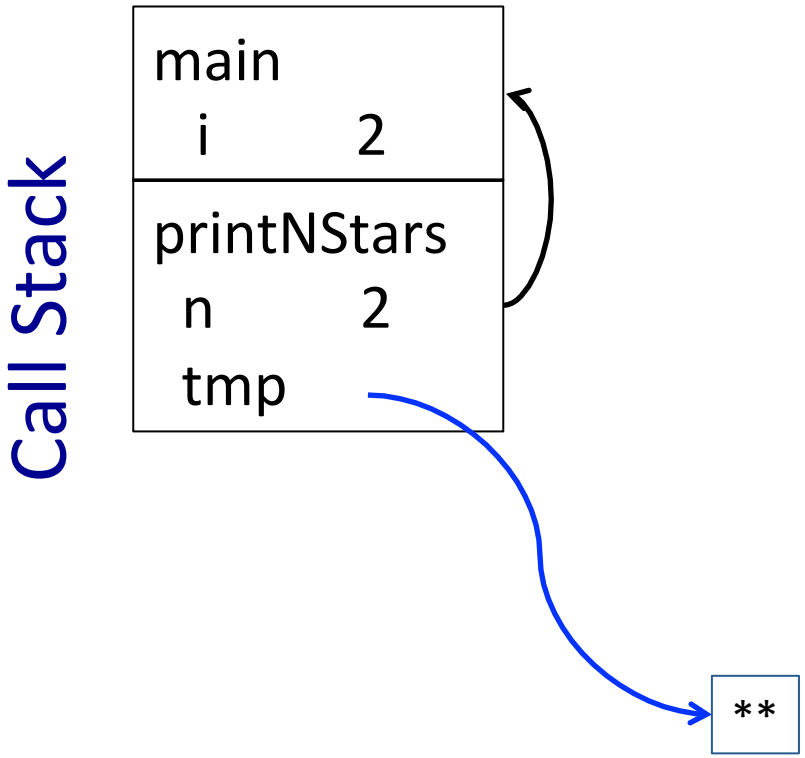
```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
```

Output

```
*
**
```

Frames

- Stars.java



Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
```

Output

```
*
**
```

Frames

- Stars.java

Call Stack

Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
```

Output

```
*
**
```

Frames

- Stars.java

Call Stack

Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
```

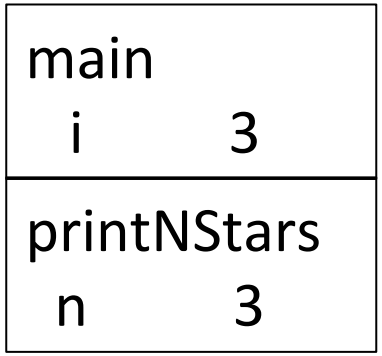
Output

```
*
**
```

Frames

- Stars.java

Call Stack



Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
printNStars(3);
```

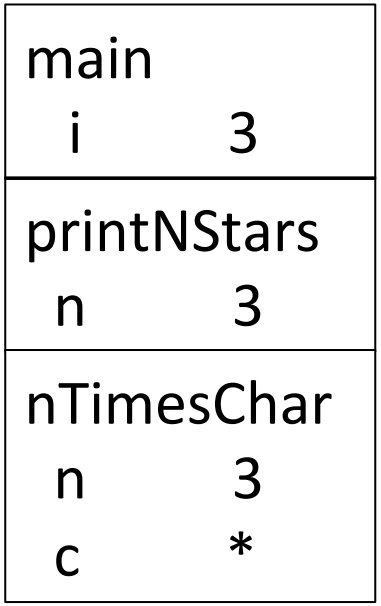
Output

```
*
**
```

Frames

- Stars.java

Call Stack



Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
printNStars(3);
nTimesChar(3, '*');
```

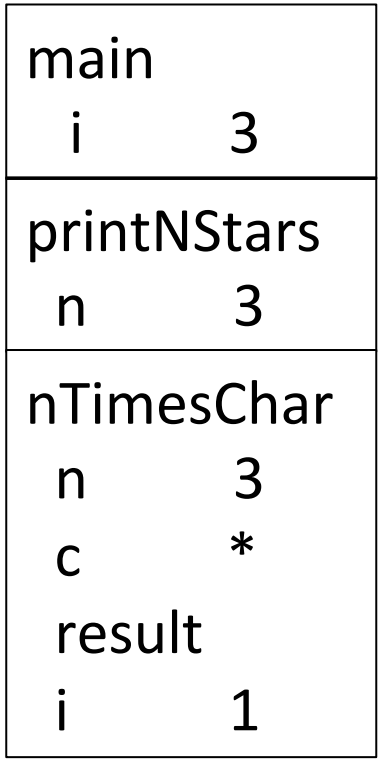
Output

