Binary search

```
int index = Collections.binarySearch(list, element);
```

- Precondition: the list must be sorted.
- If the element is contained in the list then the method returns the index at which the element can be found.
- If the element is not in the list then the method returns -1.

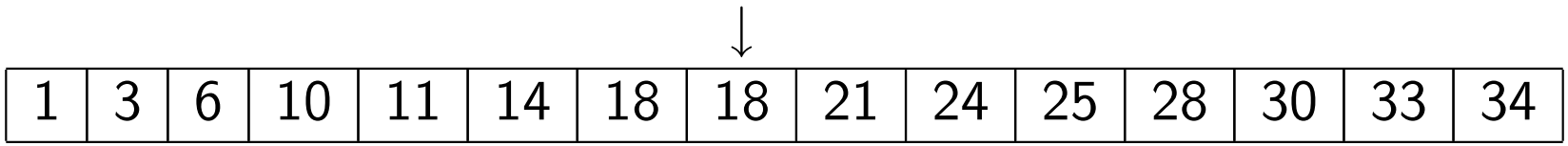
Binary search

```
final int ELEMENT = 11;
int index = Collections.binarySearch(list, ELEMENT);
```

1	3	6	10	11	14	18	18	21	24	25	28	30	33	34

Binary search

```
final int ELEMENT = 11;
int index = Collections.binarySearch(list, ELEMENT);
```



Binary search

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int index = Collections.binarySearch(list, ELEMENT);
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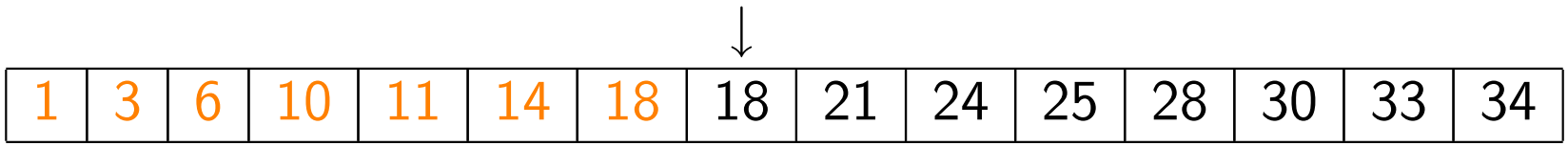

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int index = Collections.binarySearch(list, ELEMENT);
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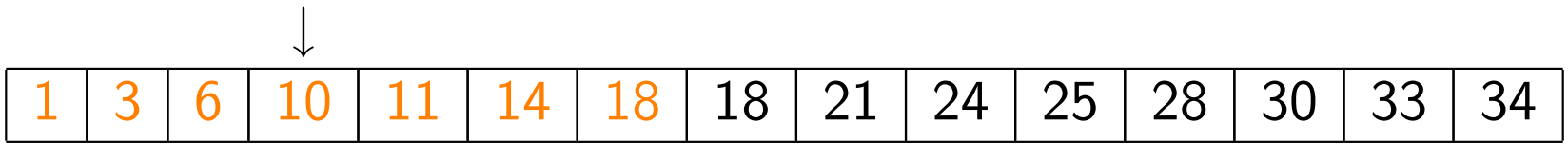

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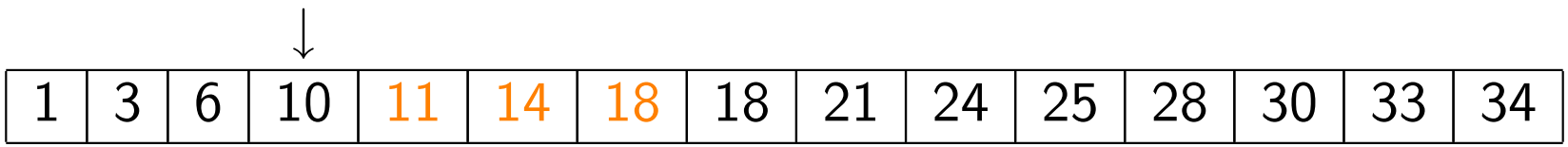

