CS2110–2111 Fall 2017. David Gries

These slides lead you simply through OO Java, rarely use unexplained terms.

Examples, rather than formal definitions, are the norm.

Pages 2..3 are an index into the slides, helping you easily find what you want.

Many slides point to pages in the CS2110 text for more info.

Use the slides as a quick reference.

The ppt version, instead of the pdf version, is best, because you can do the Slide Show and see the animations, helping you to best read/understand each slide.

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Index

Strong versus weak typing

Matlab, Python weakly typed: A variable can contain any value —5, then "a string", then an array, …

Java strongly typed: Must *declare* a variable with its type before you can use it. It can contain only values of that type

Type: Set of values together with operations on them

Type **int**: $-2^{31} .. 2^{31}-1$

values: –2147483648, –2147483647, …, –3, –2, –1,
0, 1, 2, 3, 4, 5, …, 2147483646, 2147483647

operations: +, –, *, /, %, unary –

b % c : *remainder* when b is divided by c. 67 % 60 = 7

Type: Set of values together with operations on them

Primitive types

Integer types:	**byte** 1 byte	**short** 2 bytes	**int** 4 bytes	**long** 8 bytes	usual operators
Real:	**float** 4 bytes	**double** 8 bytes		–22.51E6 24.9	usual operators
Character:	**char** 2 bytes		**'V'** **'$'**	**'\n'**	no operators
Logical:	**boolean** 1 bit		**true** **false**		and && or || not !

Single quote

Inside back cover, A-6..7

Casting among types

(**int**) 3.2   casts **double** value 3.2 to an **int**

any number type

any number expression

narrow $\xrightarrow{\text{may be automatic cast}}$ wider

byte   short   int   long   float   double

$\xleftarrow[\text{must be explicit cast, may truncate}]{}$

char is a number type: (**int**) **'V'**   (**char**) 86

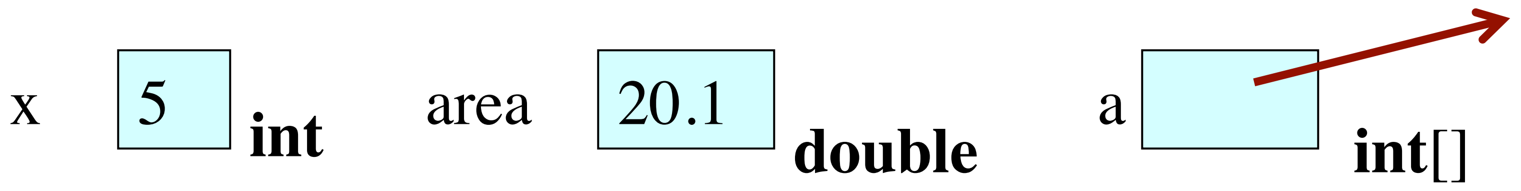
Unicode representation: 86   **'V'**

Page A-9, inside back cover

Basic variable declaration

Declaration of a variable: gives name of variable, type of value it can contain

int x;	Declaration of x, can contain an **int** value
double area;	Declaration of area, can contain a **double** value
int[] a;	Declaration of a, can contain a pointer to an **int** array. We explain arrays later



Page A-6

Assignment

<variable> = <expression> ;

Type of <variable> must be same as or wider than type of <expression>

~~x= area;~~

Illegal because type of x (**int**) is narrower than type of area (**double**)

x= (**int**) area;

But you can cast the expression

x $\boxed{5}$ **int** area $\boxed{20.0}$ **double**

Page A-6

Two aspects of a programming language

- Organization – structure
- Procedural —commands to do something

Example: Recipe book

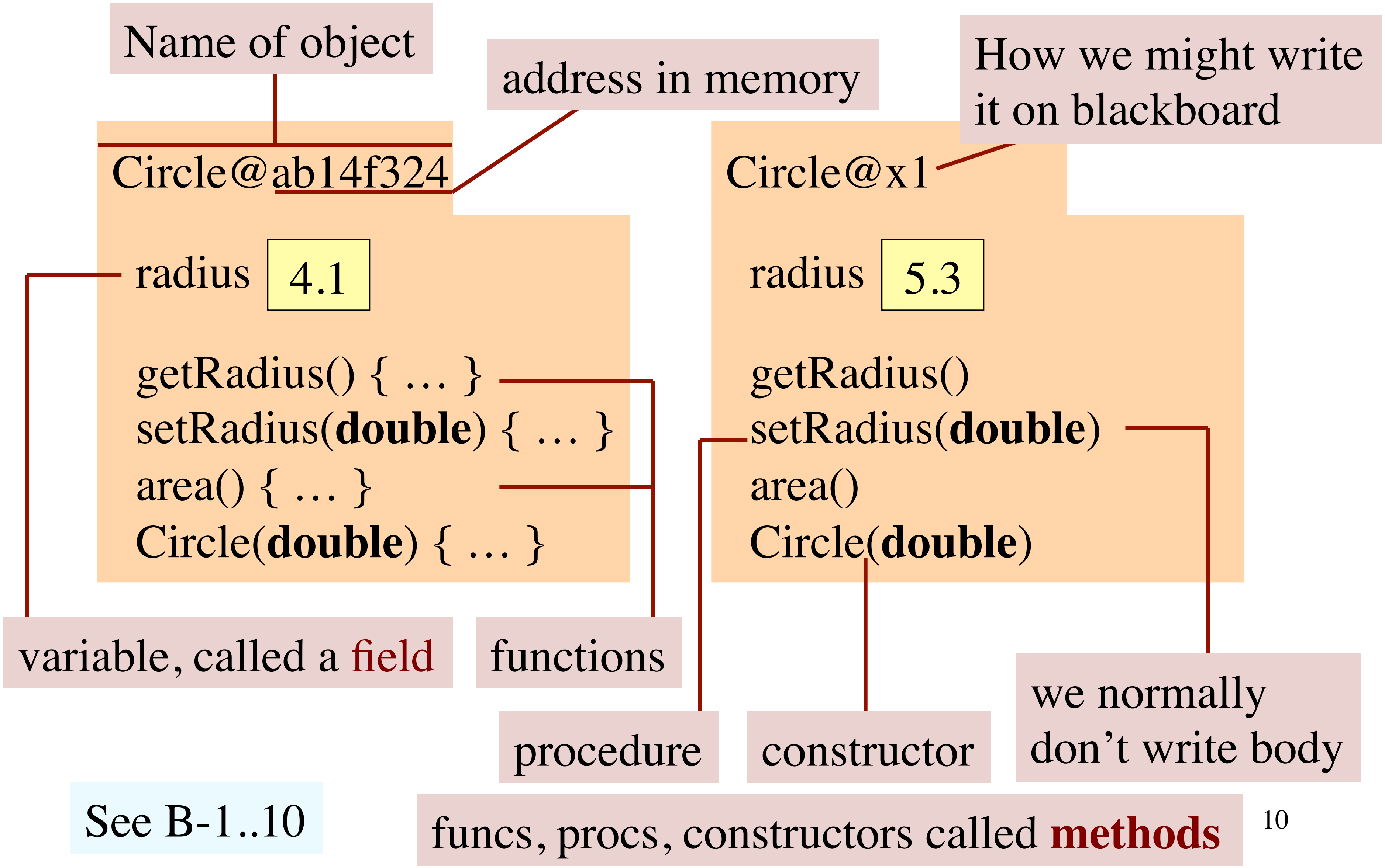
- Organization: Several options; here is one:
  - Appetizers
    - list of recipes
  - Beverages
    - list of recipes
  - Soups
    - list of recipes
  - …
- Procedural: Recipe: sequence of instructions to carry out

structural
objects
classes
interface
inheritance

procedural
assignment
return
if-statement
iteration (loops)
function call
recursion

miscellaneous
GUIs
exception handling
Testing/debugging

Two objects of class Circle



See B-1..10

Declaration of class Circle

Multi-line comment starts with /* ends with */

```
/** An instance (object) represents a circle */
public class Circle {



}
```

Precede every class with a comment

Put declarations of fields, methods in class body: { … }

Put class declaration in file Circle.java

public: Code everywhere can refer to Circle. Called **access modifier**

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Declaration of field radius, in body of class Circle

One-line comment starts with // ends at end of line

private double radius; // radius of circle. radius >= 0

Always put a definition of a field and constraints on it.
Collection of field definitions and constraints is called the **class invariant**

Access modifier private: can refer to radius only in code in Circle. Usually, fields are **private**

Page B-5..6

Declaration of functions in class Circle

Called a **getter**:
it gets value of a field

Always specify method, saying precisely what it does

```
/** return radius of this Circle */
public double getRadius() {
    return radius;
}

/** return area of Circle */
public double area() {
    return Math.PI*radius*radius;
}
```

Function header syntax: close to Python/Matlab, but return type **double** needed to say what type of value is returned

public so functions can be called from anywhere

Execution of
  return expression;
terminates execution of body and returns the value of the expression. The function call is done.

Page B-6..10

Declaration of procedure in Circle

Called a **setter**:
It sets value in a field

```
/** Set radius to r.
    Precondition: r >= 0. */
public void setRadius(double r) {

    assert r >= 0;

    radius= r;
  }
```

Tells user not to call method with negative radius

Procedure: doesn't return val. Instead of return type, use **void**

Declaration of parameter r. Parameter: var declared within ( ) of a method header

The call setRadius(-1); falsifies class invariant because radius should be ≥ 0. User's fault! Precondition told user not to do it.
Make method better by putting in **assert** statement.
Execution of **assert** e; aborts program with error message if **boolean** expression e is false.

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Declaration of constructor Circle

A constructor is called when a new object is created (we show this soon).
Purpose of constructor: initialize fields of new object so that the class invariant is true.

```
/** Constructor: instance with radius r.
    Precondition: r >= 0 */

public Circle(double r) {
    assert r >= 0;
    radius= r;
}
```

Constructor:

1. no return type
2. no **void**
3. Name of constructor is name of class

No constructor declared in a class? Java puts this one in, which does nothing, but very fast: **public** <class-name>() {}

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Creating objects

New-expression: **new** <constructor-call>

Example: **new** Circle(4.1)

Evaluation is 3 steps:

1. Create new object of the given class, giving it a name.
   Fields have default values (e.g. 0 for **int**)
2. Execute <constructor-call> —in example, Circle(4.1)
3. Give as value of the expression the name of new object.

Circle c; c | Circle@ab14f324

c= **new** Circle(4.1);

Evaluate new expression:

1. Create object
2. Execute constructor call
3. Value of exp: Circle@ab14f324

Finish assignment

Circle@ab14f324

radius | 4.1

getRadius() { … }

setRadius(**double**) { … }

area() { … }

Circle(**double**) { … }

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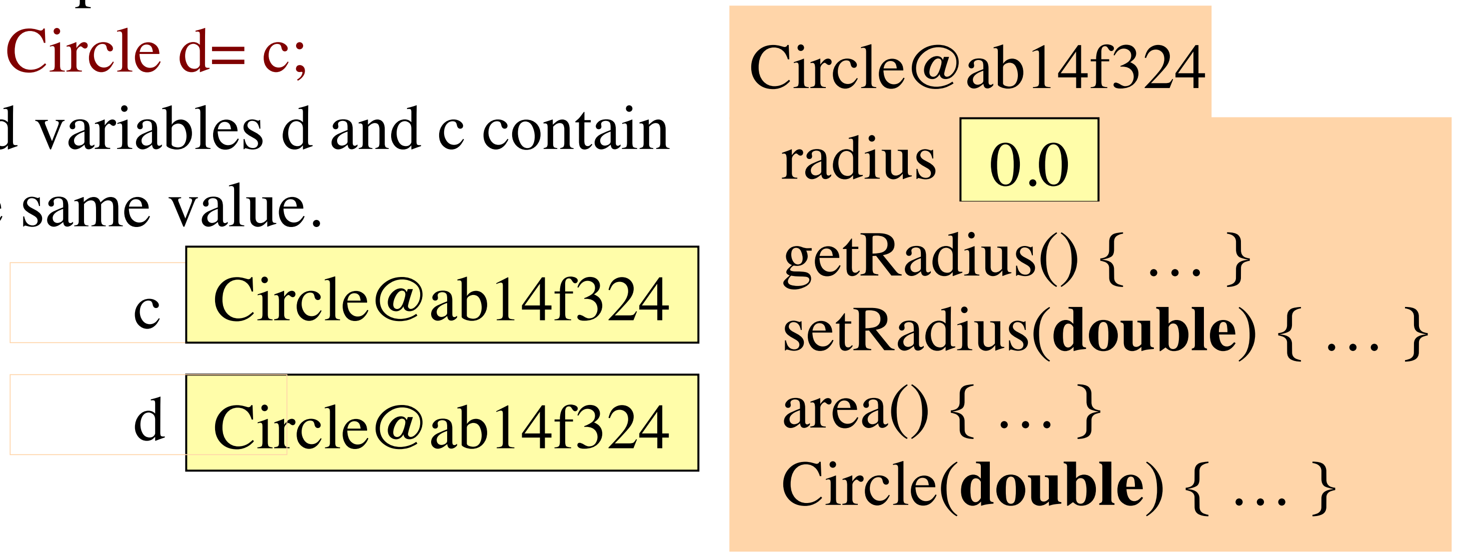
Consequences

1. Circle can be used as a type, with set of values: **null** and names of objects of class Circle
2. Objects are accessed indirectly. A variable of type Circle contains not the object but a pointer to it (i.e. its name)
3. More than one variable can contain the name of the same object. Called ***aliasing***
   Example: Execute
   ```
   Circle d= c;
   ```
   and variables d and c contain the same value.