```
*
**
```

Frames

- Stars.java

Call Stack



Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
printNStars(3);
nTimesChar(3, '*');
```

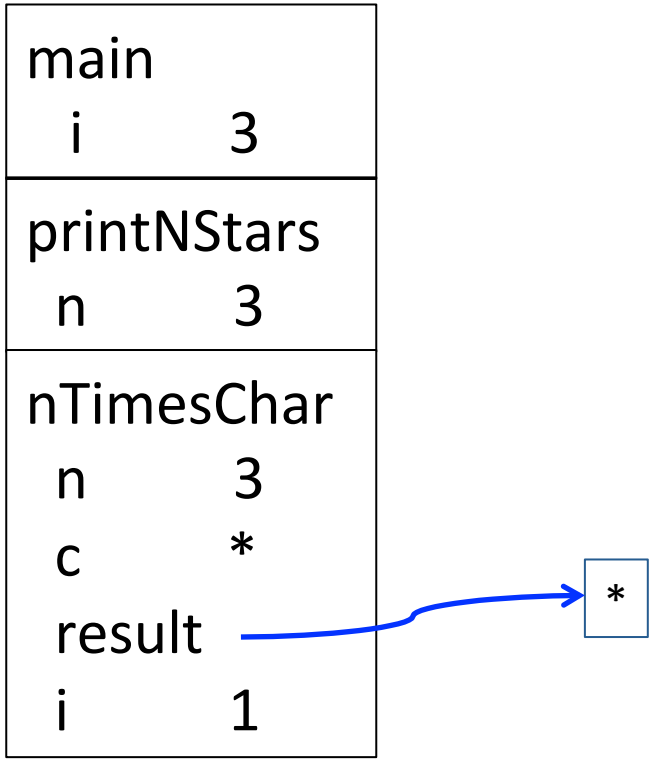
Output

```
*
**
```

Frames

- Stars.java

Call Stack



Call Sequence

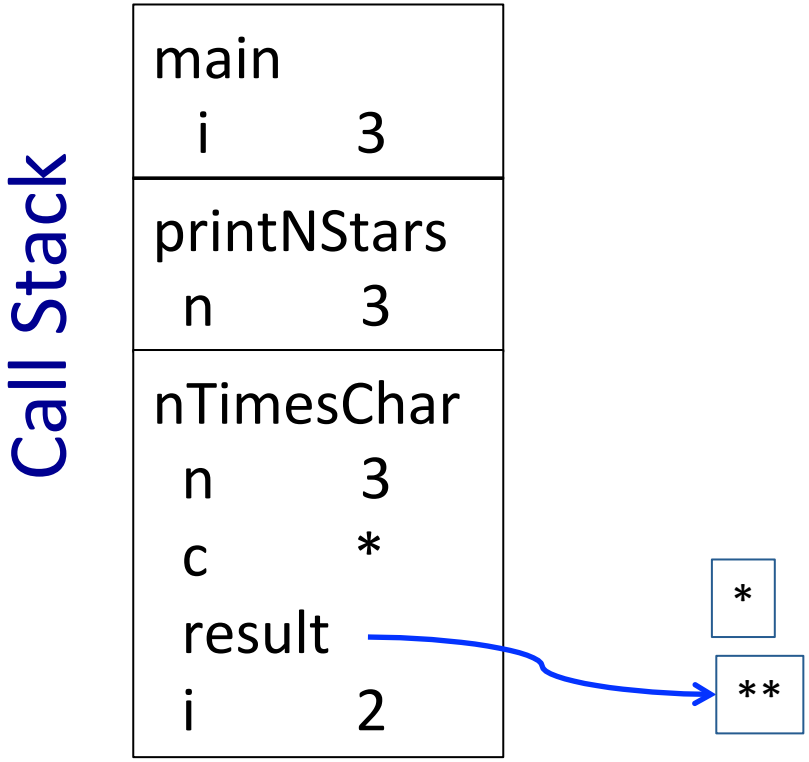
```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
printNStars(3);
nTimesChar(3, '*');
```