Binary search

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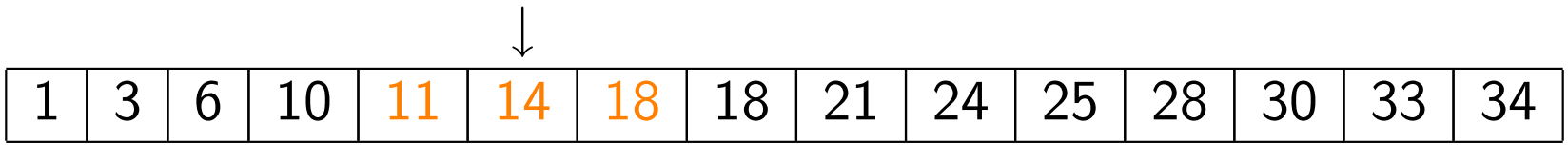
final int ELEMENT = 11;
int index = Collections.binarySearch(list, ELEMENT);
```



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final int ELEMENT = 11;
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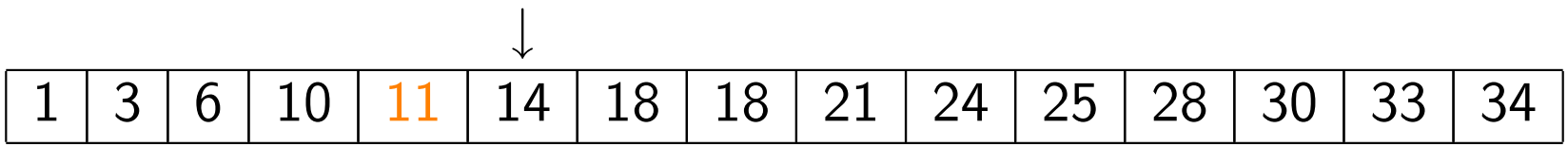

Binary search

```
final int ELEMENT = 11;
int index = Collections.binarySearch(list, ELEMENT);
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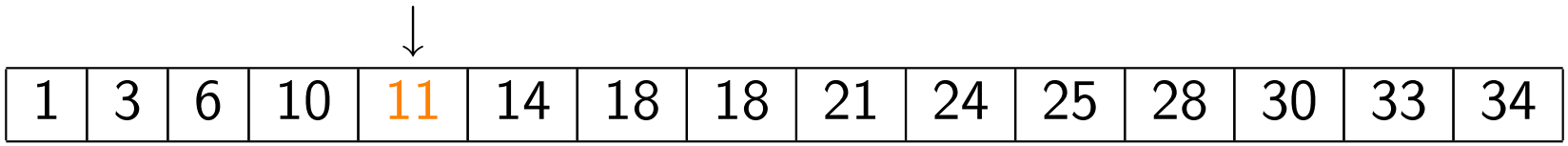

`index` gets assigned the value 4.

Binary search

Question

Consider

```
int index = Collections.binarySearch(list, ELEMENT);
```

Given that the list contains n elements, in the worst case, how many comparisons does the invocation of `binarySearch` make?

Binary search

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Given that the list contains n elements, in the worst case, how many comparisons does the invocation of `binarySearch` make?

Answer

Let n be the number of elements of the list and c the number of comparisons needed in the worst case.

n	1	2	3	4	5	6	7	8
c								

Binary search

Question

Consider

```
int index = Collections.binarySearch(list, ELEMENT);
```

Given that the list contains n elements, in the worst case, how many comparisons does the invocation of `binarySearch` make?

Answer

Let n be the number of elements of the list and c the number of comparisons needed in the worst case.

n	1	2	3	4	5	6	7	8
c	1							

Binary search

Question

Consider

```
int index = Collections.binarySearch(list, ELEMENT);
```

Given that the list contains n elements, in the worst case, how many comparisons does the invocation of `binarySearch` make?