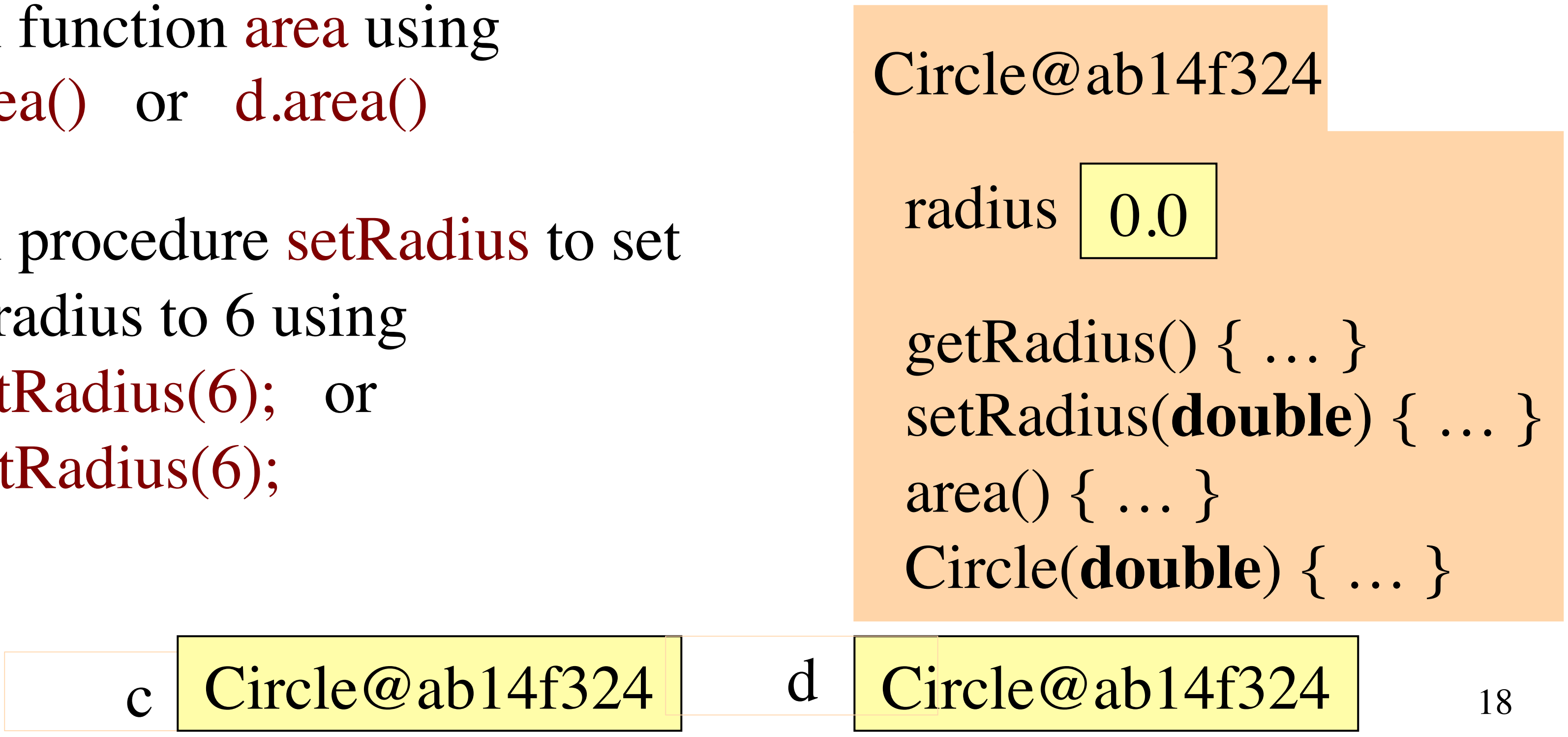
Referencing components of c

Suppose c and d contain the name Circle@ab14f324
—they contain pointers to the object.

If field radius is **public**, use c.radius to reference it
Examples: c.radius = c.radius + 1; d.radius= c.radius + 3;

Call function area using
c.area() or d.area()

Call procedure setRadius to set the radius to 6 using
c.setRadius(6); or
d.setRadius(6);

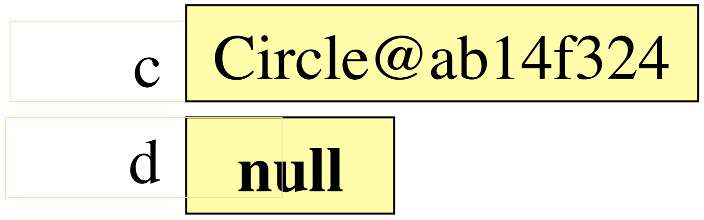


Value null

Value **null** denotes the absence of an object name or pointer

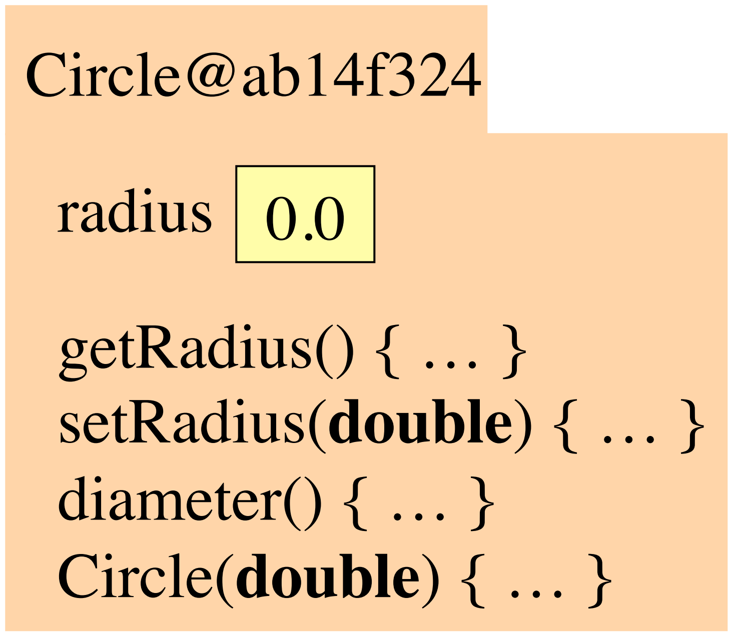
c= **new** Circle(0);

d= **null;**



c.area() has value 0.0

d.area() gives a “null-pointer exception” and program execution aborts (stops)



Packages

package: set of related classes that appear in the same directory on your hard drive.

You will not write your own package right now, but you will use packages

http://docs.oracle.com/javase/7/docs/api/

Contains specifications of all packages that come with Java. Use it often.

Package java.io contains classes used for input/output. To be able to use these classes, put this statement before class declaration: **import** java.io.*;

* Means import all classes in package

Package java.lang does not need to be imported.
Has many useful classes: Math, String, wrapper classes …

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Static variables and methods

static: component does *not* go in objects. Only one copy of it

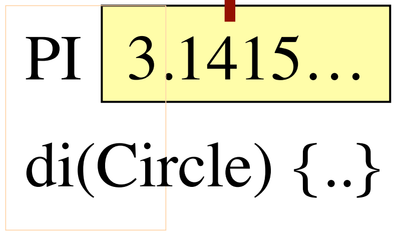
```
public class Circle {
    declarations as before

    public static final double PI= 3.141592653589793;

    /** return area of c */
    public static double di(Circle c) {
        return Math.PI * c.radius * c.radius;
    }
}
```

final: PI can't be changed
It's a **constant**

Here's PI and di



To use static PI and di:
Circle.PI
Circle.di(**new** Circle(5))

Circle@x1
Components as before, but not PI, di

Circle@x2
Components as before, but not PI, di

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Overloading

Possible to have two or more methods with same name

```
/** instance represents a rectangle */
public class Rectangle {
    private double sideH, sideV; // Horiz, vert side lengths

    /** Constr: instance with horiz, vert side lengths sh, sv */
    public Rectangle(double sh, double sv) {
        sideH= sh; sideV= sv;
    }

    /** Constructor: square with side length s */
    public Rectangle(double s) {
        sideH= s; sideV= s;
    }
    …
}
```

Lists of parameter types must differ in some way

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Use of this

```
public class Circle {
   private double radius;

   /** Constr: instance with radius radius*/
   public Circle(double radius) {
       radius= radius;
   }
```

Doesn't work because both occurrences of radius refer to parameter

this evaluates to the name of the object in which is appears

Memorize this!

```
/** Constr: instance with radius radius*/
public Circle(double radius) {
       this.radius= radius;
}
```

This works

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Avoid duplication: Call one constructor from other

Can save a lot if there are lots of fields

```
/** Constr: instance with horiz, vert sidelengths sh, sv */
public Rectangle(double sh, double sv) { … }
```

```
/** Constr: square with side length s */
public Rectangle(double s) {
    sideH= s; sideV= s;
}
```

First alternative

```
/** Constr: square with side length s */
public Rectangle(double s) {
    this (s, s);
}
```

Better alternative

Call on another constructor in same class: use **this** instead of class name

this(…) must be first statement in constructor body

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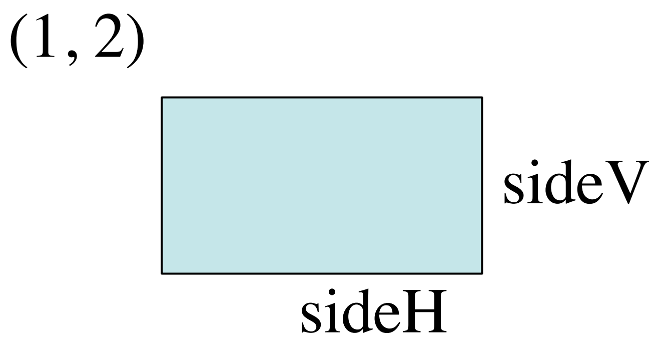
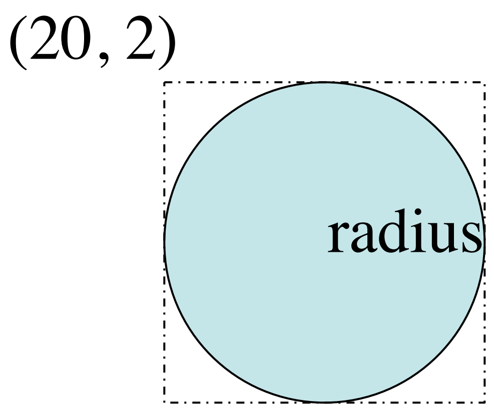
Subclasses

Situation. We will have classes Circle, Rectangle, others:
Circle: field radius: radius of circle
Rectangle: sideH, sideV: horizontal, vertical side lengths.

Want to place each object in the plane: A point (x, y) gives top-left of a rectangle or top-left of "bounding box" of a circle.