Output

```
*
**
```

Frames

- Stars.java



Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
printNStars(3);
nTimesChar(3, '*');
```

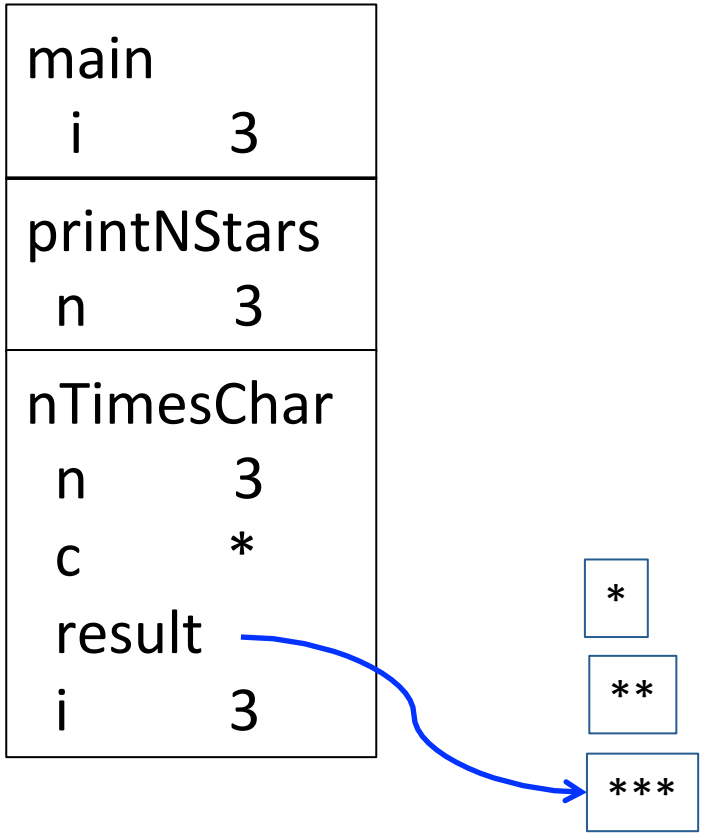
Output

```
*
**
```

Frames

- Stars.java

Call Stack



Call Sequence

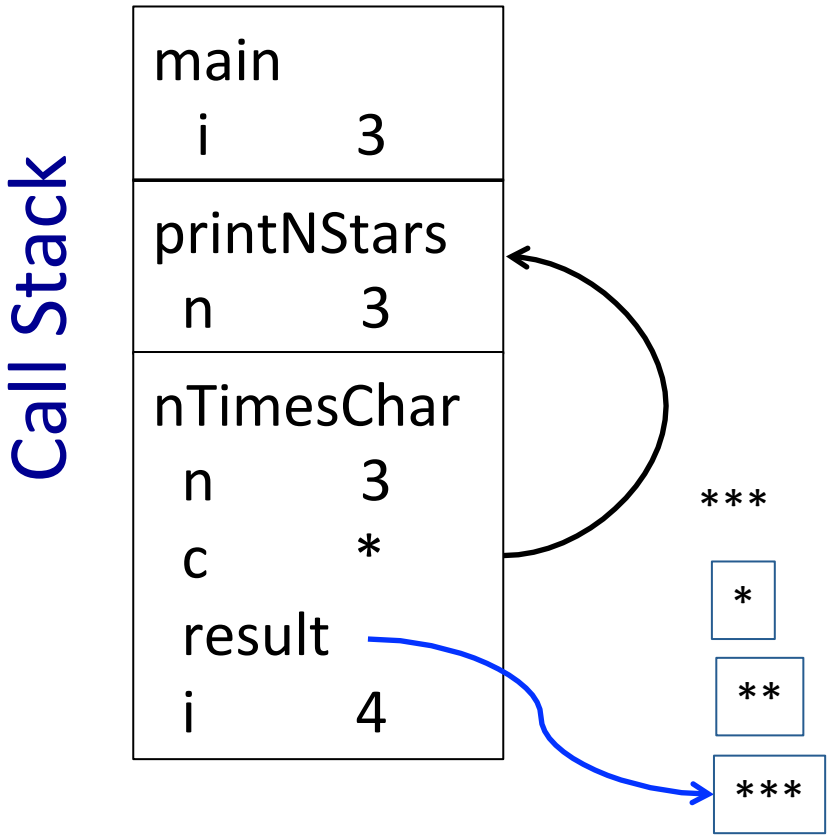
```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
printNStars(3);
nTimesChar(3, '*');
```

Output