Answer

Let n be the number of elements of the list and c the number of comparisons needed in the worst case.

n	1	2	3	4	5	6	7	8
c	1	2						

Binary search

Question

Consider

```
int index = Collections.binarySearch(list, ELEMENT);
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Given that the list contains n elements, in the worst case, how many comparisons does the invocation of `binarySearch` make?

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Binary search

Question

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```

Given that the list contains n elements, in the worst case, how many comparisons does the invocation of `binarySearch` make?

Answer

Let n be the number of elements of the list and c the number of comparisons needed in the worst case.

n	1	2	3	4	5	6	7	8
c	1	2	2	3				

Binary search

Question

Consider

```
int index = Collections.binarySearch(list, ELEMENT);
```

Given that the list contains n elements, in the worst case, how many comparisons does the invocation of `binarySearch` make?

Answer

Let n be the number of elements of the list and c the number of comparisons needed in the worst case.

n	1	2	3	4	5	6	7	8
c	1	2	2	3	3	3	3	4

Answer continued

Let n be the number of elements of the list and c the number of comparisons needed in the worst case.

n	1	2	3	4	5	6	7	8
c	1	2	2	3	3	3	3	4

Answer continued

Let n be the number of elements of the list and c the number of comparisons needed in the worst case.

n	1	2	3	4	5	6	7	8
c	1	2	2	3	3	3	3	4
2^{c-1}								

Answer continued

Let n be the number of elements of the list and c the number of comparisons needed in the worst case.

n	1	2	3	4	5	6	7	8
c	1	2	2	3	3	3	3	4
2^{c-1}	1	2	2	4	4	4	4	8

Answer continued

Let n be the number of elements of the list and c the number of comparisons needed in the worst case.

n	1	2	3	4	5	6	7	8
c	1	2	2	3	3	3	3	4
2^{c-1}	1	2	2	4	4	4	4	8

$2^{c-1} \leq n$

Answer continued

Let n be the number of elements of the list and c the number of comparisons needed in the worst case.

n	1	2	3	4	5	6	7	8
c	1	2	2	3	3	3	3	4
2^{c-1}	1	2	2	4	4	4	4	8

$2^{c-1} \leq n$

$\log_2(2^{c-1}) \leq \log_2(n)$

Answer continued

Let n be the number of elements of the list and c the number of comparisons needed in the worst case.

n	1	2	3	4	5	6	7	8
c	1	2	2	3	3	3	3	4
2^{c-1}	1	2	2	4	4	4	4	8

$2^{c-1} \leq n$
$\log_2(2^{c-1}) \leq \log_2(n)$
$c - 1 \leq \log_2(n)$

Answer continued

Let n be the number of elements of the list and c the number of comparisons needed in the worst case.

n	1	2	3	4	5	6	7	8
c	1	2	2	3	3	3	3	4
2^{c-1}	1	2	2	4	4	4	4	8

$2^{c-1} \leq n$
$\log_2(2^{c-1}) \leq \log_2(n)$
$c - 1 \leq \log_2(n)$
$c \leq \log_2(n) + 1$

Answer continued

Let n be the number of elements of the list and c the number of comparisons needed in the worst case.

n	1	2	3	4	5	6	7	8
c	1	2	2	3	3	3	3	4
2^{c-1}	1	2	2	4	4	4	4	8

$2^{c-1} \leq n$
$\log_2(2^{c-1}) \leq \log_2(n)$
$c - 1 \leq \log_2(n)$
$c \leq \log_2(n) + 1$
$O(\log_2(n))$ comparisons

Sorting

Fact

Sorting a list of n elements needs $O(n \log(n))$ comparisons.

Temperature app

The temperature app

- randomly selects a city in Ontario,
- reads a corresponding URL, and
- extracts the current temperature.

Temperature app

For each city, we need a corresponding URL. These can be stored in a file.

