

Exceptions



EECS2030 B & G: Advanced
Object Oriented Programming
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Learning Outcomes



This module is designed to help you learn about:

- Caller vs. Callee in a Method Invocation
- **Error Handling** via Console Message
- The **Catch**-or-**Specify** Requirement
- Example: To Handle or Not to Handle?
- **Error Handling** via Exceptions
- What to Do When an Exception is Thrown at Runtime
- More Examples on Exception Handling

Caller vs. Callee



- Within the body implementation of a method (`{...}`), we may call other methods.

```
1 class C1 {  
2     void m1() {  
3         C2 o = new C2();  
4         o.m2(); /* static type of o is C2 */  
5     }  
6 }
```

- From **Line 4**, we say:
 - Method **C1.m1** (i.e., method `m1` from class `C1`) is the **caller** of method **C2.m2**.
 - Method **C2.m2** is the **callee** of method **C1.m1**.

Stack of Method Calls



- Execution of a Java project **starts** from the **main method** of some class (e.g., `CircleTester`, `BankApplication`).
- Each line of **method call** involves the execution of that method's **body implementation**
 - That method's body implementation may also involve **method calls**, which may in turn involve more **method calls**, and etc.
 - It is typical that we end up with **a chain of method calls** !
 - We visualize this chain of method calls as a **call stack**.
For example:
 - `Account.withdraw` [top of stack; latest called]
 - `Bank.withdrawFrom`
 - `BankApplication.main` [bottom of stack; earliest called]
 - The closer a method is to the **top** of the call stack, the **later** its call was made.

Error Reporting via Consoles: Circles (1)



```
1 class Circle {
2     double radius;
3     Circle() { /* radius defaults to 0 */ }
4     void setRadius(double r) {
5         if (r < 0) { System.out.println("Invalid radius."); }
6         else { radius = r; }
7     }
8     double getArea() { return radius * radius * 3.14; }
9 }
```

- A negative radius is considered as an *invalid input value* to method `setRadius`.
- What if the **caller** of `Circle.setRadius` passes a negative value for `r`?
 - An error message is *printed to the console* (Line 5) to warn the **caller** of `setRadius`.
 - However, printing an error message to the console *does not force* the **caller** of `setRadius` to stop and handle invalid values of `r`.

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Error Reporting via Consoles: Bank (1)



```
class Account {
    int id; double balance;
    Account(int id) { this.id = id; /* balance defaults to 0 */ }
    void deposit(double a) {
        if (a < 0) { System.out.println("Invalid deposit."); }
        else { balance += a; }
    }
    void withdraw(double a) {
        if (a < 0 || balance - a < 0) {
            System.out.println("Invalid withdraw."); }
        else { balance -= a; }
    }
}
```

- A negative deposit or withdraw amount is *invalid*.
- When an *error* occurs, a message is *printed to the console*.
- However, printing error messages does not *force* the **caller** of `Account.deposit` or `Account.withdraw` to stop and handle invalid values of `a`.

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Error Reporting via Consoles: Circles (2)



```
1 class CircleCalculator {
2     public static void main(String[] args) {
3         Circle c = new Circle();
4         c.setRadius(-10);
5         double area = c.getArea();
6         System.out.println("Area: " + area);
7     }
8 }
```

- **L4:** `CircleCalculator.main` is **caller** of `Circle.setRadius`
- A negative radius is passed to `setRadius` in Line 4.
- The execution *always flows smoothly* from Lines 4 to Line 5, *even when there was an error* message printed from Line 4.
- It is not feasible to check if there is any kind of error message printed to the console right after the execution of Line 4.
- **Solution:** A way to *force* `CircleCalculator.main`, **caller** of `Circle.setRadius`, to realize that things might go wrong.
 - ⇒ When things do go wrong, *immediate* actions are needed.

