Recitation 3

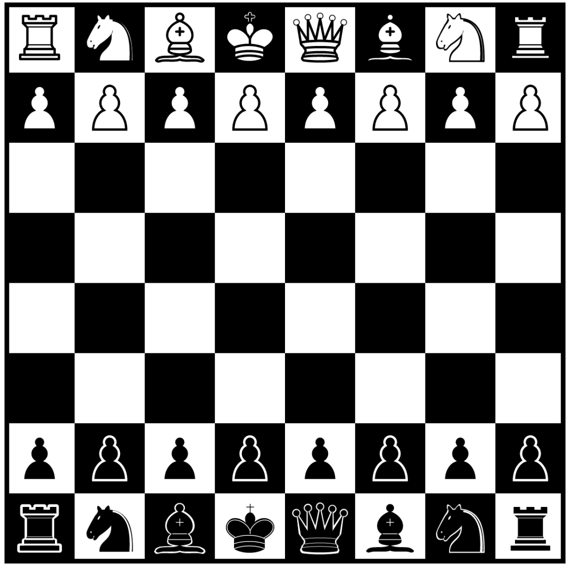
2D Arrays, Exceptions

2D arrays

Many applications have multidimensional structures:

- Matrix operations
- Collection of lists
- Board games (Chess, Checkers)
- Images (rows and columns of pixels)
- ...

$$\mathbf{A} = \begin{bmatrix} a & b \\ c & d \end{bmatrix}$$



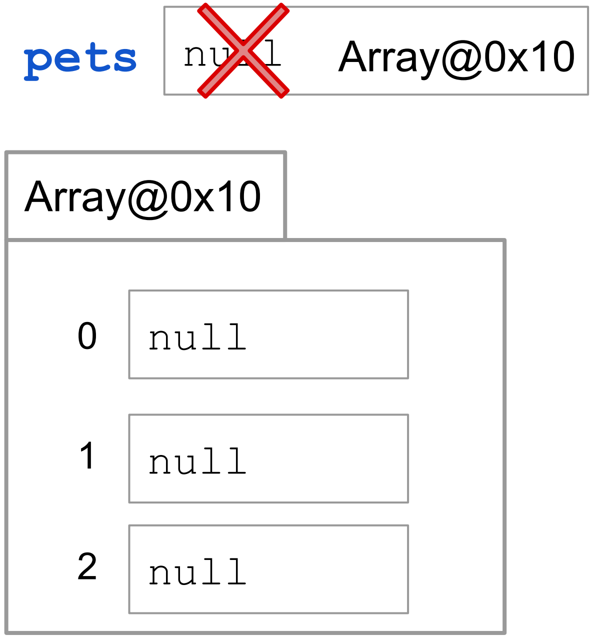
1D Array Review

```
Animal[] pets = new Animal[3];

    pets.length is 3
    pets[0] = new Animal();
    pets[0].walk();
```

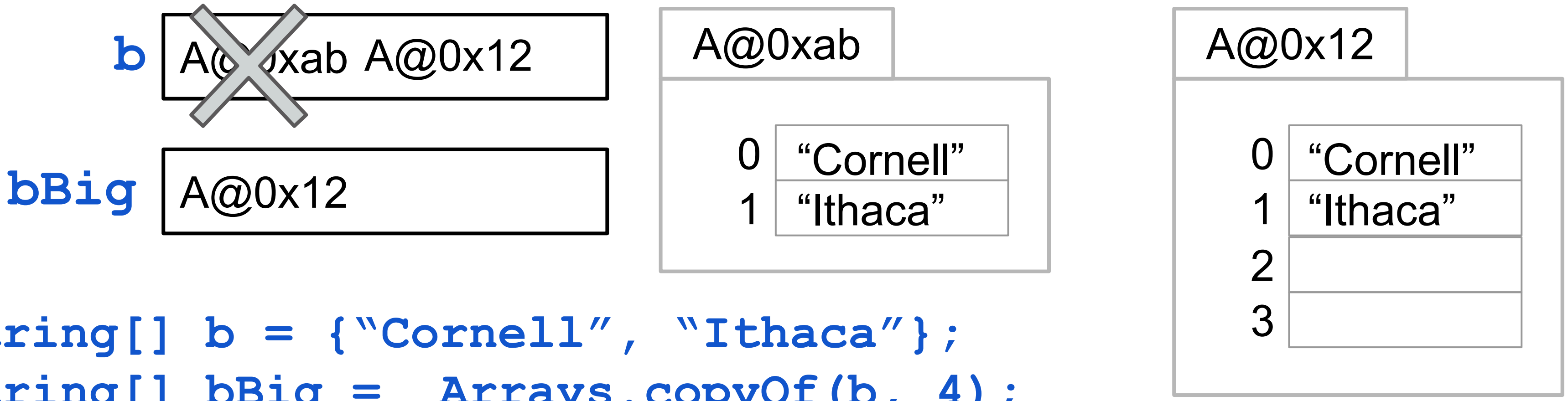
Why is the following illegal?

```
    pets[1] = new Object();
```