```
on-122_metric_e.html  Alexandria
on-1_metric_e.html  Algonquin Park (Brent)
on-29_metric_e.html  Algonquin Park (Lake of Two Rivers)
on-114_metric_e.html  Alliston
on-30_metric_e.html  Apsley
on-111_metric_e.html  Armstrong
on-148_metric_e.html  Atikokan
on-164_metric_e.html  Attawapiskat
...
```

Temperature app

Question

What is the most appropriate collection to store the cities and their URLs? A list, a set or a map?

Temperature app

Question

What is the most appropriate collection to store the cities and their URLs? A list, a set or a map?

Answer

A map.

Temperature app

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Question

What are the types of the keys and values of the map?

Temperature app

Question

What is the most appropriate collection to store the cities and their URLs? A list, a set or a map?

Answer

A map.

Question

What are the types of the keys and values of the map?

Answer

`String` and `URL`.

Object Serialization

Rather than reading a string representation of an object from a file and creating the object, we can also read the object from a file directly.

```
ObjectInputStream objectInput =
    new ObjectInputStream(
        new FileInputStream("cities.dat"));
Map<String, URL> map =
    (Map) objectInput.readObject();
objectInput.close();
```

Object Serialization

Rather than writing a string representation of an object to a file, we can also save the object to a file directly.

```
ObjectOutputStream objectOutput =
  new ObjectOutputStream(
     new FileOutputStream("cities.dat"));
objectOutput.writeObject(map);
objectOutput.close();
```

Object Serialization

Question

Which objects can be serialized?

Object Serialization

Question

Which objects can be serialized?

Answer

Those objects that are an instance of a class that implements the interface `Serializable`.

Exception Handling

CSE 1020

moodle.yorku.ca

Sources of Crashes

- The user

  Enter your choice (1–5): a

- The client

```
List<Integer> list = ...
for (int i = 0; i <= list.size(); i++) {
    output.println( list .get(i ));
}
```

- The implementer

```
import com.cheapbutquestionable.Integers;
 ...
int value = Integer.parseInt(input.nextInt());
```

- The runtime environment

```
List<String> list = ...
while (true) {
    list .add(new String("Hello"));
```

API

Which exceptions a method may throw are specified in the API.

`E get(int index)`

Returns the element at the specified position in this list.

Parameters:

`index` – index of the element to return

Returns:

the element at the specified position in this list

Throws:

`IndexOutOfBoundsException` – if the index is out of range (`index < 0 || index >= size()`)

Preconditions versus Exceptions

Question

Why do we need exceptions? Can't we prevent crashes by introducing appropriate preconditions?

Preconditions versus Exceptions

Question

Why do we need exceptions? Can't we prevent crashes by introducing appropriate preconditions?

Answer

Introducing an appropriate precondition is not always practical and in some cases impossible.

Preconditions versus Exceptions

The method Double.valueOf(String) throws a NumberFormatException if the argument is not a parsable number.

If this exception were replaced with a precondition, the client would have to check that the argument is a parsable number. Although this can be done using a regular expression, as shown in the API of the method Double.valueOf(String), using exception handling is much easier.

Preconditions versus Exceptions

Each constructor throws an OutOfMemoryError when the Java Virtual Machine cannot allocate an object because it is out of memory, and no more memory could be made available by the garbage collector.

If this error were replaced with a precondition, the client would have to check if there would be sufficient memory before creating each object, which is obviously extremely tedious (if at all possible).

How to Handle Exceptions

Step 1

Place a try block around the statement(s) that may throw the exception.

```
try {
    ...
}
```

Step 2

Place a catch block right after the try block.

```
catch  (... Exception e) {
    ...
}
```

Exceptions

Compiling

```
File file = new File("test.txt");
PrintStream fileOutput = new PrintStream(file);
```

gives rise to the error

```
Client.java:13: unreported exception java.io.
FileNotFoundException; must be caught or declared
to be thrown
    PrintStream fileOutput = new PrintStream(file);
                             ^
1 error
```

Why?

Answer

Because the constructor `PrintStream(File)` throws a `FileNotFoundException` if the `file` object does not denote an existing, writable regular file and a new regular file of that name cannot be created, or if some other error occurs while opening or creating the file (see API).

Answer

Because the constructor `PrintStream(File)` throws a `FileNotFoundException` if the `file` object does not denote an existing, writable regular file and a new regular file of that name cannot be created, or if some other error occurs while opening or creating the file (see API).

Question

How does a client fix a "must be caught or declared to be thrown" error?

Answer

Because the constructor `PrintStream(File)` throws a `FileNotFoundException` if the `file` object does not denote an existing, writable regular file and a new regular file of that name cannot be created, or if some other error occurs while opening or creating the file (see API).

Question

How does a client fix a "must be caught or declared to be thrown" error?

Answer

Catch the exception. (An implementer may also decide the declare the exception to be thrown.)

How to Catch Exceptions?