One way: add fields x and y to Circle, Rectangle, other classes for shapes. Not good: too much duplication of effort.
Better solution: **use subclasses**





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```
/** An instance represents a shape at a point in the plane */
public class Shape {
    private double x, y; // top-left point of bounding box
    /** Constructor: a Shape at point (x1, y1) */
    public Shape (double x1, double y1) {
        x= x1;  y= y1;
    }
    /** return x-coordinate of bounding box*/
    public double getX() {
        return x;
    }
    /** return y-coordinate of bounding box*/
    public double getY() {
        return y;
    }
}
```

Class Shape

Subclass and superclass

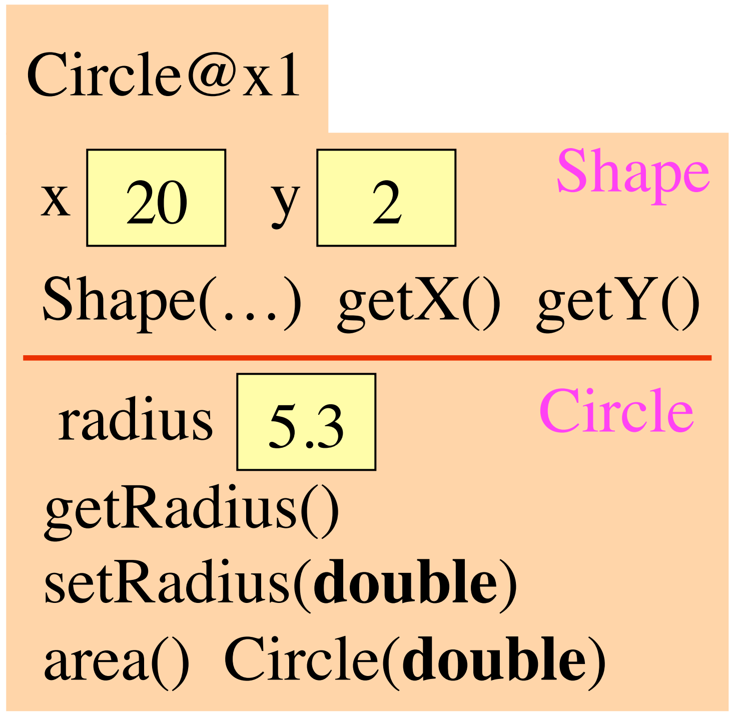
```
/** An instance represents circle at point in plane */
public class Circle extends Shape {
    all declarations as before
}
```

Circle is subclass of Shape
Shape is superclass of Circle

Circle **inherits** all components of Shape: they are in objects of class Circle.

put Shape components above

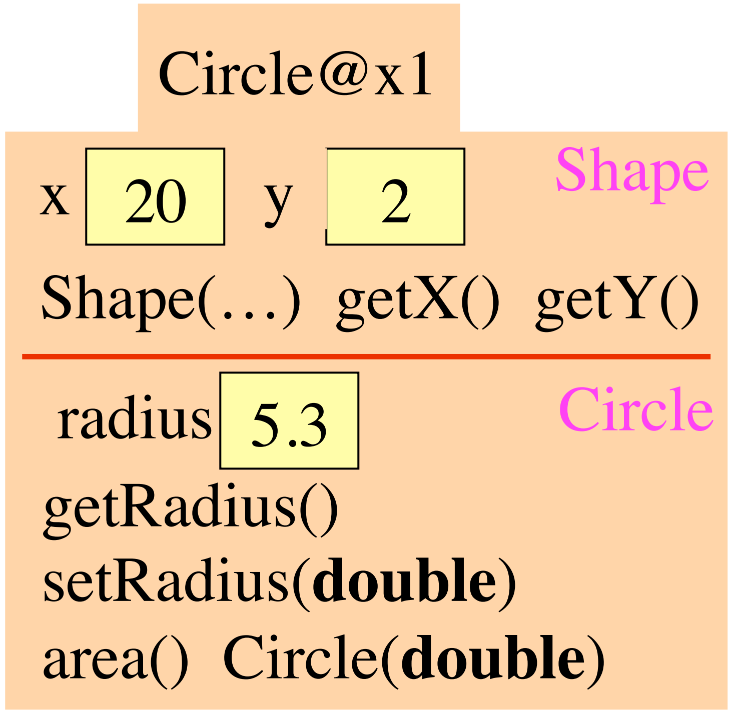
put Circle components below (Circle is subclass)



Modify Circle constructor

```
/** An instance represents circle at point in plane */
public class Circle extends Shape {
    all declarations as before except
    /** Constructor: new Circle of radius r at (x, y)*/
    public Circle(double r, double x, double y) {
        super (x, y);
        radius= r;
    }
}
```

how to call constructor in superclass



Principle: initialize superclass fields first, then subclass fields.
Implementation: Start constructor with call on superclass constructor

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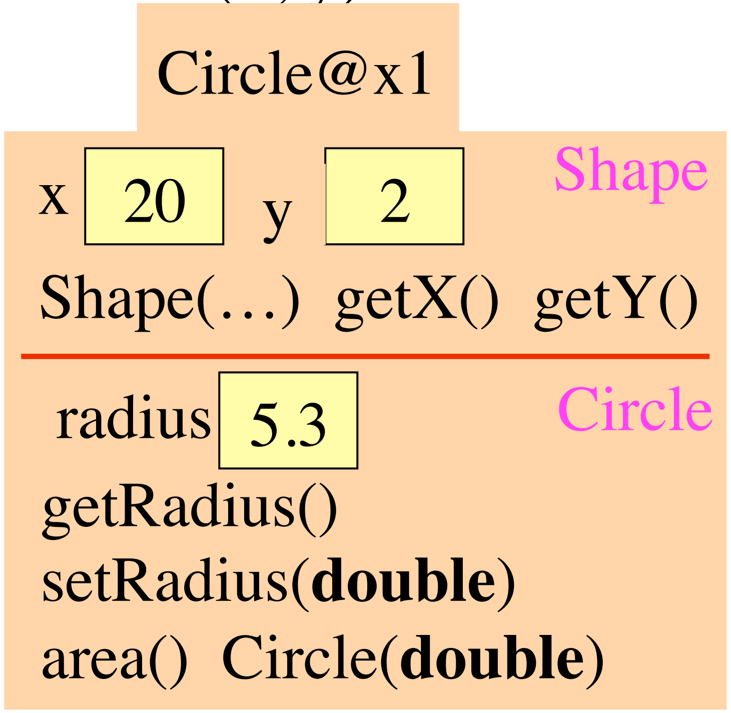
Default Constructor Call

```
/** An instance represents circle at point in plane */
public class Circle extends Shape {
    all declarations as before except
    /** Constructor: new Circle of radius r at (x, y)*/
    public Circle(double, r, x, y) {
            radius= r;
    }
}
```



Rule. Constructor body must begin with call on another constructor. If missing, Java inserts this:

super();

Consequence: object always has a constructor, but it may not be one you want. In this case, error: Shape doesn't have Shape()

Object: superest class of them all

Class doesn't explicitly extend another one? It automatically extends class Object. Among other components, Object contains:

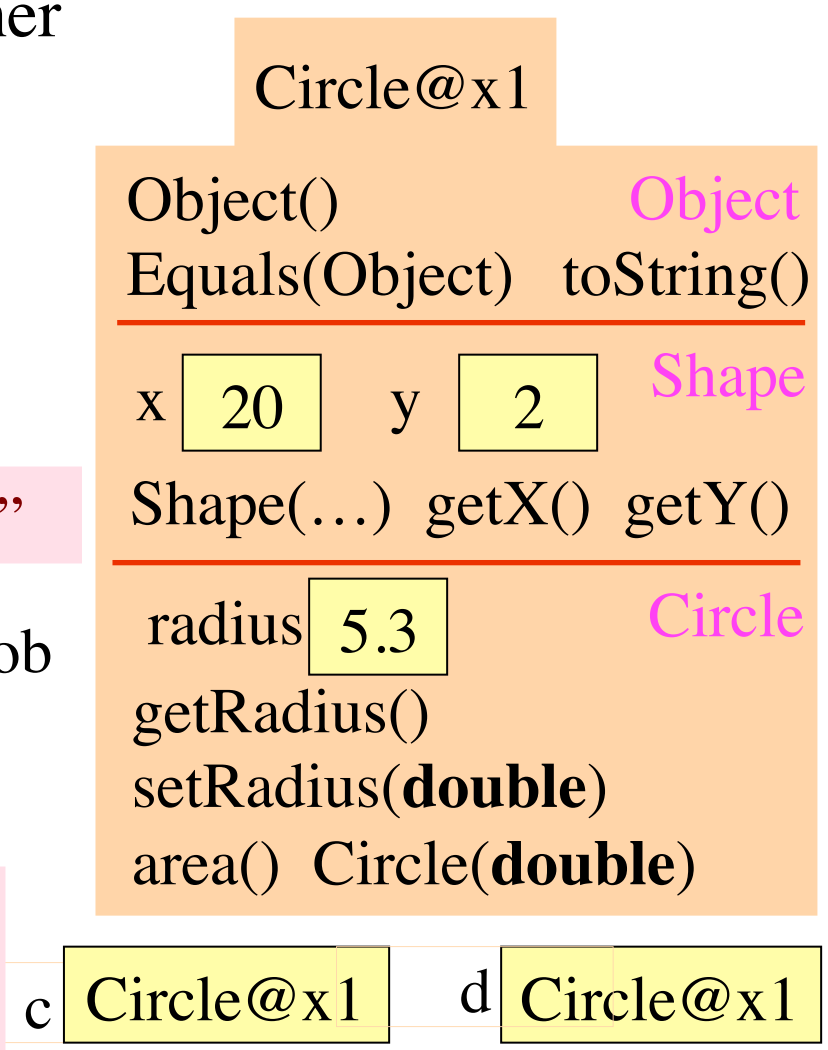
Constructor: **public** Object() {}

/** return name of object */
public String toString()

c.toString() is "Circle@x1"

/** return value of "this object and ob are same", i.e. of **this** == ob */
public boolean equals(Object ob)

c.equals(d) is **true**
c.equals(**new** Circle(…)) is **false**



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Example of overriding: toString

Override an inherited method: define it in subclass

Put in class Shape