Java arrays vs Python lists

Java arrays do not change size!



```
String[] b = {"Cornell", "Ithaca"};
String[] bBig =  Arrays.copyOf(b, 4);
b = bBig;
```

Java array initialization

Instead of

```
    int[] c= new int[5];
    c[0]= 5; c[1]= 4; c[2]= 7; c[3]= 6; c[4]= 5;
```

Use an array initializer:

```
    int[] c= new int[] {5, 4, 7, 6, 5};
```

Note: The length of c is the number of values in the list.

Exercise 1: Looping over an array

```
/** Return index of occurrence number n of t in b.
 *  Precondition: n >= 1.
 *  Return -1 if not found. */
public static int get(int[] b, int n, int t) {
   ...
}
get(new int[]{2110, 0, 1, 2110, 2110}, 2, 2110);
```

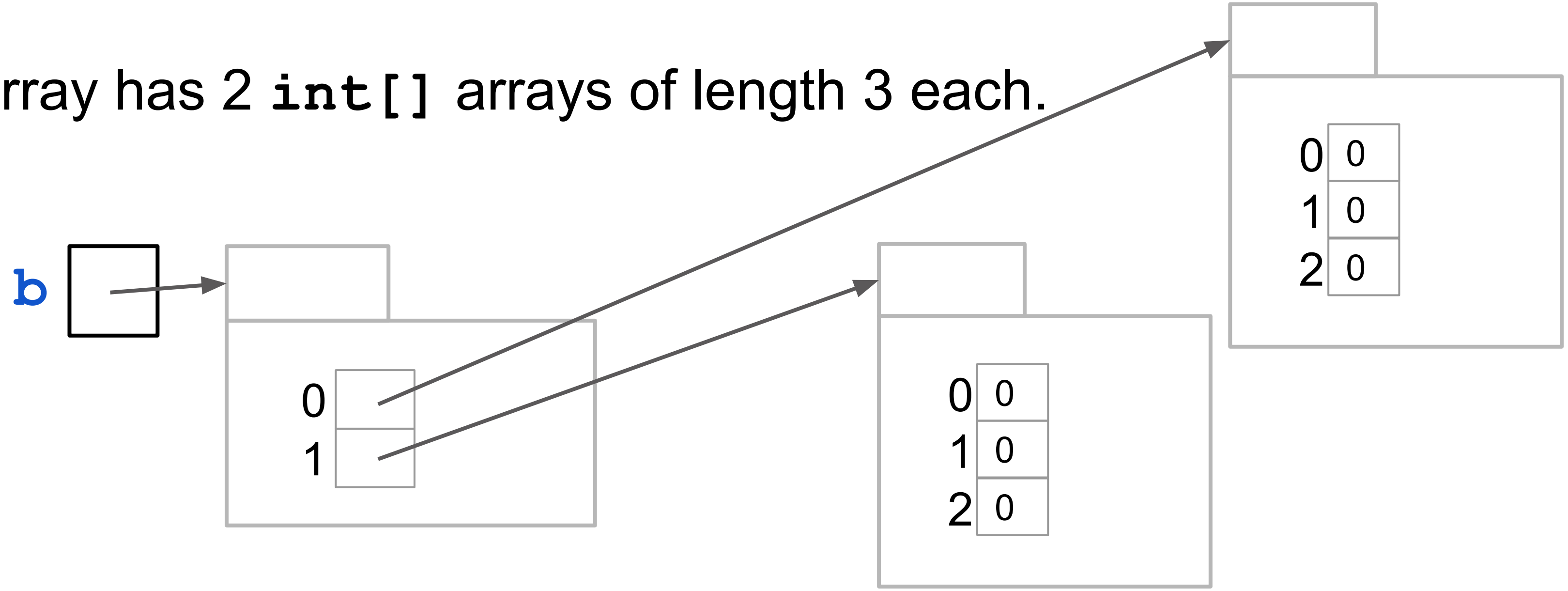
would return 3

2D arrays: An array of 1D arrays.

Java only has 1D arrays, whose elements can also be arrays.

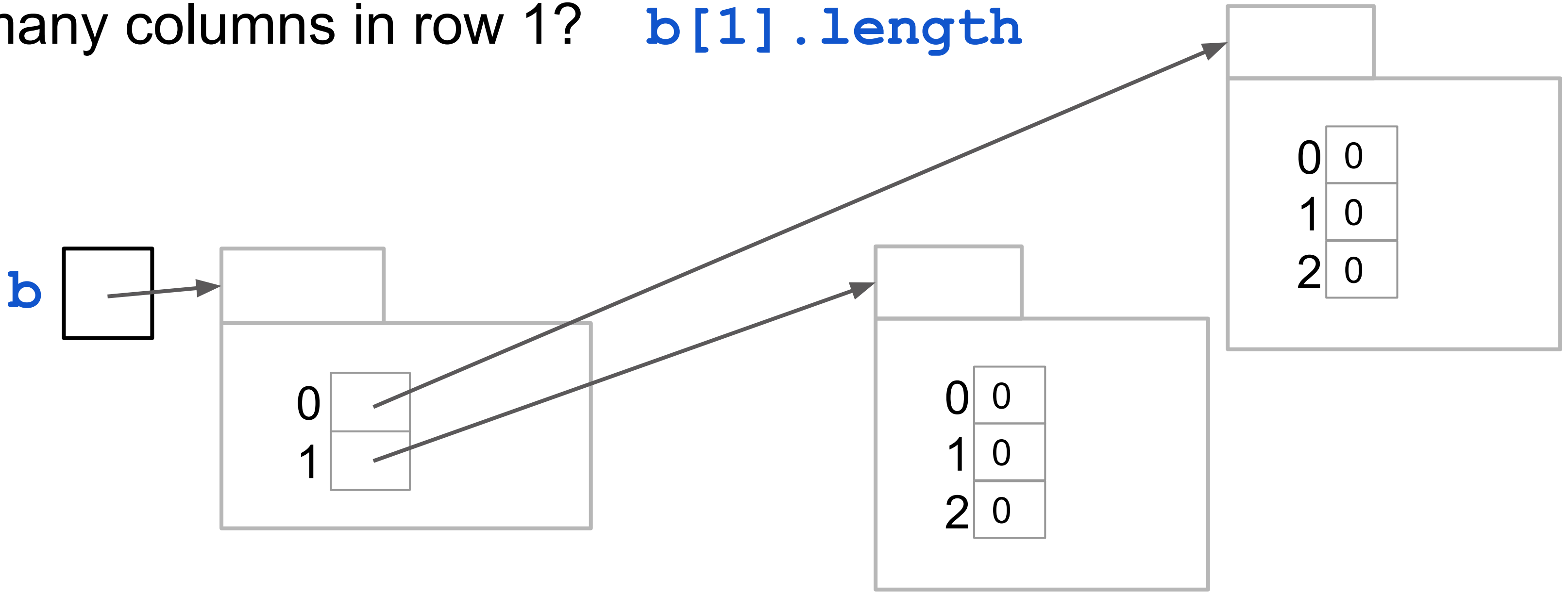
```
int[][] b = new int[2][3];
```

This array has 2 `int[]` arrays of length 3 each.



2D arrays: An array of 1D arrays.