```
*
**
```

Frames

- Stars.java



Call Sequence

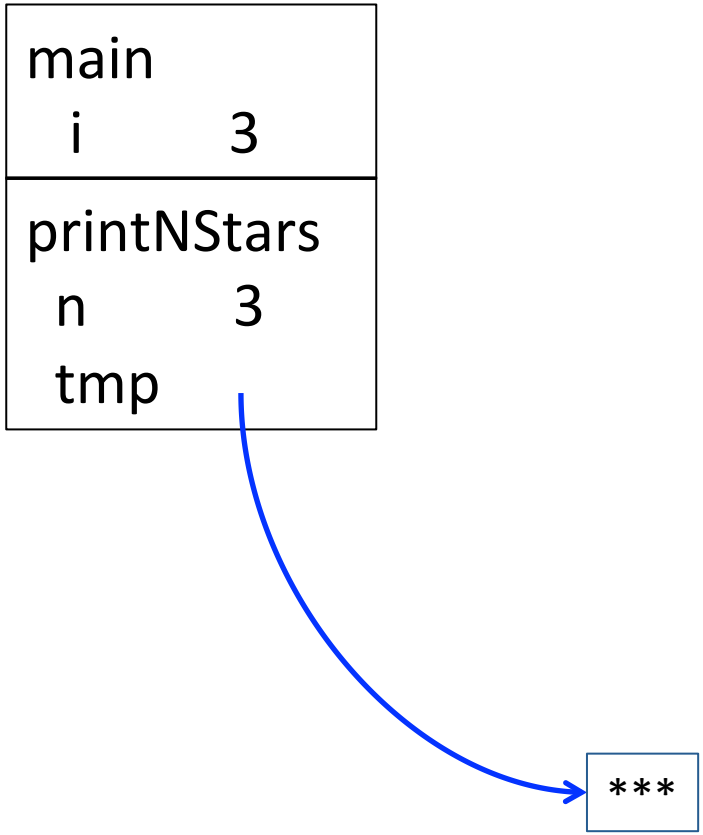
```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
printNStars(3);
nTimesChar(3, '*');
```

Output
```
*
**
```

Frames

- Stars.java

Call Stack



Call Sequence

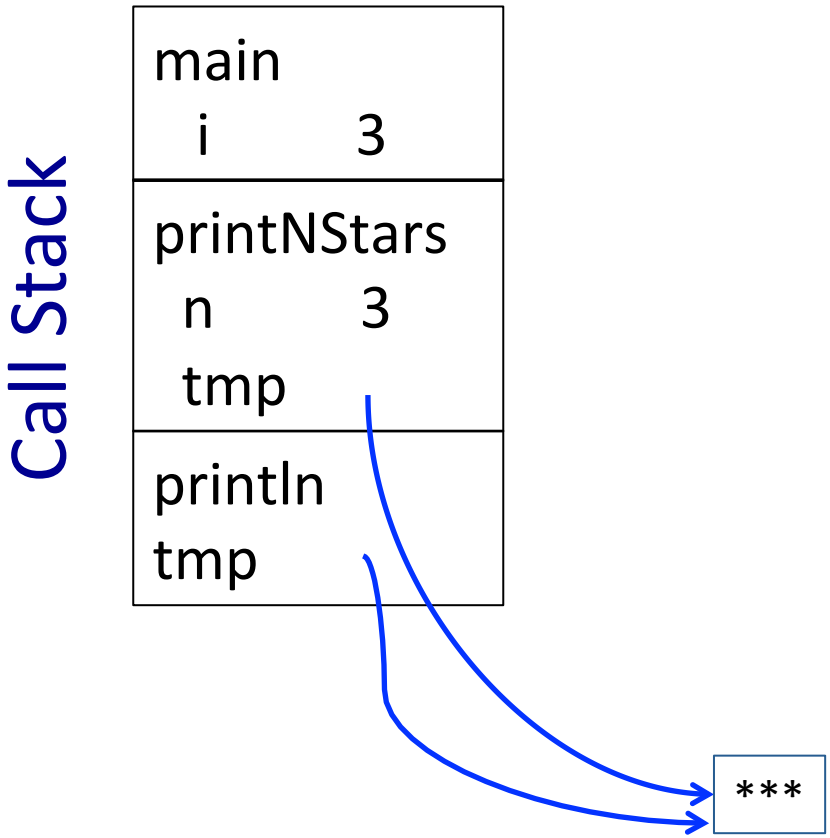
```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
printNStars(3);
nTimesChar(3, '*');
```

Output

```
*
**
```

Frames

- Stars.java



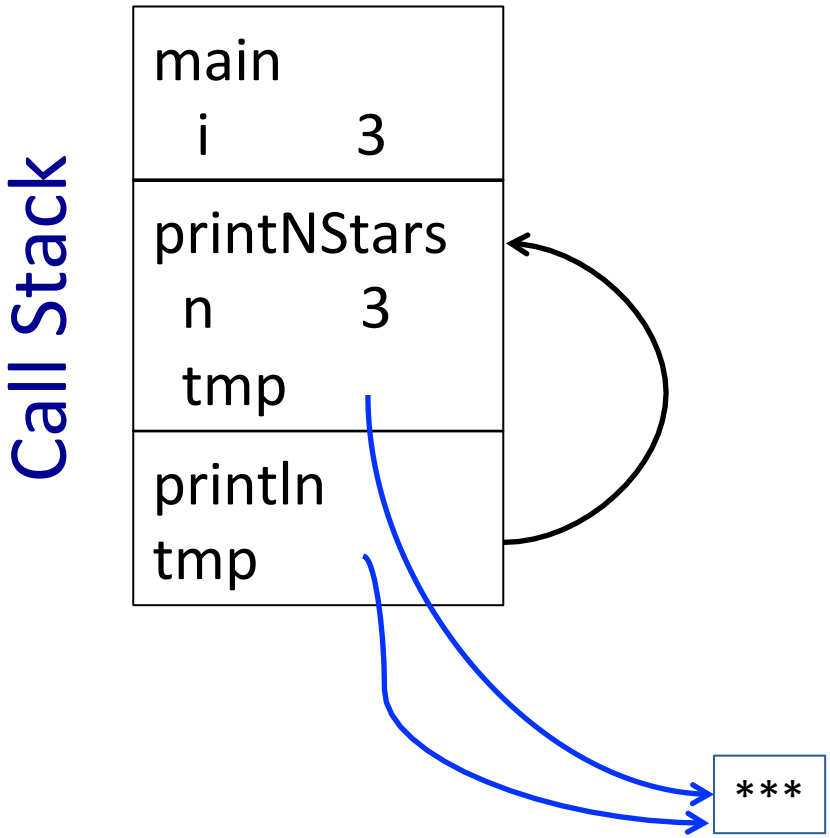
Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
printNStars(3);
nTimesChar(3, '*');
println("***");
```