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Error Reporting via Consoles: Bank (2)



```
1 class Bank {
2     Account[] accounts; int numberOfAccounts;
3     Bank(int id) { ... }
4     void withdrawFrom(int id, double a) {
5         for(int i = 0; i < numberOfAccounts; i++) {
6             if(accounts[i].id == id) {
7                 accounts[i].withdraw(a);
8             }
9         } /* end for */
10    } /* end withdraw */
11 }
```

- **L7:** `Bank.withdrawFrom` is **caller** of `Account.withdraw`
- What if in Line 7 the value of `a` is negative?
Error message `Invalid withdraw` printed from method `Account.withdraw` to console.
- Impossible to *force* `Bank.withdrawFrom`, the **caller** of `Account.withdraw`, to stop and handle invalid values of `a`.

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Error Reporting via Consoles: Bank (3)



```

1 class BankApplication {
2     public static void main(String[] args) {
3         Scanner input = new Scanner(System.in);
4         Bank b = new Bank(); Account acc1 = new Account(23);
5         b.addAccount(acc1);
6         double a = input.nextDouble();
7         b.withdrawFrom(23, a);
8         System.out.println("Transaction Completed.");
9     }

```

- There is a chain of method calls:
 - BankApplication.main** calls **Bank.withdrawFrom**
 - Bank.withdrawFrom** calls **Account.withdraw**.
- The actual update of balance occurs at the Account class.
 - What if in **Line 7** the value of **a** is negative?
 - Invalid withdraw** printed from **Bank.withdrawFrom**, originated from **Account.withdraw** to console.
 - However, impossible to stop **BankApplication.main** from continuing to execute **Line 8**, printing **Transaction Completed**.
- Solution:** Define error checking only once and let it **propagate**.

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What to Do When an Exception Is Thrown?



- After a method **throws an exception**, the **runtime system** searches the corresponding **call stack** for a method that contains a block of code to **handle** the exception.
 - This block of code is called an **exception handler**.
 - An exception handler is **appropriate** if the **type** of the **exception object thrown** matches the **type** that can be handled by the handler.
 - The exception handler chosen is said to **catch** the exception.
 - The search goes from the **top** to the **bottom** of the call stack:
 - The method in which the **error** occurred is searched first.
 - The **exception handler** is not found in the current method being searched $\Rightarrow$ Search the method that calls the current method, and *etc.*
 - When an appropriate **handler** is found, the **runtime system** passes the exception to the handler.
 - The **runtime system** searches all the methods on the **call stack** without finding an **appropriate exception handler**
 - $\Rightarrow$ The program terminates and the exception object is directly "thrown" to the console!

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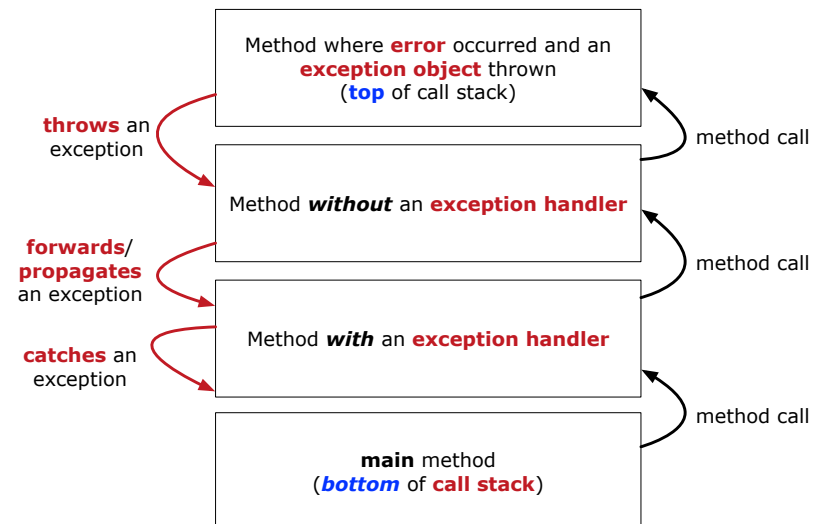
What is an Exception?