```
/** return representation of this */
public @Override String toString() {
   return "(" + x + ", " + y + ")";
}
```

c.toString() calls overriding method, one nearest to bottom of object

c.toString() is "(20, 2)"

Do not override a field! Useless. Called shadowing. Not used in 2110

Don't need @Override. Helps catch errors. Use it.

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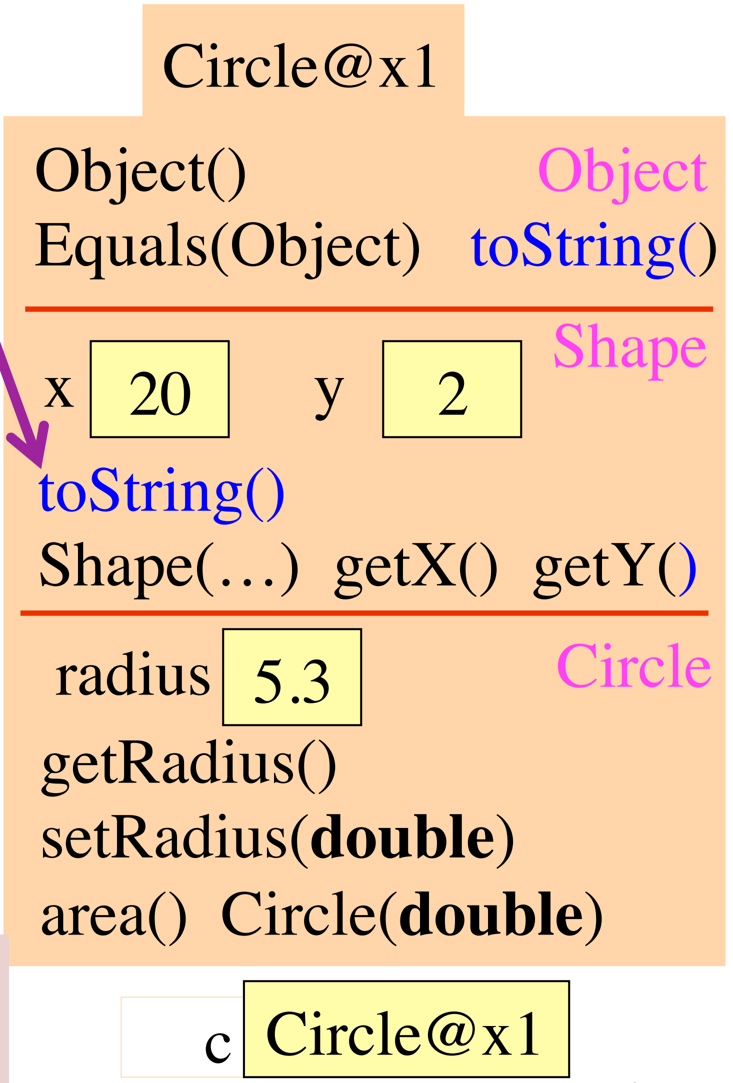


toString() is special in Java

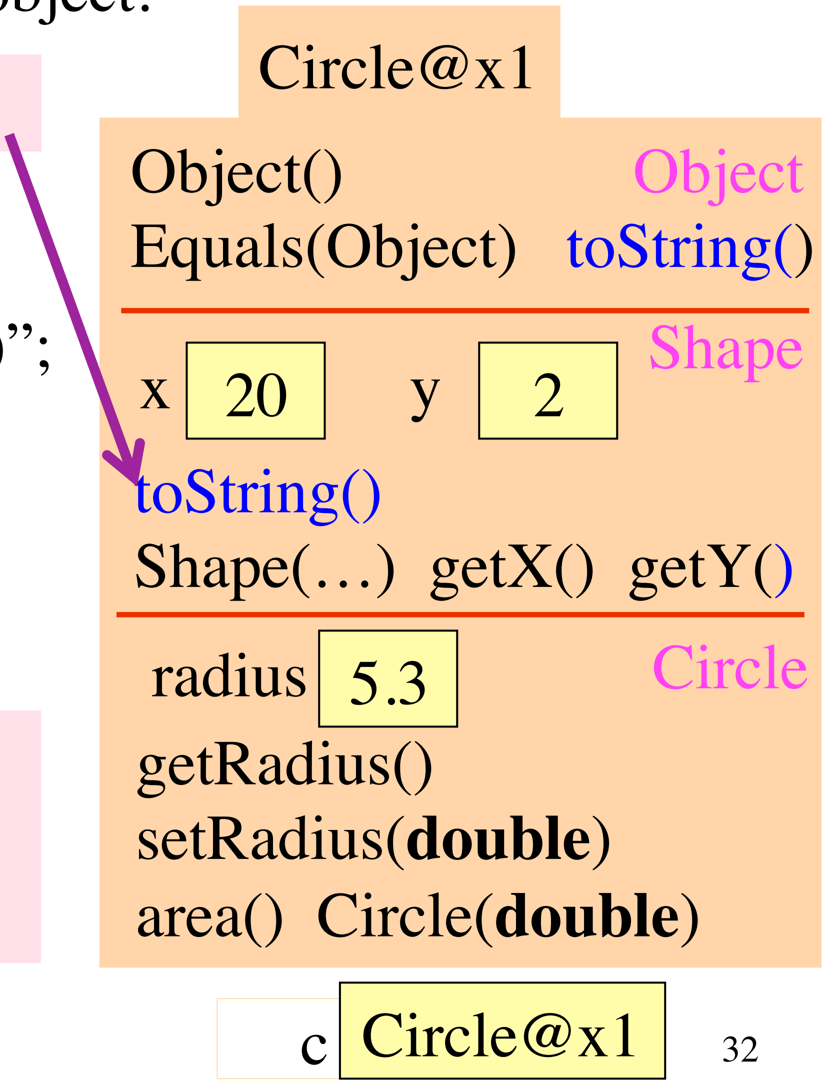
Good debugging tool: Define toString in every class you write, give values of (some of) fields of object.

Put in class Shape

```
/** return representation of this */
public String toString() {
   return "(" + x + ", " + y + ")";
}
```

In some places where String is expected but class name appears, Java automatically calls toString.

System.out.println("c is: " + c);
prints
"c is (20, 2)"



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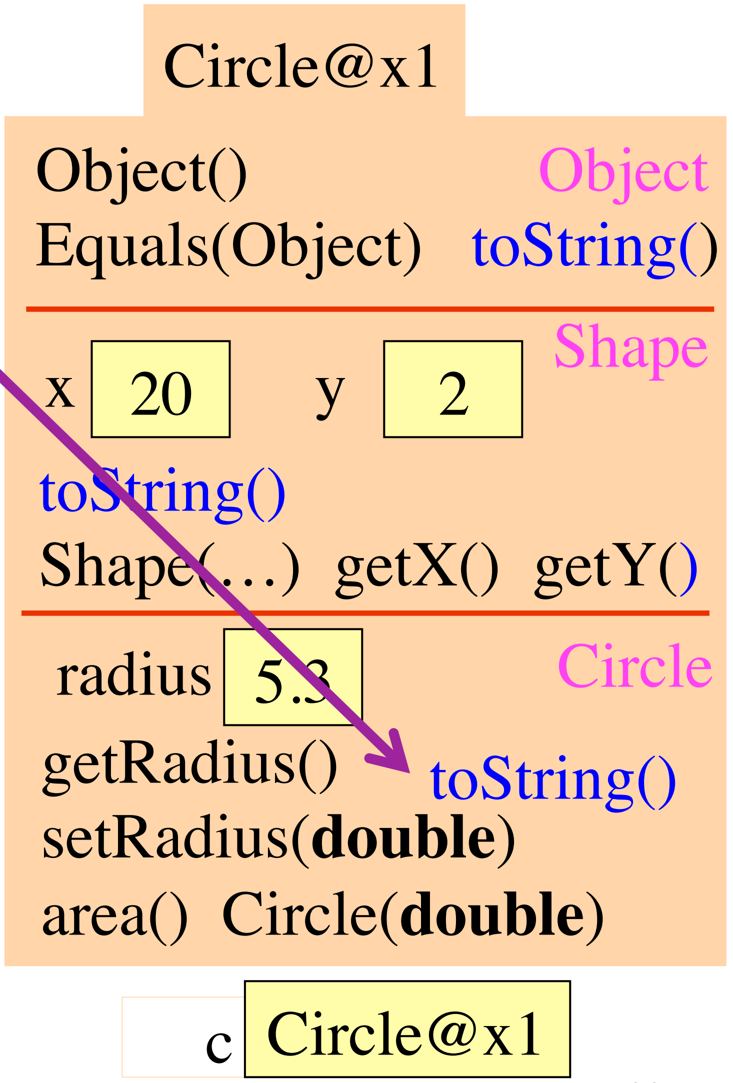
Calling overridden method

Within method of class, use **super**.
to call overridden method —one in a higher partition, in some superclass

Put in class Circle

```
/** return representation of this */
public @Override String toString() {
    return "Circle radius " +
        radius + " at " +
        super.toString();
}
```

c.toString() is
"Circle radius 5.3 at (20, 3)"



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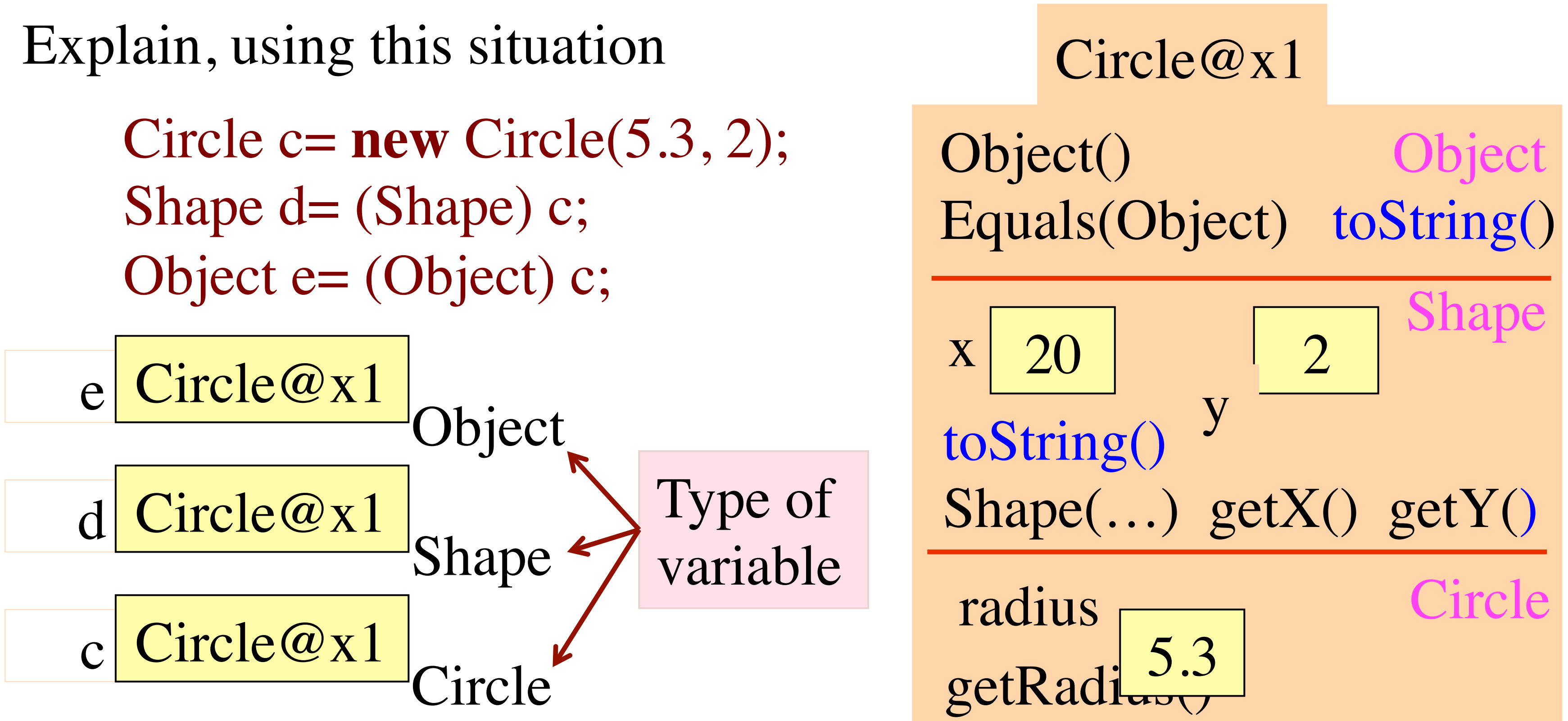
Casting among class-types

(**int**) (5.0 / 3)   // cast value of expression from **double** to **int**

(Shape) c   // cast value in c from Circle to Shape

Explain, using this situation