Output
```
*
**
```

Frames

- Stars.java



Call Sequence

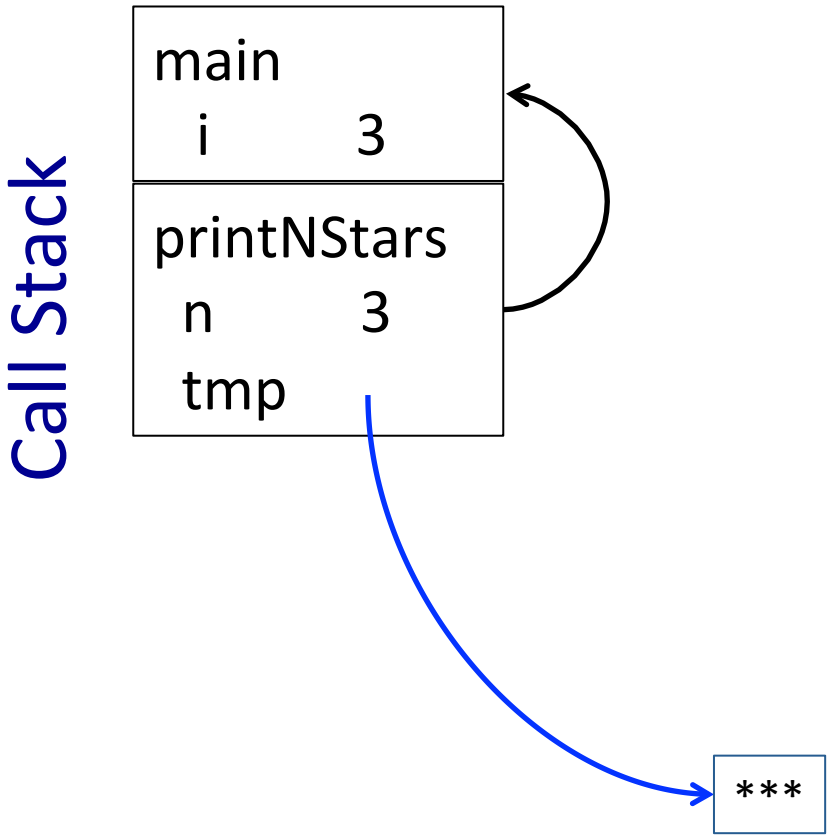
```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
printNStars(3);
nTimesChar(3, '*');
println("***");
```

Output

```
*
**
***
```

Frames

- Stars.java



Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
printNStars(3);
nTimesChar(3, '*');
println("***");
```

Output

```
*
**
***
```

Frames

- Stars.java

Call Stack

Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
printNStars(3);
nTimesChar(3, '*');
println("***");
```

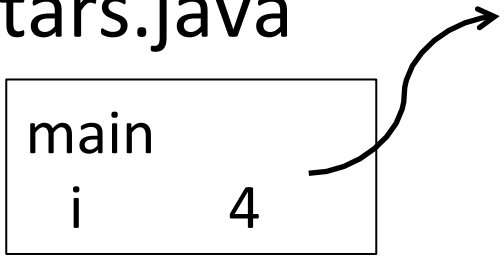
Output

```
*
**
***
```

Frames

- Stars.java

Call Stack



Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
printNStars(3);
nTimesChar(3, '*');
println("***");
```

Output

```
*
**
***
```

Frames

- Stars.java

Call Stack

Call Sequence

```
printNStars(1);
nTimesChar(1, '*');
println("*");
printNStars(2);
nTimesChar(2, '*');
println("**");
printNStars(3);
nTimesChar(3, '*');
println("***");
```

Output

```
*
**
***
```

The String Class

- A string is a sequence of characters
  - "cs111"
  - ""
  - "Are you listening?"
- Position of a character in the String: *index*
  - "now and then"