- An **exception** is an **event**, which
 - occurs during the **execution of a program**
 - disrupts the normal flow** of the program's instructions
- When an error occurs within a method:
 - the method throws an exception:
 - first creates an **exception object**
 - then hands it over to the **runtime system**
 - the exception object contains information about the error:
 - type [e.g., NegativeRadiusException]
 - the state of the program when the error occurred

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What to Do When an Exception Is Thrown?



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The Catch or Specify Requirement (1)



Code (e.g., a method call) that might throw certain exceptions must be enclosed by one of the two ways:

1. The “Catch” Solution: A `try` statement that **catches** and **handles** the **exception** (**without** propagating that exception to the method's **caller**).

```
main(...) {  
    Circle c = new Circle();  
    try {  
        c.setRadius(-10);  
    }  
    catch (NegativeRadiusException e) {  
        ...  
    }  
}
```

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The Catch or Specify Requirement (2)



Code (e.g., a method call) that might throw certain exceptions must be enclosed by one of the two ways:

2. The “Specify” Solution: A method that specifies as part of its **header** that it may (or may not) **throw** the **exception** (which will be thrown to the method's **caller** for handling).

```
class Bank {  
    Account[] accounts; /* attribute */  
    void withdraw (double amount)  
        throws InvalidTransactionException {  
        ...  
        accounts[i].withdraw(amount);  
        ...  
    }  
}
```

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Example: to Handle or Not to Handle? (1.1)



Consider the following three classes:

```
class A {  
    ma(int i) {  
        if (i < 0) { /* Error */ }  
        else { /* Do something. */ }  
    }  
}
```

```
class B {  
    mb(int i) {  
        A oa = new A();  
        oa.ma(i); /* Error occurs if i < 0 */  
    }  
}
```

```
class Tester {  
    public static void main(String[] args) {  
        Scanner input = new Scanner(System.in);  
        int i = input.nextInt();  
        B ob = new B();  
        ob.mb(i); /* Where can the error be handled? */  
    }  
}
```

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Example: to Handle or Not to Handle? (1.2)



- We assume the following kind of error for negative values:

```
class NegValException extends Exception {  
    NegValException(String s) { super(s); }  
}
```

- The above kind of exception may be thrown by calling `A.ma`.
- We will see three kinds of possibilities of handling this exception:
 - Version 1:**
Handle it in `B.mb`
 - Version 2:**
Pass it from `B.mb` and handle it in `Tester.main`
 - Version 3:**
Pass it from `B.mb`, then from `Tester.main`, then throw it to the console.

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Example: to Handle or Not to Handle? (2.1)



Version 1: Handle the exception in B.mb.

```
class A {
    ma(int i) throws NegValException {
        if(i < 0) { throw new NegValException("Error."); }
        else { /* Do something. */ }
    }
}

class B {
    mb(int i) {
        A oa = new A();
        try { oa.ma(i); }
        catch(NegValException nve) { /* Do something. */ }
    }
}

class Tester {
    public static void main(String[] args) {
        Scanner input = new Scanner(System.in);
        int i = input.nextInt();
        B ob = new B();
        ob.mb(i); /* Error, if any, would have been handled in B.mb. */
    }
}
```

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Example: to Handle or Not to Handle? (3.1)