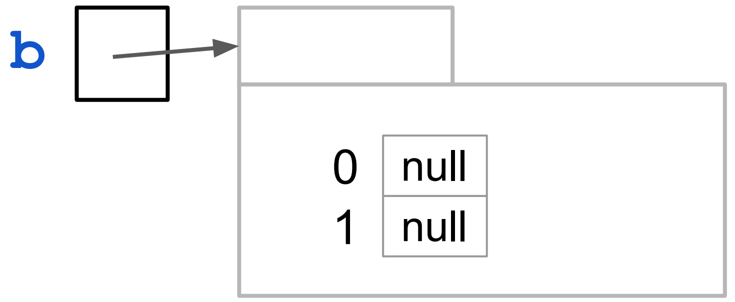
How many rows in `b`?	`b.length`
How many columns in row 0?	`b[0].length`
How many columns in row 1?	`b[1].length`



2D arrays: An array of 1D arrays.

```
int[][] b = new int[2][];
```

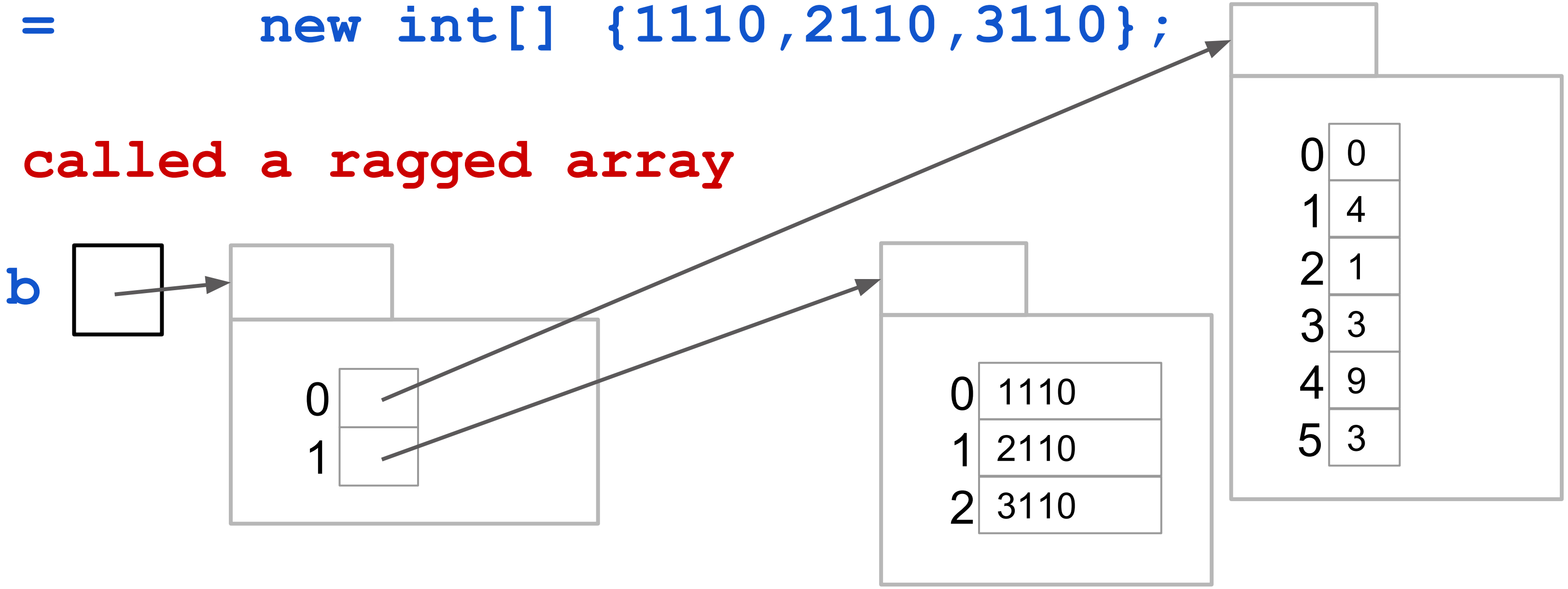
The elements of b are of type `int[]`.