```
Circle c= new Circle(5.3, 2);
Shape d= (Shape) c;
Object e= (Object) c;
```



Class casting: costs nothing at runtime, just provides different perspective on object.

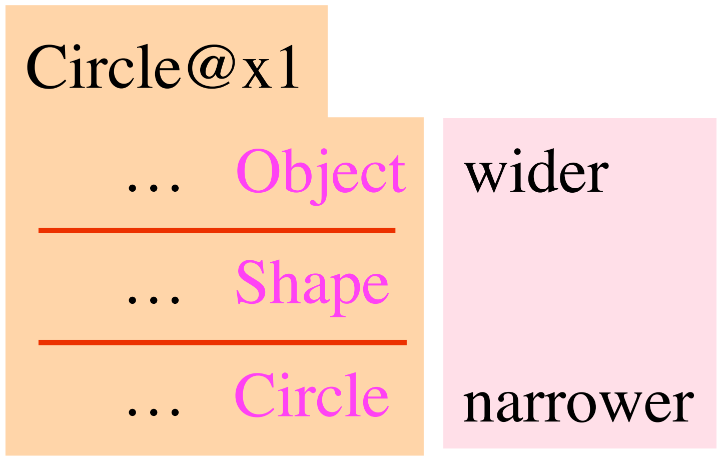
Page C-23, but not good

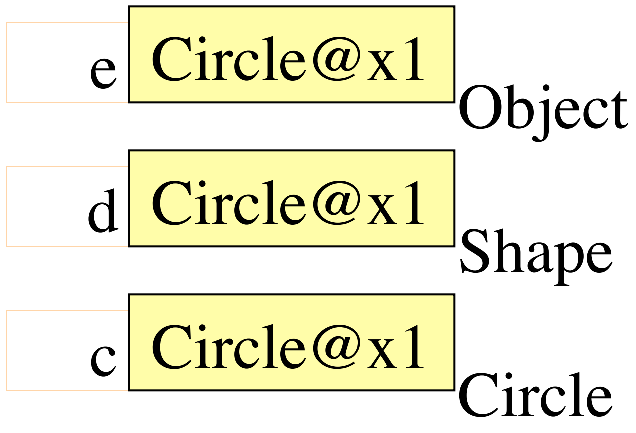
Casting among class-types

Important: Object Circle@x1 has partitions for Object, Shape, Circle. Can be cast only to these three classes.

Circle@x1 **is a** Circle, Shape, Object

Cast (String) c is illegal because Circle@x1 is not a String —does not have a partition for String





(Object) c widening cast, may be done automatically

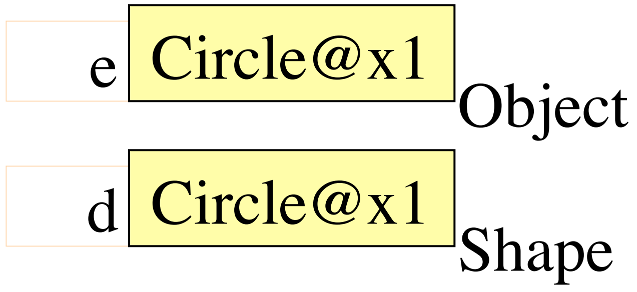
(Circle) e narrowing cast, must be done explicitly

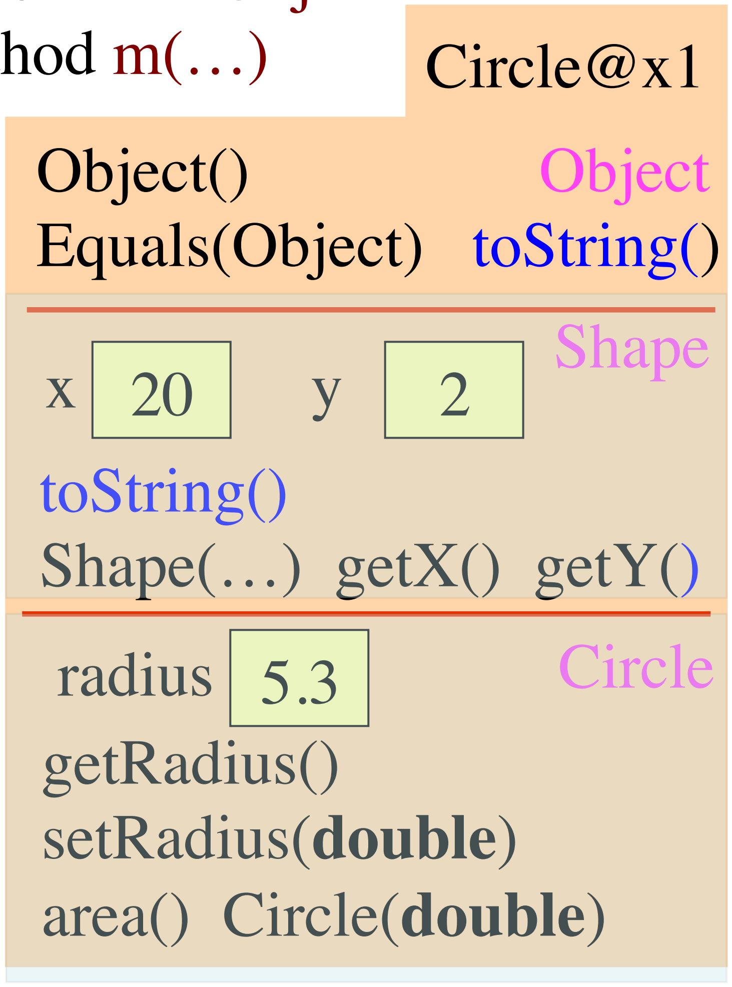
Page C-23, but not good

Different perspectives of object

e looks at Circle@x1 from perspective of class Object.
e.m(…) **syntactically legal** only if method m(…)
is in Object partition.
Example: e.toString() legal
e.getX() illegal.

d looks at Circle@x1 from perspective
Of Shape.
d.m(…) syntactically legal only if
m(…) is in Shape or Object partition.
Example: e.area() illegal





Page C-23, not good

More on the perspective

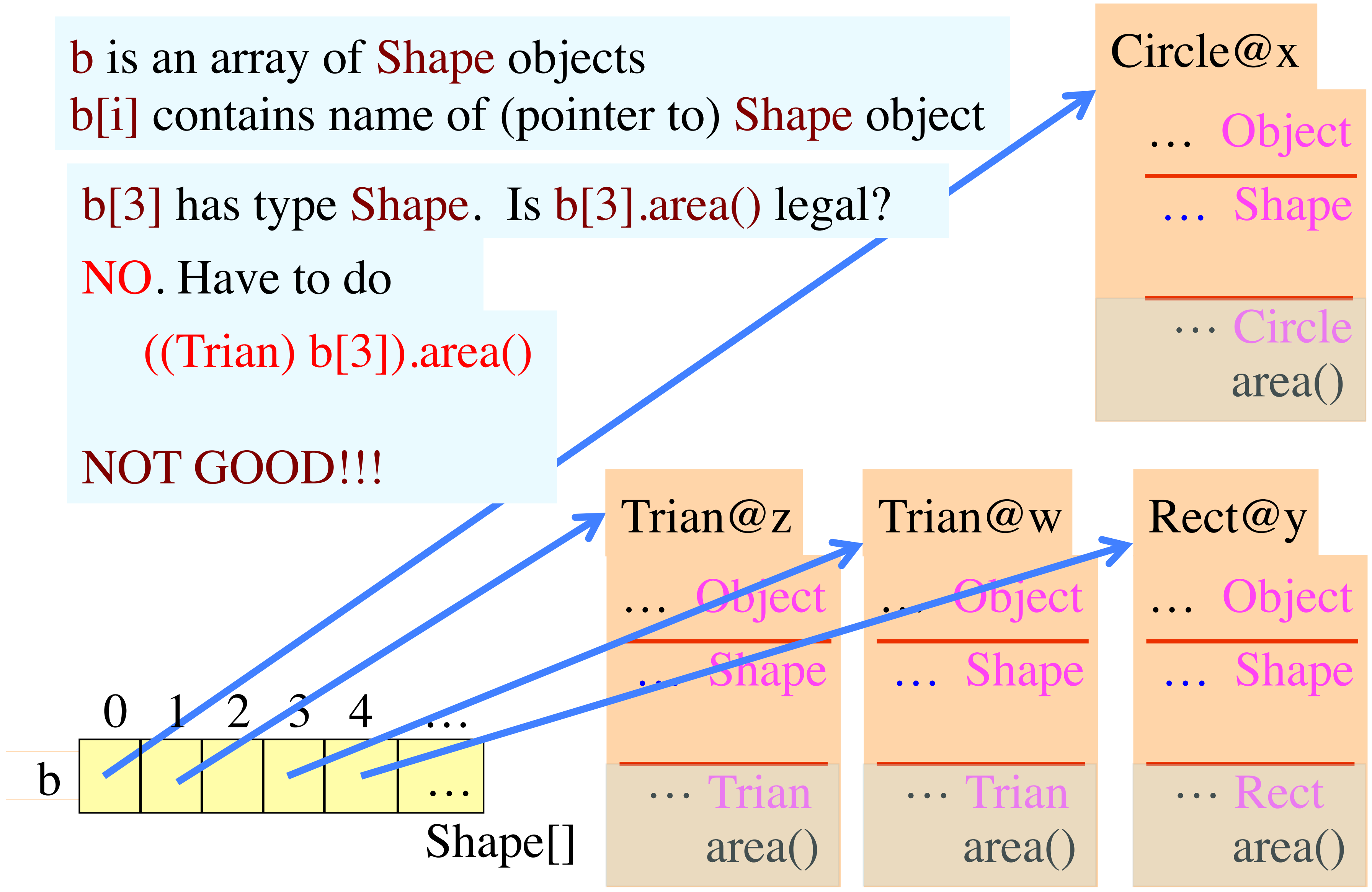
b is an array of Shape objects
b[i] contains name of (pointer to) Shape object

b[3] has type Shape. Is b[3].area() legal?

NO. Have to do

((Trian) b[3]).area()

NOT GOOD!!!



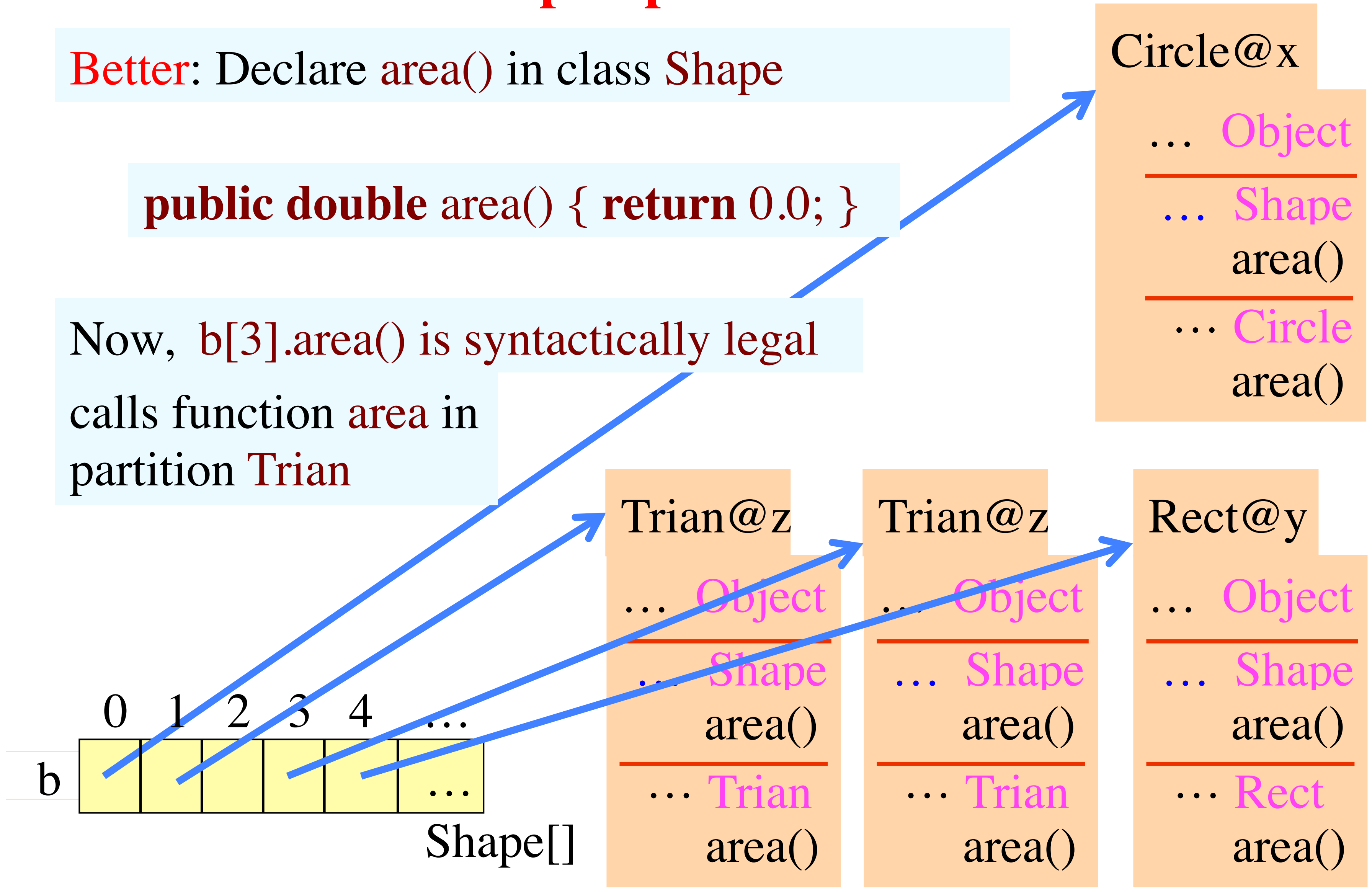
More on the perspective

Better: Declare area() in class Shape