```
|   |  |  |   |
0   3  5  7   11
```

  - length of the String: 12 characters
    - last index = length - 1

Strings, Classes and Objects

- String is not a primitive data type but a class
  - Whenever we create a string we create an object
- Classes
  - can be used to describe objects
    - in this role the class describes a special kind of data type
  - can be containers for static variables and methods
- Objects are the instantiation of a class

Variables, Primitive Data Types and References

A variable can only hold primitive data types OR references to objects

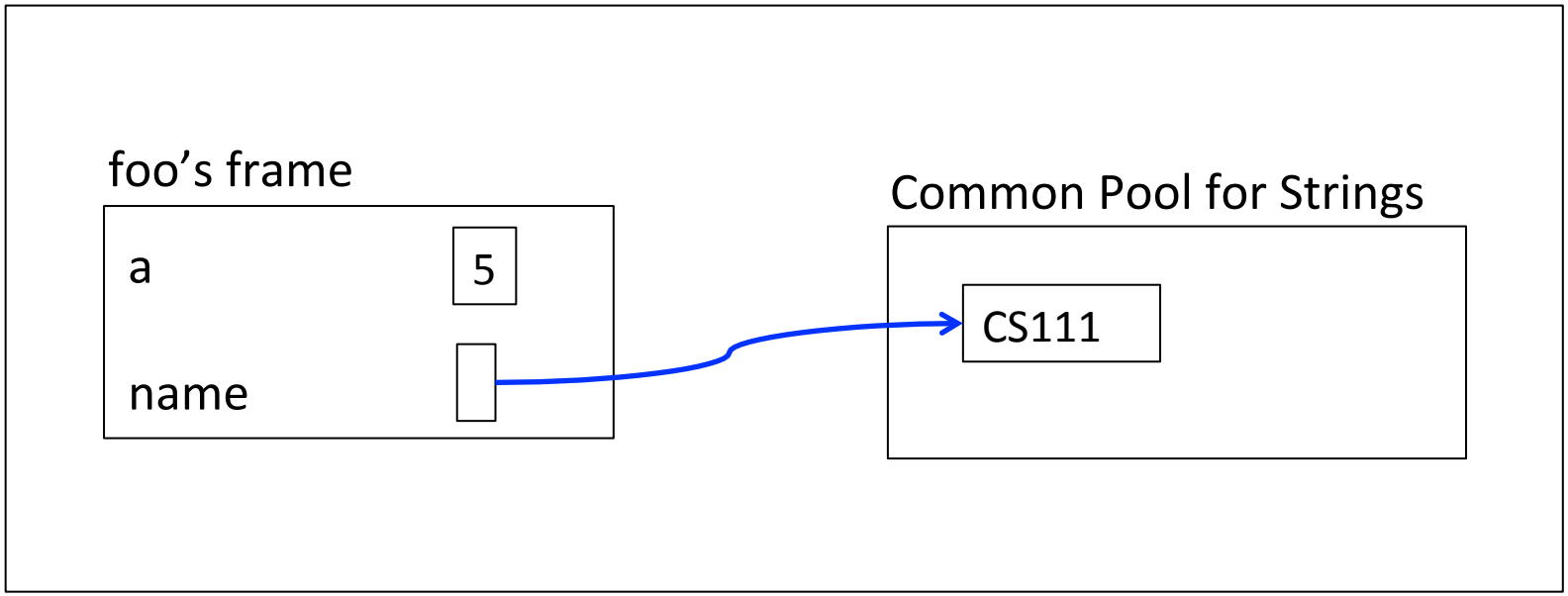
- Variables are kept in the methods' frame
- Objects are kept (held) elsewhere
  - a variable can only hold a reference to an object not the object itself
  - what is a reference?
    - the address of the object

Strings, Classes, Objects and References

```
public static void foo () {
    int a = 5;
    String name = "CS111";
}
```

- name **is** a reference to the String object "CS111"
- name has the address of the "CS111" object

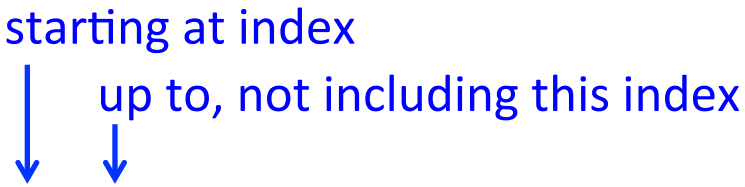
Java Virtual Machine (JVM)



String Methods: operations

- `String name = "cs111";`
- Length of a string

  `name.length()` ⟶ 5
- Substring: copy a consecutive sequence of characteres