2D arrays: An array of 1D arrays.

```
int[][] b = new int[2][];
b[0] =      new int[] {0,4,1,3,9,3};
b[1] =      new int[] {1110,2110,3110};
```

b is called a ragged array



Exercise 2: Transpose Matrix

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \qquad A^T = \begin{bmatrix} a_{11} & a_{21} & a_{31} \\ a_{12} & a_{22} & a_{32} \\ a_{13} & a_{23} & a_{33} \end{bmatrix}$$

$(A[i][j])^T$ is $A[j][i]$

Exceptions

Exceptions make your code crash

```
public static void main(String[] args) {
    System.out.println(args[0]);
}

public static void main(String[] args) {
    System.out.println(8 / 0);
}

public static void main(String[] args) {
    System.out.println(null.toString());
}
```

What could happen without exceptions?

```
public static double getAverage(double[] b) {
    double sum = 0;
    for (int i = 0; i < b.length; i++) {
        sum += b[i];
    }
    return sum / b.length;
}
```

If `b.length` is 0, what should be returned?

- Infinity
- “special” int: Integer.MAX_VALUE? 2110? 0?

The superclass of exceptions: Throwable

`class Throwable:`

- Superclass of Error and Exception
- Does the “crashing”
- Contains the constructors and methods
- `Throwable()`
- `Throwable(String)`

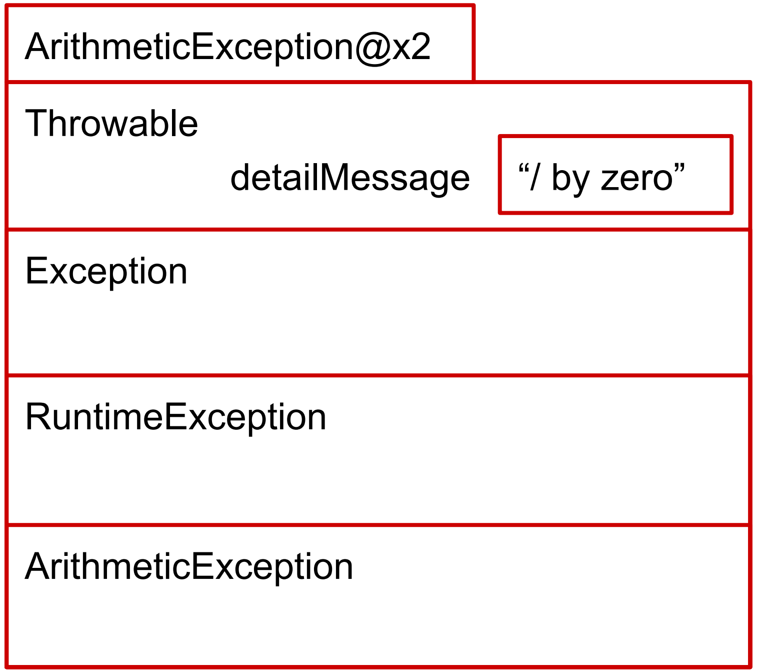
`class Error:`

- A very serious problem and should not be handled Example: StackOverflowError

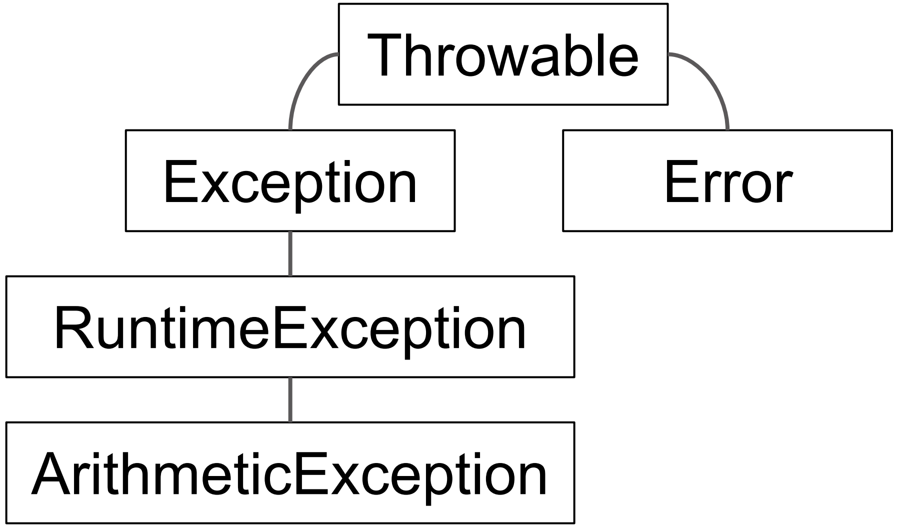
`class Exception:`

- Reasonable application might want to crash or handle the Exception in some way

A Throwable instance: ArithmeticException



There are so many exceptions we need to **organize** them.