```
public double area() { return 0.0; }
```

Now, b[3].area() is syntactically legal

calls function area in partition Trian

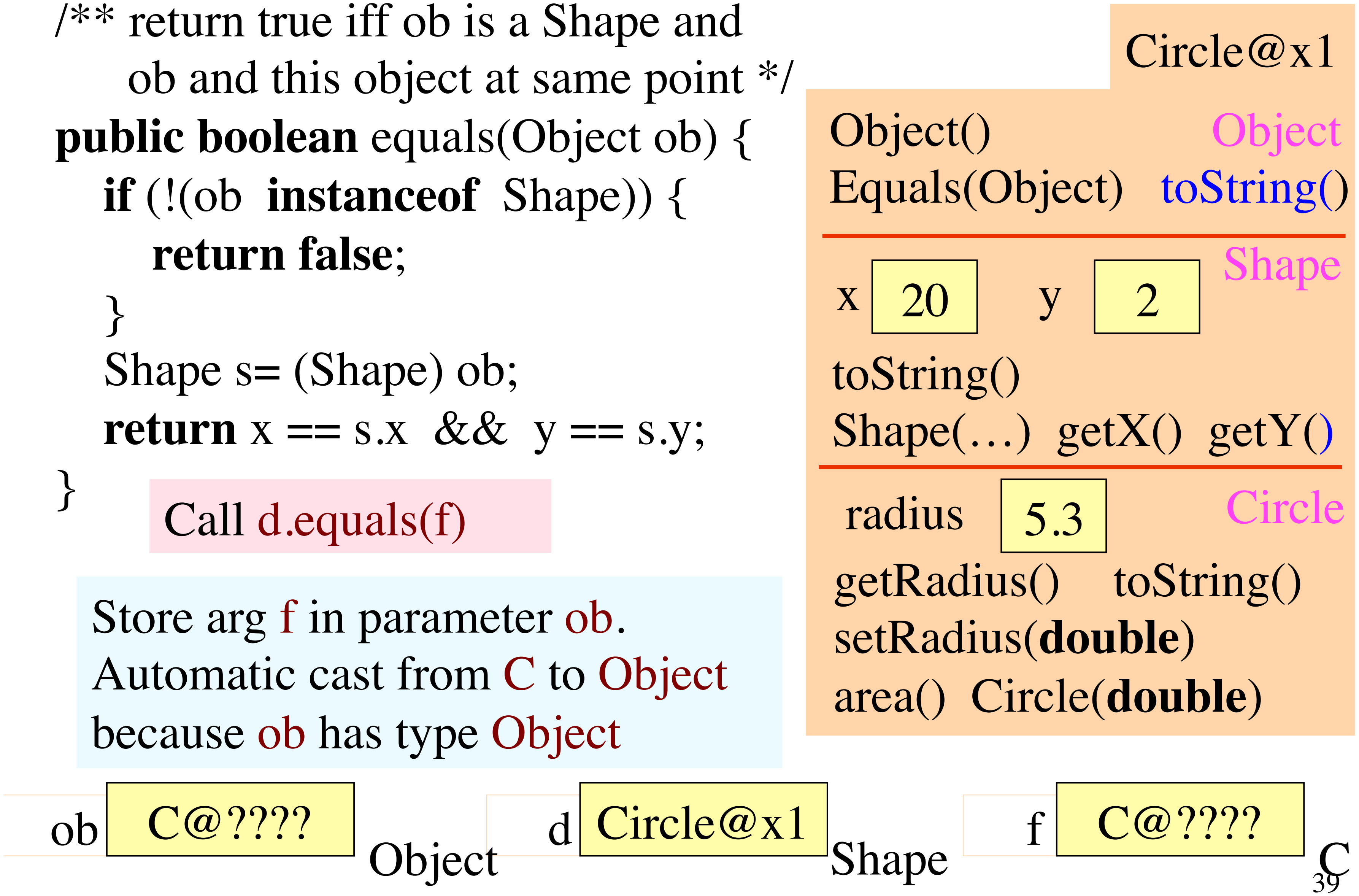


E.g. overriding function equals (an automatic cast)

```
/** return true iff ob is a Shape and
    ob and this object at same point */
public boolean equals(Object ob) {
   if (!(ob  instanceof  Shape)) {
      return false;
   }
   Shape s= (Shape) ob;
   return x == s.x  &&  y == s.y;
}
```

Call d.equals(f)

Store arg f in parameter ob.
Automatic cast from C to Object
because ob has type Object



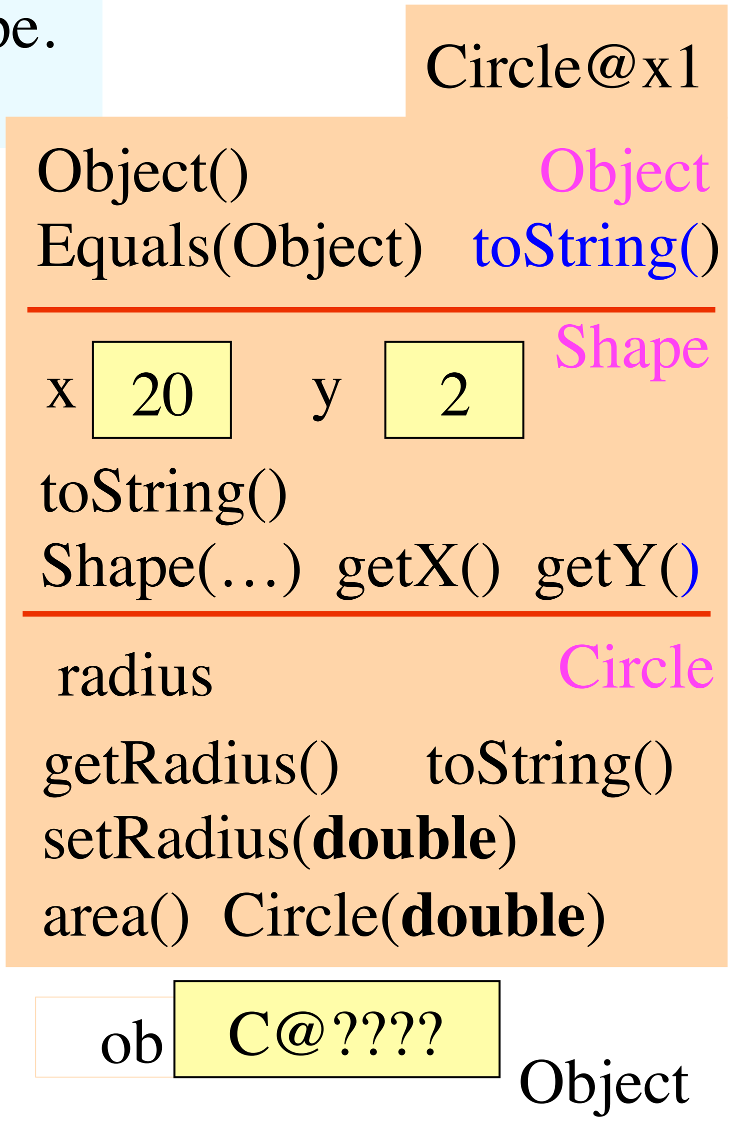
E.g. overriding function equals (instanceof)

Spec says return false if ob not a Shape.
That's what if-statement does

```
/** return true iff ob is a Shape and
     ob and this object at same point */
public boolean equals(Object ob) {
   if (!(ob  instanceof  Shape)) {
      return false;
   }
   …
}
```

New operator: instanceof

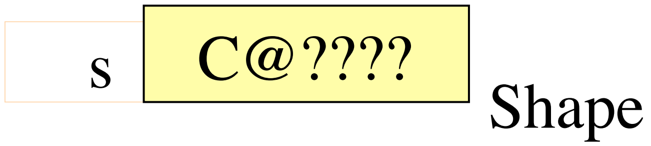
c **instanceof** C true iff object
c has a partition for class C

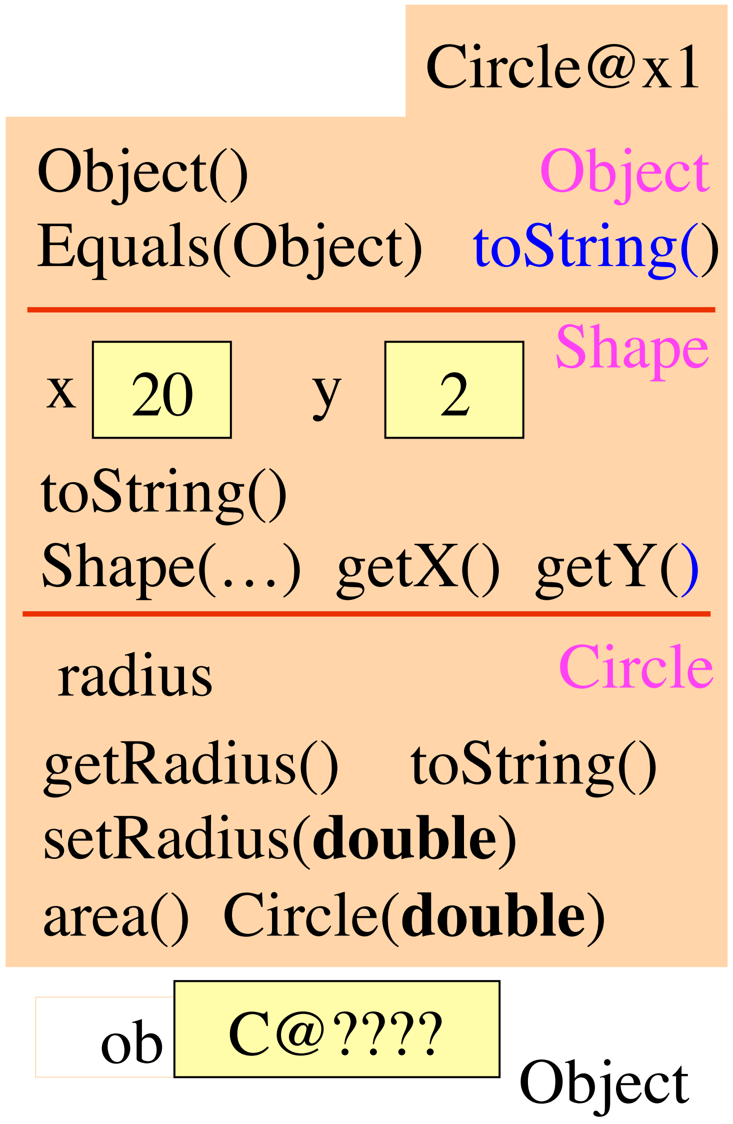


E.g. overriding function equals (need for cast)