```
import java.io.FileNotFoundException;
 ...
try{
    File   file   = new File("test.txt");
    PrintStream fileOutput = new PrintStream(file);
}
catch (FileNotFoundException e){
    output.println("Failed to write to file : "
        + e.getMessage())
}
```

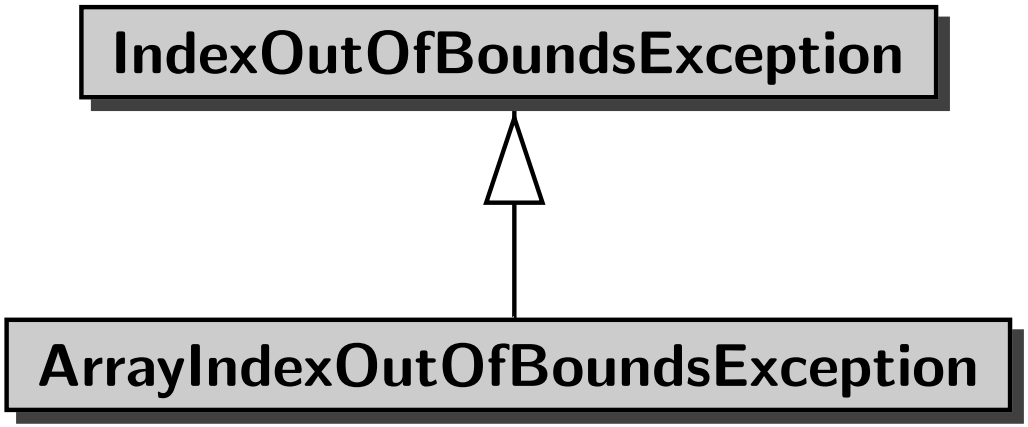
Exceptions

```
try{
    output.println(args [0]);
}
catch (IndexOutOfBoundsException e){
    output.println(e.getMessage());
}
catch (ArrayIndexOutOfBoundsException e){
    e.printStackTrace();
}
```

gives rise to the compile-time error