```
name.substring(1,3);  ⟶ "s1"
name.substring(4,7);  ⟶ error
name.substring(1);    ⟶ "s111"
```

String Methods: operations

- Index of the first occurrence of a character

  `"cs111".indexof('1');` ⟶ 2

  `"cs111".indexof('x');` ⟶ -1

- The character at index 2

  `"cs111".charAt(3);` ⟶ 1

- In all upper case

  `"aBcde".toUpperCase();` ⟶ "ABCDE"

- In all lower case

  `"ABCde".toLowerCase();` ⟶ "abcde"

String Methods: operations

- Test if two strings are the same

```
name1.equals(name2);
```

- Test if one string is alphabetically before another

int c = name1.compareTo(name2);

c < 0 means name1 comes before name2

c == 0 means name1 equals name2

c > 0 means name1 comes after name2

See the alphabeticalOrder method in Methods.java

String Methods: operations

- None of the operations changes the existing string

```
String name = “Joe”;
String upperName = name.toUpperCase();
System.out.println(upperName); // JOE
System.out.println(name); // Joe
```

CS111
Introduction to Computer Science

- More on Strings
- Classes, Objects and References

Creating Formatted Strings

- Printing a formatted string

  System.out.printf("The value of a float variable is %f, the value of an integer variable is %d and the string is %s\n", floatVar, intVar, stringVar);

- You can also write

  String fs = String.format("The value of a float variable is %f, the value of an integer variable is %d and the string is %s\n", floatVar, intVar, stringVar);

  System.out.println(fs);

Program: Count Spaces in a String

Given a String, count how many spaces the String has:

"Are you listening?"

2

- Initialize a count variable
- Loop through all the characters of the string
- Update count if character is a space

Implement characterCount method in Methods.java

Program: letter frequency

- Given a String, output the frequency of each letter:

  "Are you listening?"

  a 1, r 1, e 2, y 1, o 1, u 1, l 1, i 2, s 1, t 1, n 2, g 1

- For each letter in the alphabet
  - Output its frequency on the String

Loop over alphabet

Create a method to count character frequency

See the letterFrequency method in Methods.java

Face Class and Objects

- Face.java
  - Class describing a Face object

- To create an instance of Face (object)

```
Face f = new Face();
```

Face Class and Objects

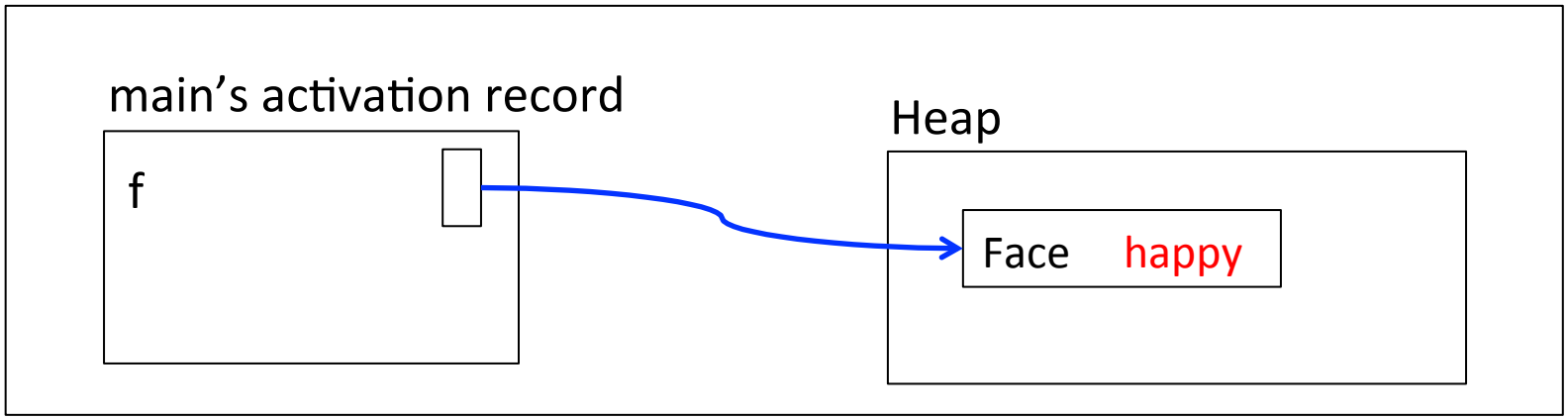
```
public static void main (String[] args) {
    Face f = new Face();
    f.setExpression("happy");
    f.setExpression("mad");
}
```

f **is** a reference to an object of type Face

new creates an instance of Face on the Heap

The **Heap** is where objects created with new live

Java Virtual Machine (JVM)

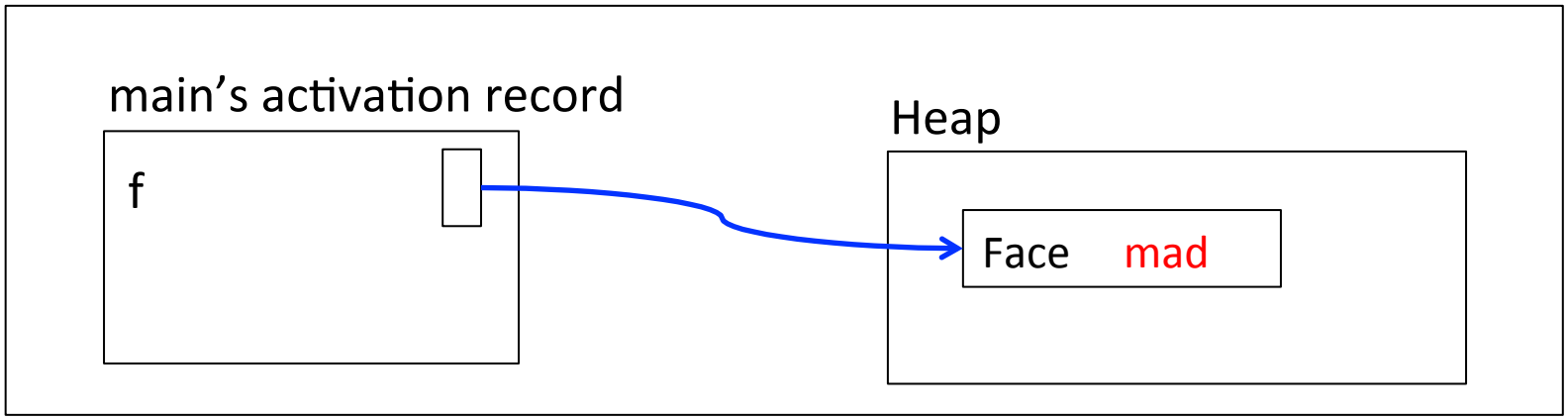


Face is a Mutable Object