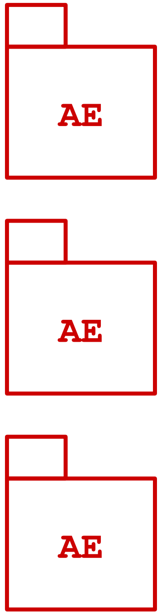
Bubbling up exceptions

Exceptions will bubble up the call stack and crash the methods that called it.

Method call: `first();`

Console:

```
Exception in thread "main"
  java.lang.ArithmeticException:
    at Ex.third(Ex.java:11)
    at Ex.second(Ex.java:7)
    at Ex.first(Ex.java:3)
```

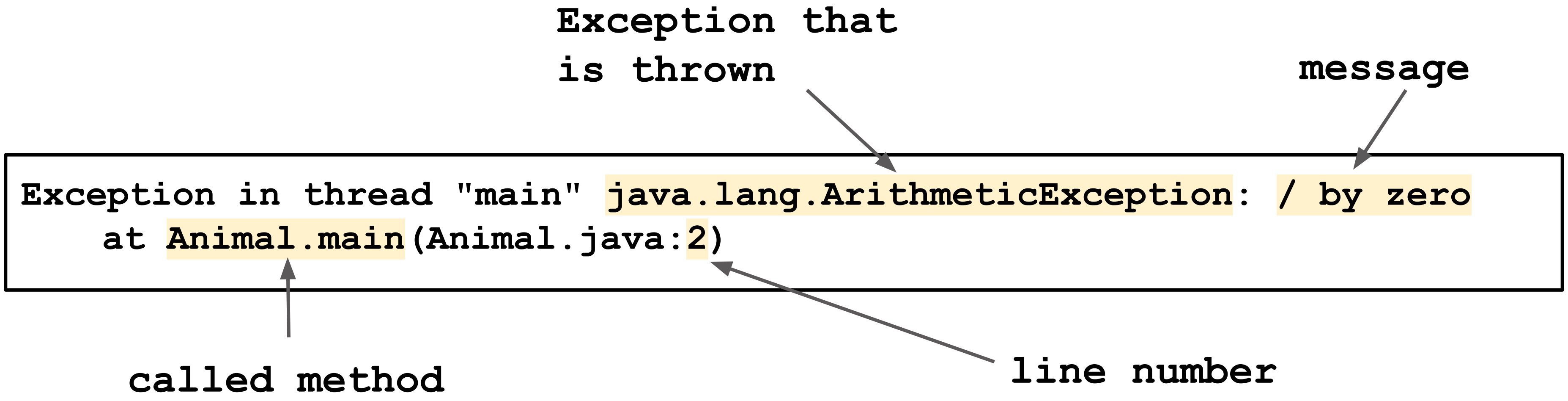


```
1  class Ex {
2       void first() {
3            second();
4       }
5
6       void second() {
7            third();
8       }
9
10      void third() {
11           int c = 5/0;
12       }
13 }
```

AE = ArithmeticException

Decoding the output from an exception

```java
1  public static void main(String[] args) {
2      int div = 5/0;
3  }
```



```
Exception in thread "main" java.lang.ArithmeticException: / by zero
    at Animal.main(Animal.java:2)
```

Try-catch blocks

An exception will bubble up the call stack and crash the methods that called it

… unless it is caught.