```
Client.java:19: exception java.lang.
ArrayIndexOutOfBoundsException has already been
caught
    catch (ArrayIndexOutOfBoundsException e)
    ^
1 error
```

Exceptions

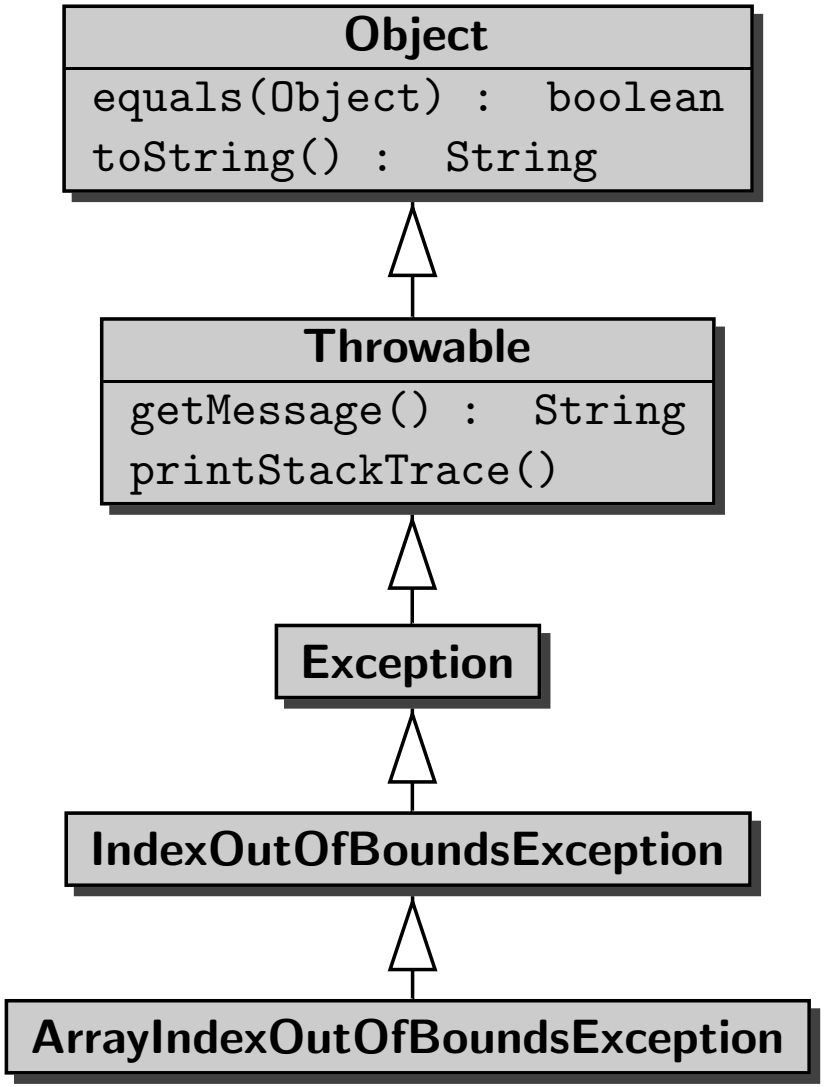

IndexOutOfBoundsException
ArrayIndexOutOfBoundsException

Exceptions

```
try{
    output.println(args [0]);
}
catch (IndexOutOfBoundsException e){
    output.println(e.getMessage());
}
catch (ArrayIndexOutOfBoundsException e){
    e.printStackTrace();
}
```

The second catch block is redundant, because an `ArrayIndexOutOfBoundsException` is-an `IndexOutOfBoundsException`.

Inheritance Hierarchy



Question

May the method `charAt(int)` of the class `String` throw an exception?

Exceptions

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May the method `charAt(int)` of the class `String` throw an exception?

Answer

Yes.

Exceptions

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Question

Which type of exception?

Exceptions

Question

May the method `charAt(int)` of the class `String` throw an exception?

Answer

Yes.

Question

Which type of exception?

Answer

An `IndexOutOfBoundsException`.

Exceptions

```
String word = ...;
output.println(word.charAt(2));
```

Question

Why does the above snippet not give rise to a "must be caught or declared to be thrown" error?

Exceptions