```
/** return true iff ob is a Shape and
      ob and this object at same point */
public boolean equals(Object ob) {
    if (!(ob  instanceof  Shape)) {
        return false;
    }
    Shape s= (Shape) ob;
    return x == s ob  &&  y == ob.y;
}
```

Need to test ob.x, ob.y —these are illegal! So cast ob to Shape. Then test



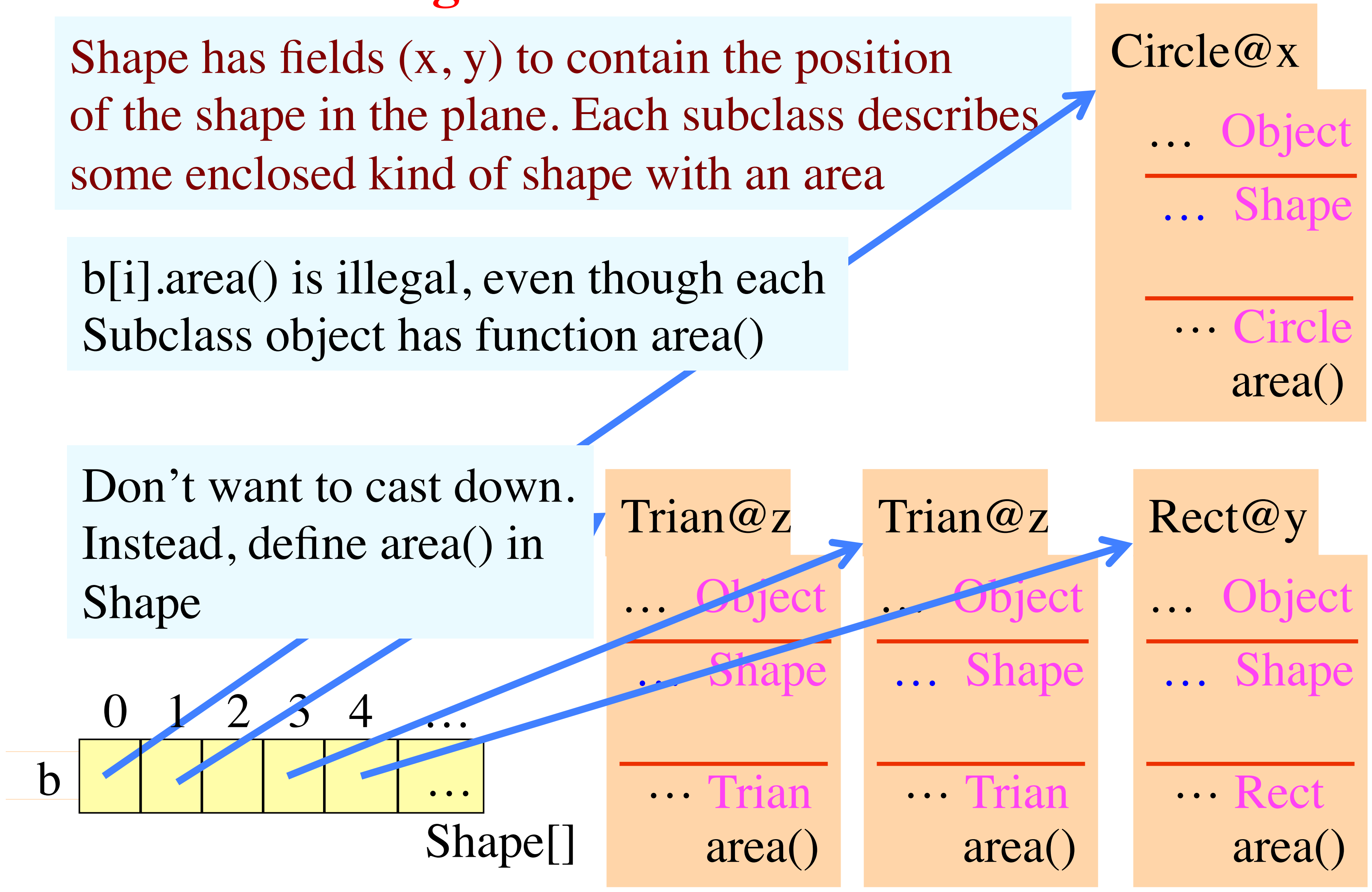


Motivating abstract classes

Shape has fields (x, y) to contain the position of the shape in the plane. Each subclass describes some enclosed kind of shape with an area

b[i].area() is illegal, even though each Subclass object has function area()

Don’t want to cast down. Instead, define area() in Shape



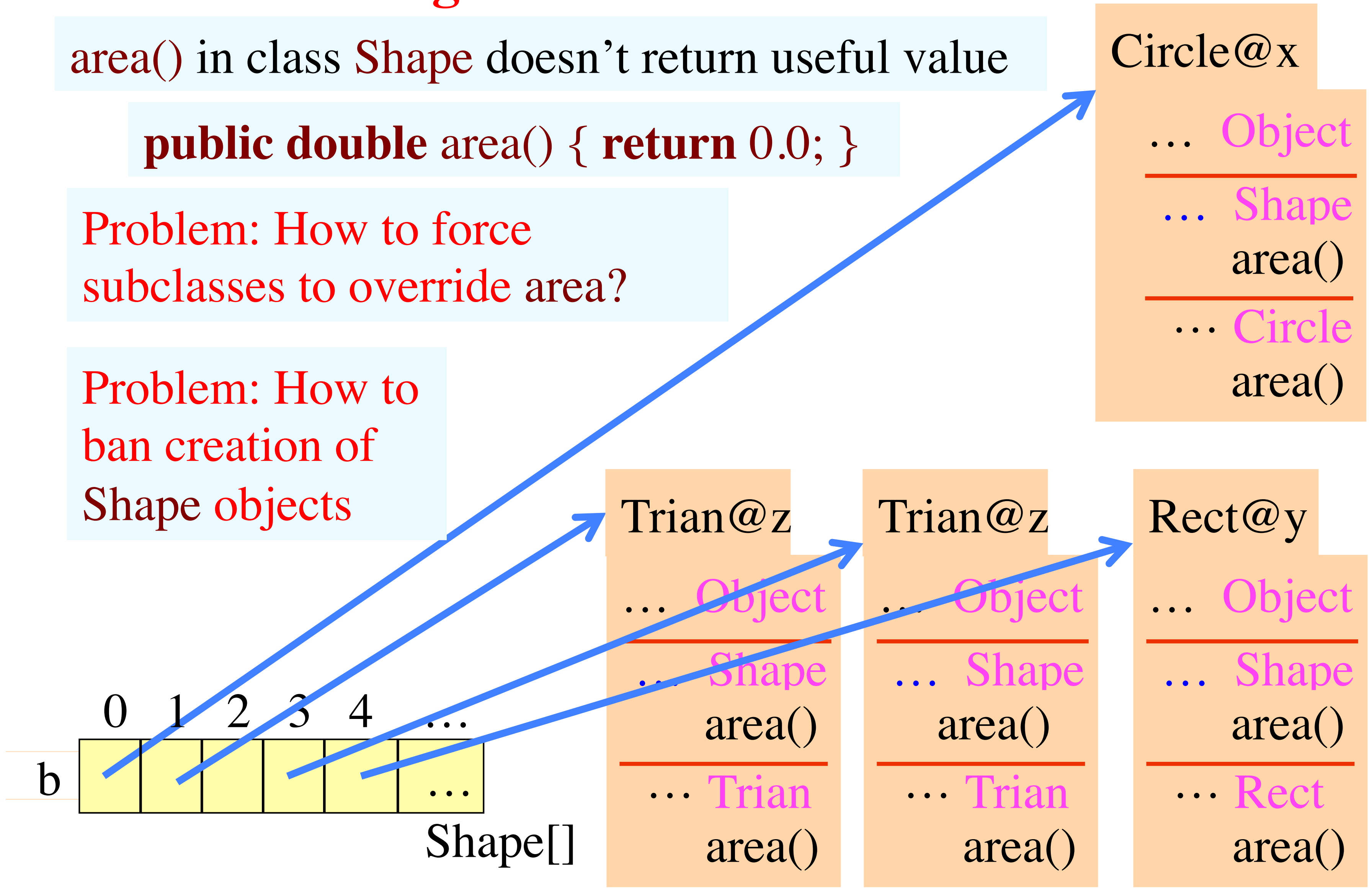
Motivating abstract classes

area() in class Shape doesn't return useful value

public double area() { **return** 0.0; }

Problem: How to force subclasses to override area?

Problem: How to ban creation of Shape objects



Abstract class and method solves both problems

Abstract class. Means can't create object of Shape:
new Shape(…) syntactically illegal

public abstract class Shape {

public abstract double area();

…

}

Place abstract method only in abstract class.

Body is replaced by ;

Abstract method. Means it must be overridden in any subclass

Java has 4 kinds of variable

```
public class Circle {
   private double radius;

   private static int t;

   public Circle(double r) {
      double r1= r;
      radius= r1;
}
```

Field: declared non-static. Is in every object of class. Default initial val depends on type, e.g. 0 for **int**

Class (static) var: declared **static**. Only one copy of it. Default initial val depends on type, e.g. 0 for **int**

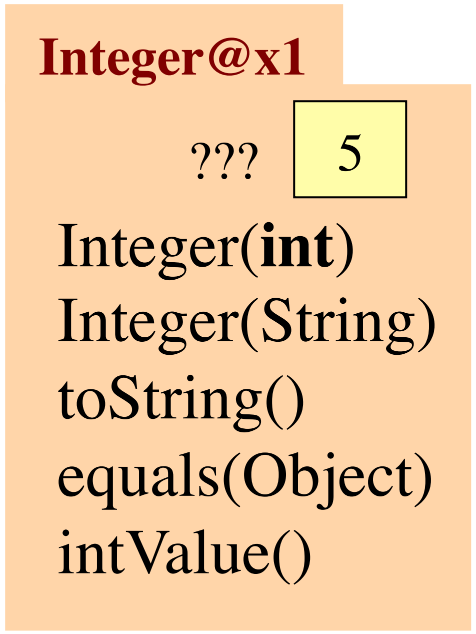
Parameter: declared in () of method header. Created during call before exec. of method body, discarded when call completed. Initial value is value of corresp. arg of call. Scope: body.

Local variable: declared in method body. Created during call before exec. of body, discarded when call completed. No initial value. Scope: from declaration to end of block.

Page B-19..20, B-8

Wrapper classes (for primitive types) in package java.lang. Need no import

object of class Integer “wraps” one value of type **int**.
Object is *immutable*: can’t change its value.



Reasons for wrapper class Integer:

1. Allow treating an **int** value as an object.
2. Provide useful static variables, methods

Integer.MIN_VALUE:
smallest **int** value: -2^{31}

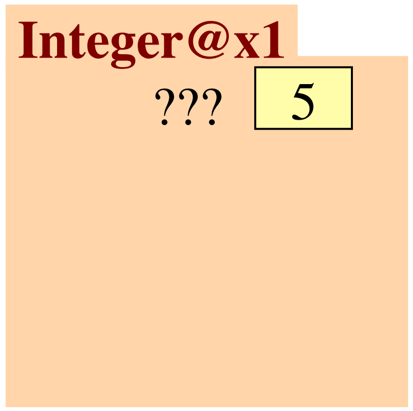
Static components:
MIN_VALUE MAX_VALUE
toString(int) toBinary(int)
valueOf(String) parseInt(String)

Page A-51..54

Why “wrapper” class?

sandwich wrapper

wriggle wrapper



int wrapper

A wrapper wraps something

Wrapper classes (for primitive types)

Wrapper class for each primitive type. Want to treat prim. value as an object? Just wrap it in an object of wrapper class!

Primitive type	Wrapper class
int	Integer
long	Long
float	Float
double	Double
char	Character
boolean	Boolean

Wrapper class has:

- Instance methods, e.g. equals, constructors, toString,
- Useful static constants and methods.

```
Integer k= new Integer(63);          int j= k.intValue();
```

Page A-51..54

Wrapper-class autoboxing in newer Java versions

Autoboxing: process of automatically creating a wrapper-class object to contain a primitive-type value. Java does it in many situations:

Instead of `Integer k= new Integer(63);`

do `Integer k= 63;` This autoboxes the 63

Auto-unboxing: process of automatically extracting the value in a wrapper-class object. Java does it in many situations:

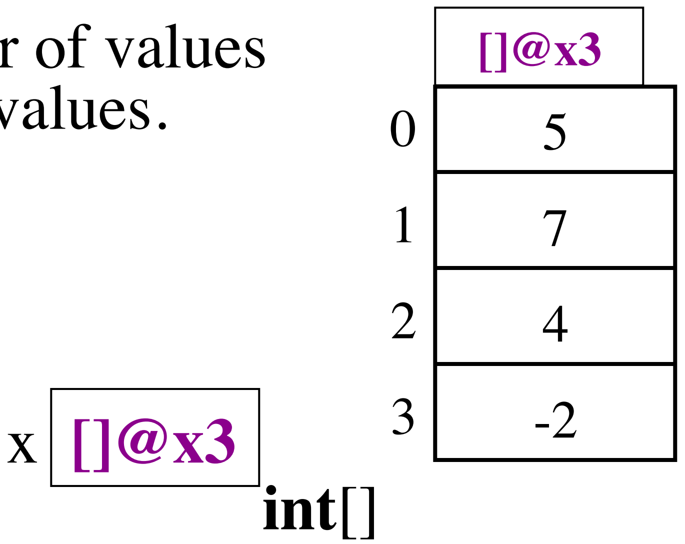
Extract the value from k, above:
Instead of `int i= k.intValue();`

do `int i= k;` This auto-unboxes value in k

Page A-51..54

Array

Array: object. Can hold a fixed number of values of the same type. Array to right: 4 **int** values.



The **type** of the array:

int[]

Variable contains name of the array.

Basic form of a declaration:

<type> <variable-name> ;

A declaration of x. **int**[] x ;

Does not create array, only declares x.
x's initial value is **null**.

Elements of array are numbered: 0, 1, 2, …, x.length–1;

Array length

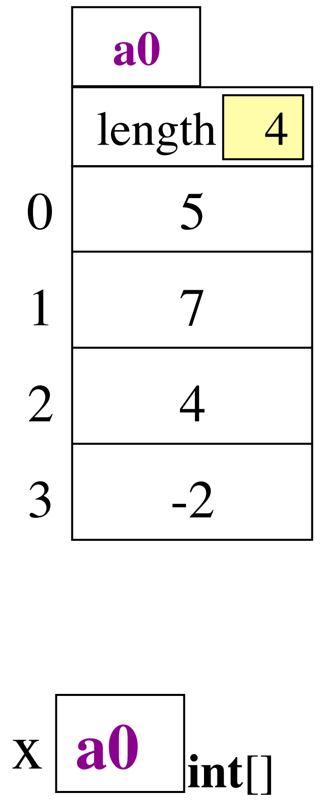
Array length: an instance field of the array.

This is why we write x.length, not x.length( )

Length field is **final:** cannot be changed.

Length remains the same once the array has been created.

We omit it in the rest of the pictures.



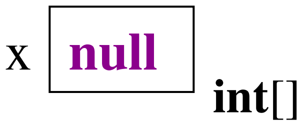
The length is not part of the array type.

The type is **int**[]

An array variable can be assigned arrays of different lengths.

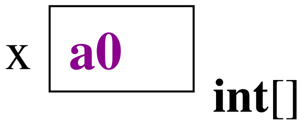
Arrays

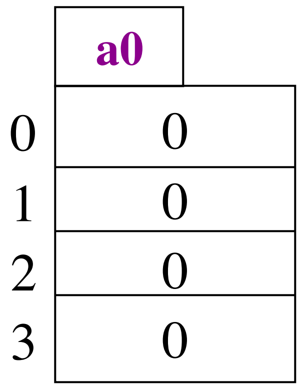
```
int[] x ;
```