`catch` will handle any exceptions of type *Exception* (and its subclasses) that happened in the `try` block

```
Console:
 in
 error
```

```
class Ex {
    void first() {
        second();
    }
    void second() {
        try {
            System.out.println("in");
            third();
            System.out.println("out");
        } catch (Exception e){
            System.out.print("error");
        }
    }

    void third() {
        int c = 5/0;
    }                    ArithmeticException!
}
```

Exception Type

`throw` keyword: Forcing a crash

Why might I want to crash the application?

```
parseInt("42") -> 42
parseInt("Sid") -> ???
```

```
class Integer {
  /** Parse the string argument as a
    *  signed decimal integer. Throw a
    * NumberFormatException if not possible
*/
  public static int parseInt(String s){
    if (can't convert to int){
      throw new NumberFormatException();
    }

          ...
  }
}
```

Exercise 3: Illegal Arguments

Create `class Person` with two fields, `name` and `age`. Throw an `IllegalArgumentException` instead of having preconditions when given a `null` name or a non-positive age.

How to write an exception class

```
/** An instance is an exception */
public class OurException extends Exception {

    /** Constructor: an instance with message m*/
    public OurException(String m) {
        super(m);
    }

    /** Constructor: an instance with no message */
    public OurException() {
        super();
    }
}
```

throws clause for checked exceptions

```
/** Class to illustrate exception handling */
public class Ex {
    public static void main() {
        try { second(); } catch (OurException e) {}
    }
    public static void second() throws OurException {
        third();
    }
    public static void third() throws OurException {
        throw new OurException("mine");
    }
}
```

If you're interested in the "controversy", http://docs.oracle.com/javase/tutorial/essential/exceptions/runtime.html

Demo 1: Pythagorean Solver

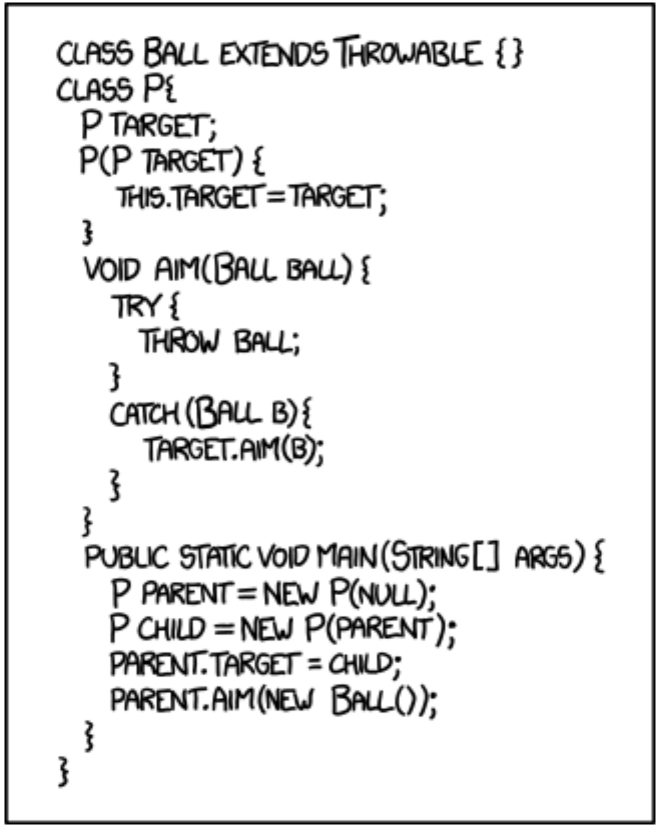
- Given *a* and *b*: solve for *c* in $a^2 + b^2 = c^2$
- Reads in input from keyboard
- Handles any exceptions

Exercise: Prelim Review

Analyze try-catch code to see what values will throw an exception

Key takeaways

1. Java arrays do not extend!
2. A 2D array is just an array of 1D arrays.
3. Thrown exceptions bubble up the call stack until they are handled by a try-catch block. In the system, the call of method main **is** in a try-catch statement, and its catch block prints out information about the thrown exception.



```
CLASS BALL EXTENDS THROWABLE {}
CLASS P{
  P TARGET;
  P(P TARGET) {
     THIS.TARGET=TARGET;
  }
  VOID AIM(BALL BALL) {
    TRY {
      THROW BALL;
    }
    CATCH (BALL B){
      TARGET.AIM(B);
    }
  }
  PUBLIC STATIC VOID MAIN(STRING[] ARGS) {
    P PARENT = NEW P(NULL);
    P CHILD = NEW P(PARENT);
    PARENT.TARGET = CHILD;
    PARENT.AIM(NEW BALL());
  }
}
```

http://xkcd.com/1188/