```
String word = ...;
output.println(word.charAt(2));
```

Question

Why does the above snippet not give rise to a "must be caught or declared to be thrown" error?

Answer

The "must be caught or declared to be thrown" rule is only applicable to checked exceptions and an `IndexOutOfBoundsException` is not checked.

What are Checked Exceptions?

Definition

An exception is checked if

- it is `Exception` or any of its subclasses, and
- it is not `RuntimeException` or any of its subclasses.

Question

Is `NullPointerException` checked?

What are Checked Exceptions?

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Question

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No.

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Answer

No.

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Is `InvalidPropertiesFormatException` checked?

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Yes.

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Is `Exception` checked?

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Yes.

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Is `RuntimeException` checked?

What are Checked Exceptions?

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Is `Exception` checked?

Answer

Yes.

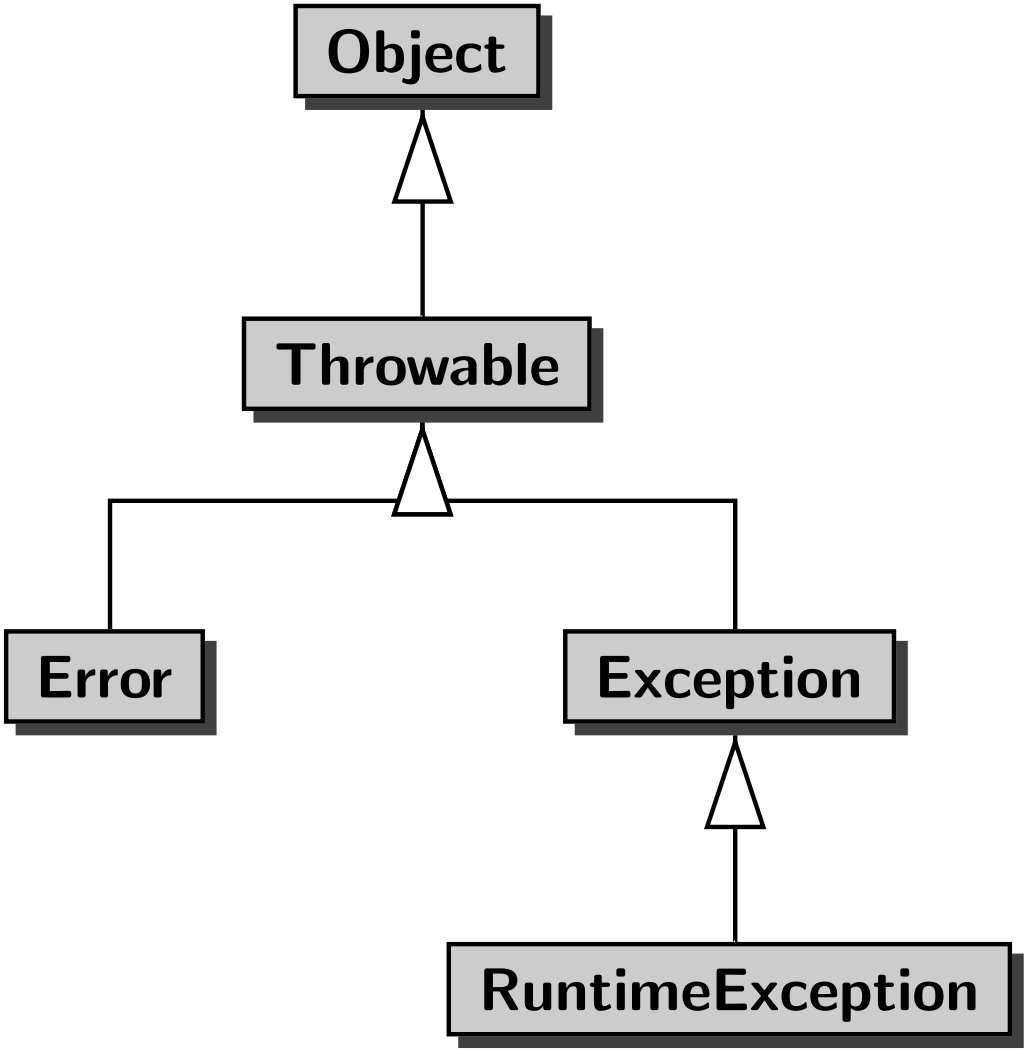
Question

Is `RuntimeException` checked?

Answer

No.

Inheritance Hierarchy



Errors

Question

Why are `Errors` exempt from the "must be caught or declared to be thrown" rule?

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Why are `Errors` exempt from the "must be caught or declared to be thrown" rule?

Answer

`Errors` represent conditions that are so abnormal the reliability of the whole environment is suspect and, hence, the code in the catch block may not run properly either.

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Question

Why are `RuntimeExceptions` exempt from the "must be caught or declared to be thrown" rule?

Errors

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Why are `Errors` exempt from the "must be caught or declared to be thrown" rule?

Answer

`Errors` represent conditions that are so abnormal the reliability of the whole environment is suspect and, hence, the code in the catch block may not run properly either.

Question

Why are `RuntimeExceptions` exempt from the "must be caught or declared to be thrown" rule?

Answer

`RuntimeExceptions` represent conditions that can be validated by the client.

To do

- Study Section 11.1–11.3 of the textbook.