Version 2: Handle the exception in Tester.main.

```
class A {
    ma(int i) throws NegValException {
        if(i < 0) { throw new NegValException("Error."); }
        else { /* Do something. */ }
    }
}

class B {
    mb(int i) throws NegValException {
        A oa = new A();
        oa.ma(i);
    }
}

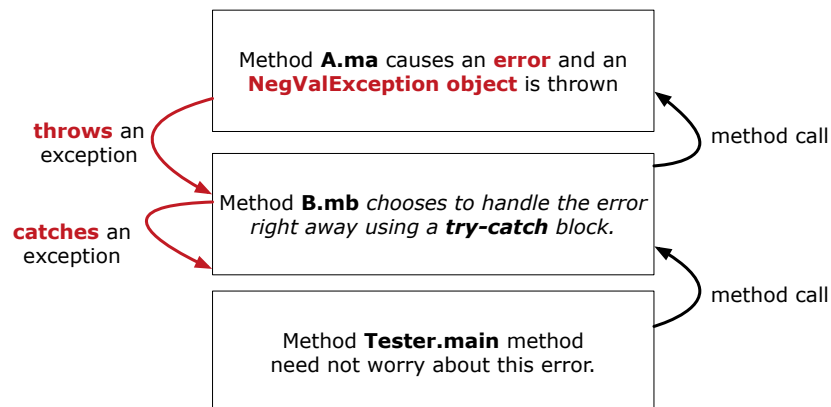
class Tester {
    public static void main(String[] args) {
        Scanner input = new Scanner(System.in);
        int i = input.nextInt();
        B ob = new B();
        try { ob.mb(i); }
        catch(NegValException nve) { /* Do something. */ }
    }
}
```

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Example: to Handle or Not to Handle? (2.2)



Version 1: Handle the exception in B.mb.

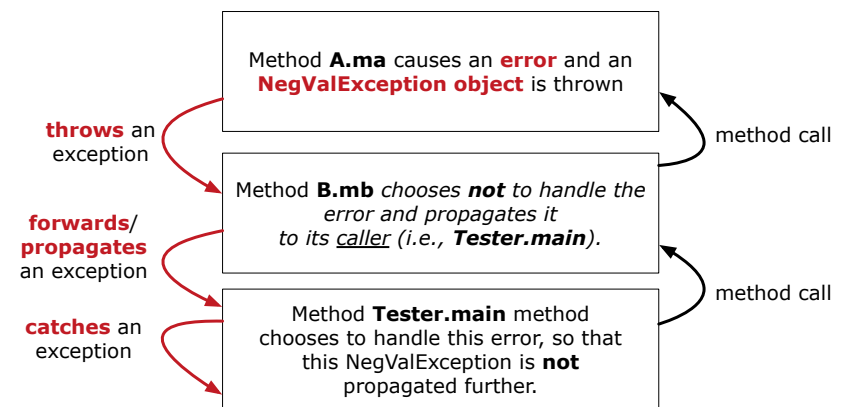


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Example: to Handle or Not to Handle? (3.2)



Version 2: Handle the exception in Tester.main.



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Example: to Handle or Not to Handle? (4.1)



Version 3: Handle in neither of the classes.

```
class A {
    ma(int i) throws NegValException {
        if(i < 0) { throw new NegValException("Error."); }
        else { /* Do something. */ }
    }
}

class B {
    mb(int i) throws NegValException {
        A oa = new A();
        oa.ma(i);
    }
}

class Tester {
    public static void main(String[] args) throws NegValException {
        Scanner input = new Scanner(System.in);
        int i = input.nextInt();
        B ob = new B();
        ob.mb(i);
    }
}
```

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Error Reporting via Exceptions: Circles (1)



```
public class InvalidRadiusException extends Exception {
    public InvalidRadiusException(String s) {
        super(s);
    }
}
```

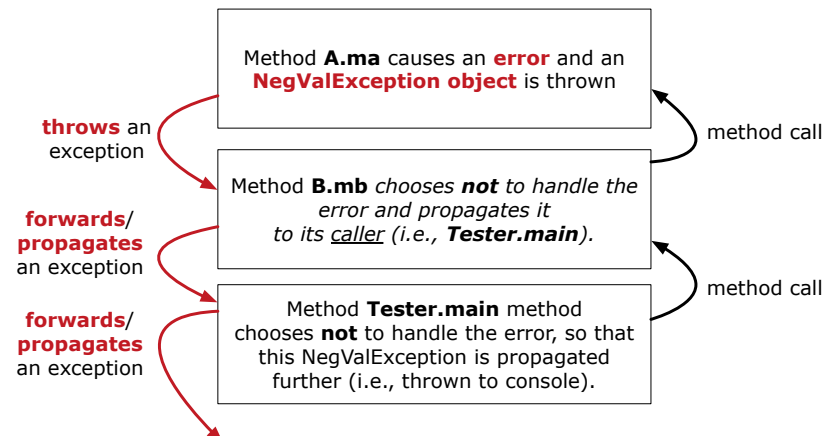
- A new kind of Exception: InvalidRadiusException
- For any method that can have this kind of error, we declare at that method's **header** that it may **throw** an InvalidRadiusException object.