```
public static void main (String[] args) {
    Face f = new Face();
    f.setExpression("happy");
    f.setExpression("mad");
}
```

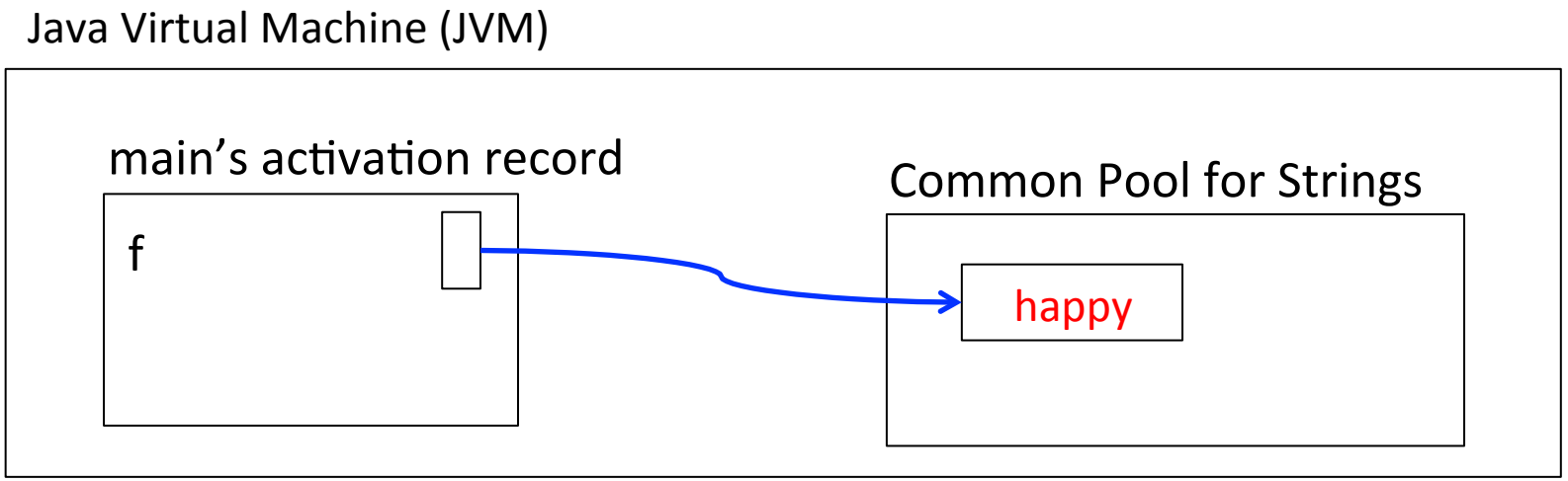
setExpression changes the object Face from happy to mad

Java Virtual Machine (JVM)



String is an Immutable Object

```
public static void main (String[] args) {
    String f = “happy”;
    f = “mad”;
}
```



String is an Immutable Object

```
public static void main (String[] args) {
    String f = "happy";
    f = "mad";
}
```

This statement does not change the String object **happy**
It creates another String object **mad** and **f** now references it

Java Virtual Machine (JVM)