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Example: to Handle or Not to Handle? (4.2)



Version 3: Handle in neither of the classes.



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Error Reporting via Exceptions: Circles (2)



```
class Circle {
    double radius;
    Circle() { /* radius defaults to 0 */ }
    void setRadius(double r) throws InvalidRadiusException {
        if (r < 0) {
            throw new InvalidRadiusException("Negative radius.");
        }
        else { radius = r; }
    }
    double getArea() { return radius * radius * 3.14; }
}
```

- As part of the **header** of setRadius, we declare that it may **throw** an InvalidRadiusException object at runtime.
- Any method that calls setRadius will be forced to **deal with this potential error**.

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Error Reporting via Exceptions: Circles (3)



```
1 class CircleCalculator1 {
2     public static void main(String[] args) {
3         Circle c = new Circle();
4         try {
5             c.setRadius(-10);
6             double area = c.getArea();
7             System.out.println("Area: " + area);
8         }
9         catch(InvalidRadiusException e) {
10             System.out.println(e);
11         }
12     } }
```

- Line 5 is forced to be wrapped within a **try-catch** block, since it may **throw** an InvalidRadiusException object.
- If an InvalidRadiusException object is thrown from Line 6, then the normal flow of execution is **interrupted** and we go to the catch block starting from Line 9.

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Error Reporting via Exceptions: Circles (5)



```
1 public class CircleCalculator2 {
2     public static void main(String[] args) {
3         Scanner input = new Scanner(System.in);
4         boolean inputRadiusIsValid = false;
5         while(!inputRadiusIsValid) {
6             System.out.println("Enter a radius:");
7             double r = input.nextDouble();
8             Circle c = new Circle();
9             try { c.setRadius(r);
10                 inputRadiusIsValid = true;
11                 System.out.print("Circle with radius " + r);
12                 System.out.println(" has area: " + c.getArea()); }
13             catch(InvalidRadiusException e) { print("Try again!"); }
14         } }
```

- At L7, if the user's input value is:
 - Non-Negative: L8 – L12. [inputRadiusIsValid set **true**]
 - Negative: L8, L9, L13. [inputRadiusIsValid remains **false**]

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Error Reporting via Exceptions: Circles (4)



Exercise: Extend CircleCalculator1: repeatedly prompt for a new radius value until a valid one is entered (i.e., the InvalidRadiusException does not occur).

```
Enter a radius:
-5
Radius -5.0 is invalid, try again!
Enter a radius:
-1
Radius -1.0 is invalid, try again!
Enter a radius:
5
Circle with radius 5.0 has area: 78.5
```

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Error Reporting via Exceptions: Bank (1)



```
public class InvalidTransactionException extends Exception {
    public InvalidTransactionException(String s) {
        super(s);
    }
}
```

- A new kind of Exception:
InvalidTransactionException
- For any method that can have this kind of error, we declare at that method's **header** that it may **throw** an InvalidTransactionException object.

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Error Reporting via Exceptions: Bank (2)



```
class Account {
    int id; double balance;
    Account() { /* balance defaults to 0 */ }
    void withdraw(double a) throws InvalidTransactionException {
        if (a < 0 || balance - a < 0) {
            throw new InvalidTransactionException("Invalid withdraw.");
        } else { balance -= a; }
    }
}
```

- As part of the **header** of withdraw, we declare that it may **throw** an InvalidTransactionException object at runtime.
- Any method that calls withdraw will be forced to **deal with this potential error**.

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Error Reporting via Exceptions: Bank (4)



```
1 class BankApplication {
2     public static void main(String[] args) {
3         Bank b = new Bank();
4         Account acc1 = new Account(23);
5         b.addAccount(acc1);
6         Scanner input = new Scanner(System.in);
7         double a = input.nextDouble();
8         try {
9             b.withdraw(23, a);
10            System.out.println(acc1.balance);
11        } catch (InvalidTransactionException e) {
12            System.out.println(e);
13        }
14    }
15 }
```

- Lines 9 is forced to be wrapped within a **try-catch** block, since it may **throw** an InvalidTransactionException object.
- If an InvalidTransactionException object is thrown from Line 9, then the normal flow of execution is interrupted and we go to the catch block starting from Line 11.

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Error Reporting via Exceptions: Bank (3)



```
class Bank {
    Account[] accounts; int numberOfAccounts;
    Account(int id) { ... }
    void withdraw(int id, double a)
        throws InvalidTransactionException {
        for(int i = 0; i < numberOfAccounts; i++) {
            if(accounts[i].id == id) {
                accounts[i].withdraw(a);
            }
        }
    } /* end for */ } /* end withdraw */ }
```

- As part of the **header** of withdraw, we declare that it may **throw** an InvalidTransactionException object.
- Any method that calls withdraw will be forced to **deal with this potential error**.
- We are **propagating** the potential error for the right party (i.e., BankApplication) to handle.

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More Examples (1)



```
double r = ...;
double a = ...;
try{
    Bank b = new Bank();
    b.addAccount(new Account(34));
    b.deposit(34, 100);
    b.withdraw(34, a);
    Circle c = new Circle();
    c.setRadius(r);
    System.out.println(r.getArea());
}
catch(NegativeRadiusException e) {
    System.out.println(r + " is not a valid radius value.");
    e.printStackTrace();
}
catch(InvalidTransactionException e) {
    System.out.println(r + " is not a valid transaction value.");
    e.printStackTrace();
}
```

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More Example (2.1)



The `Integer` class supports a method for parsing Strings:

```
public static int parseInt(String s)
    throws NumberFormatException
```

e.g., `Integer.parseInt("23")` returns 23

e.g., `Integer.parseInt("twenty-three")` throws a `NumberFormatException`

Write a fragment of code that prompts the user to enter a string (using `nextLine` from `Scanner`) that represents an integer.

If the user input is not a valid integer, then prompt them to enter again.

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More Example (2.2)



```
Scanner input = new Scanner(System.in);
boolean validInteger = false;
while (!validInteger) {
    System.out.println("Enter an integer:");
    String userInput = input.nextLine();
    try {
        int userInteger = Integer.parseInt(userInput);
        validInteger = true;
    }
    catch (NumberFormatException e) {
        System.out.println(userInput + " is not a valid integer.");
        /* validInteger remains false */
    }
}
```

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Beyond this lecture...



- Practice creating a new **exception** class upon a method throwing it in the body of implementation (e.g., `InvalidRadiusException`, `InvalidTransactionException`).
 - Play with the source code:
 - `ExceptionsCircleAndBank.zip`
 - `ExceptionsToHandleOrNotToHandle.zip`
- Tip.** Change input values so as to explore, in Eclipse *debugger*, possible (*normal* vs. *abnormal*) **execution paths**.

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Learning Outcomes

Caller vs. Callee

Stack of Method Calls

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Error Reporting via Consoles: Circles (2)

Error Reporting via Consoles: Bank (1)

Error Reporting via Consoles: Bank (2)

Error Reporting via Consoles: Bank (3)

What is an Exception?

What to Do When an Exception Is Thrown? (1)

What to Do When an Exception Is Thrown? (2)

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The Catch or Specify Requirement (2)

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More Examples (1)

More Example (2.1)

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Beyond this lecture...

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