```
x= new int[4];
```

Create array object of length 4, store its name in x

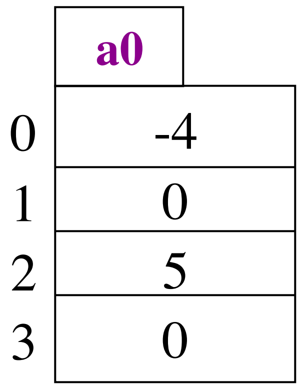




```
x[2]= 5;
x[0]= -4;
```

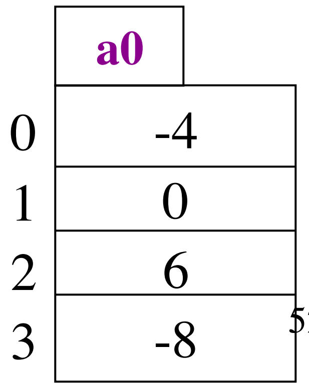
Assign 5 to array element 2 and -4 to array element 0

x[2] is a reference to element number 2 of array x



```
int k= 3;
x[k]= 2* x[0];
x[k-1]= 6;
```

Assign 2*x[0], i.e. -8, to x[3]
Assign 6 to x[2]



Array initializers

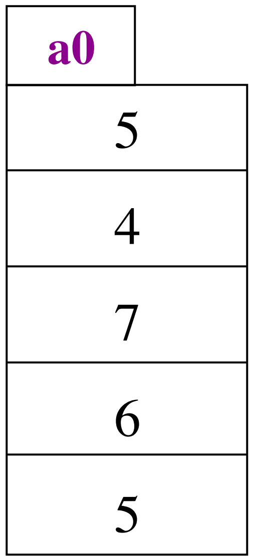
Instead of

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};



No expression between brackets [ ].

array initializer: gives values to be in the array initially. Values must have the same type, in this case, **int**. Length of array is number of values in the list

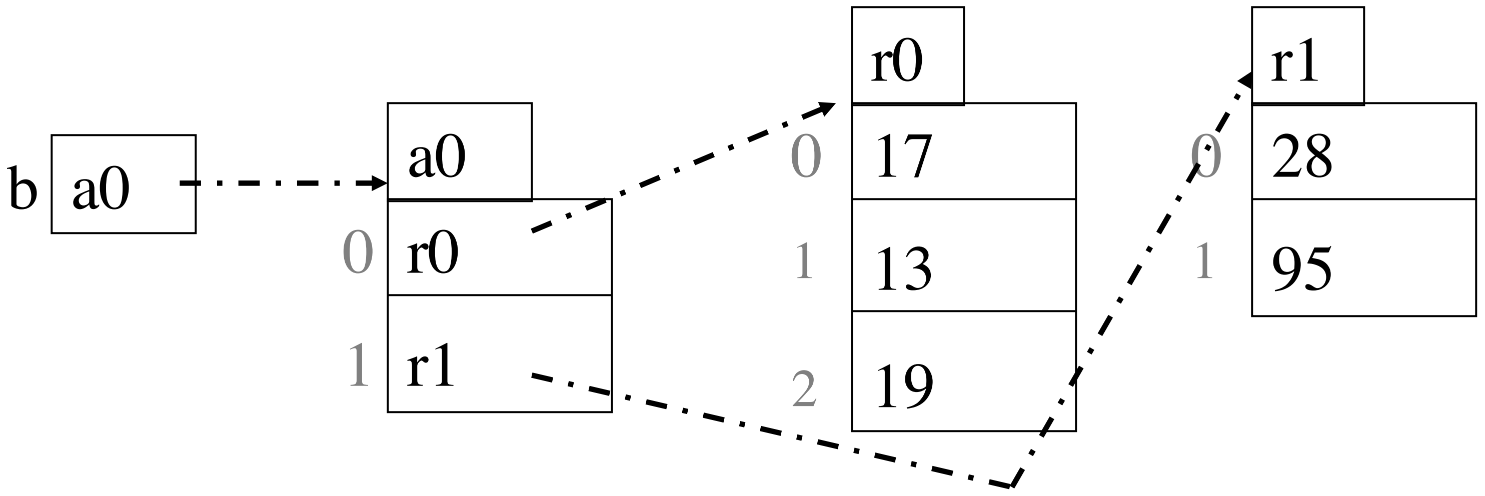
Ragged arrays: rows have different lengths

int[][] b; Declare variable b of type **int**[][]

b= **new int**[2][] Create a 1-D array of length 2 and store its name in b. Its elements have type **int**[] (and start as **null**).

b[0]= **new int**[] {17, 13, 19}; Create **int** array, store its name in b[0].

b[1]= **new int**[] {28, 95}; Create **int** array, store its name in b[1].



Pascal’s Triangle in a ragged array

```
/** = first n rows of Pascal’s triangle. Precondition: 0 ≤ n */
public static int[][] pascalTriangle(int n) {
  int[][] b= new int[n][];      // array with n rows (can be 0!)
  // inv: rows 0..i-1 have been created
  for (int i=  0; i != b.length; i=  i+1) {
    b[i]= new int[i+1]; // Create array for row i

    // Calculate row i of Pascal's triangle
    b[i][0]=  1;
    // inv: b[i][0..j-1] have been created
    for (int j= 1; j < i; j= j+1) {
        b[i][j]=  b[i–1][j–1] + b[i–1][j];
    }
    b[i][i]= 1;
  }
  return b;
}
```

```
                 1
             1       1
         1       2       1
     1       3       3       1
  1      4       6       4       1
1     5      10      10      5      1
```

Generic types —made as simple as possible

Suppose you use Box to hold only Integer objects
When you get value out, you have to cast it to Integer to use it.

```
Box b= new Box();
b.set(new Integer(35));
Object x= b.get();
…  (Integer) x …
```

```
public class Box {
   private Object object;

   public void set(Object ob) {
      object = ob;
   }
   public Object get() {
     return object;
   }   …
```

Generic types: a way, when creating an object of class Box, to say that it will hold only Integer objects and avoid the need to cast.

parameter T (you choose name)

Basic class Box

```
public class Box {
   private Object object;

   public void set(Object ob) {
      object = ob;
   }

   public Object get() {
     return object;
   }   …
```

Written using generic type

```
public class Box<T> {
   private T object;

   public void set(T ob) {
      object = ob;
   }

   public T get() {
     return object;
   }   …
```

Replace type Object everywhere by T

New code

```
Box<Integer> b= new Box<Integer>();
b.set(new Integer(35));
Integer x= b.get();
```

Can extend only one class

```
public class C extends ~~C1~~, C2 {
    public void p() {
        …; h=  m(); …
    }
}
```

if we allowed multiple inheritance, which m used?

```
public class C1 {
   public int m() {
       return 2;
   }
   …
}
```

```
public class C2 {
   public int m() {
       return 3;
   }
  …
}
```

Can extend only one class

public class C **extends** ~~C1,~~ C2 { … }

```
public abstract class C1  {
   public abstract int m();
   public abstract int p();
}
```

```
public abstract class C2  {
  public abstract int m();
  public abstract int q();
}
```

Use abstract classes? Seems OK, because method bodies not given!

But Java does not allow this.

Instead, Java has a construct, the interface, which is like an abstract class.

Interface declaration and use of an interface

```
public class C implements C1, C2 {
…
}
```

C must override all methods in C1 and C2

```
public interface C1 {
   int m();
   int p();
   int FF= 32;
}
```

```
public interface C2 {
   int m();
   int q();
}
```

Field declared in interface automatically public, static, final

Must have initialization

Use of public, static, final optional

Methods declared in interface are automatically public, abstract

Use of public, abstract is optional

Use ; not { … }

Eclipse: Create new interface? Create new class, change keyword **class** to **interface**

Casting with interfaces

class B **extends** A **implements** C1, C2 { … }

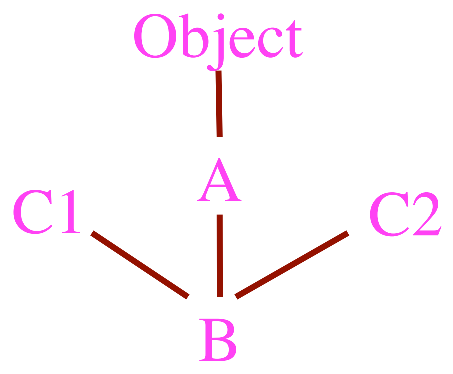
interface C1 { … }

interface C2 { … }

class A { … }

b= **new** B();
What does object b look like?

Draw b like this, showing only names of partitions:



Object b has 5 perspectives. Can cast b to any one of them at any time. Examples:

(C2) b (Object) b
(A)(C2) b (C1) (C2) b

You'll see such casting later

Add C1, C2 as new dimensions:

Look at: interface java.lang.Comparable

```
/** Comparable requires method compareTo */
public interface Comparable<T> {

   /** = a negative integer if this object < c,
         = 0 if this object = c,
         = a positive integer if this object > c.
         Throw a ClassCastException if c cannot
         be cast to the class of this object. */
   int compareTo(T c);

}
```

When a class implements Comparable it decides what < and > mean!

We haven't talked about Exceptions yet. Doesn't matter here.

Classes that implement Comparable

Boolean
Byte
Double
Integer
…
String
BigDecimal
BigInteger
Calendar
Time
Timestamp
…

```
/** An instance maintains a time of day */
class TimeOfDay implements Comparable<TimeOfDay> {
    int hour; // range 0..23
    int minute; // minute within the hour, in 0..59

    /** = -1 if this time less than ob's time, 0 if same,
            1 if this time greater than ob's time */
    public int compareTo(TimeOfDay ob) {
        if (hour < ob.hour) return -1;
        if (hour > ob.hour) return 1;
        // {hour = ob.hour}
        if (minute < ob.minute) return -1;
        if (minute > ob.minute) return 1;
        return 0;
    }
}
```

Note TimeOfDay used here

Note: Class implements Comparable

Class has lots of other methods, not shown. Function compareTo allows us to compare objects, e.g. can use to sort an array of TimeOfDay objects.

```
/** Sort array b, using selection sort */
public static void sort(Comparable[] b) {
    // inv: b[0..i-1] sorted and contains smaller elements
    for (int i= 0; i < b.length; i= i+1) {
        // Store in j the position of smaller of b[i..]
        int j= i;
        // inv: b[j] is smallest of b[i..k-1]
        for (int k= i+1; k < b.length; k= k+1) {
            if (b[k].compareTo(b[j]) < 0)  j= k;
        }
        Comparable t= b[i]; b[i]= b[j]; b[j]= t;
    }
}
```

```
TimeOfDay[] b;
…
sort(b)
```

Note use of function compareTo

Beauty of interfaces: sorts an array C[] for *any* class C, as long as C implements interface Comparable.

Exceptions

```
public static void main(String[] args) {
      int b= 3/0;    This is line 7
   }
```

Division by 0 causes an “Exception to be thrown”.
program stops with output:

```
Exception in thread "main"
                    java.lang.ArithmeticException: / by zero
        at C.main(C.java:7)
```

Happened in C.main on line 7

The “Exception” that is “thrown”

parseInt throws a NumberFormatException if the arg is not an int (leading/trailing spaces OK)

```
public static void main(String[] args) {
      int b= Integer.parseInt("3.2");
   }
```

Used NFE instead of NumberFormatException to save space

Output is:

```
Exception in thread "main" java.lang.NFE:  For input string: "3.2"
   at java.lang.NFE.forInputString(NFE.java:48)
   at java.lang.Integer.parseInt(Integer.java:458)
   at java.lang.Integer.parseInt(Integer.java:499)
   at C.main(C.java:6)
```

3.2 not an int

called from C.main, line 6

called from line 499

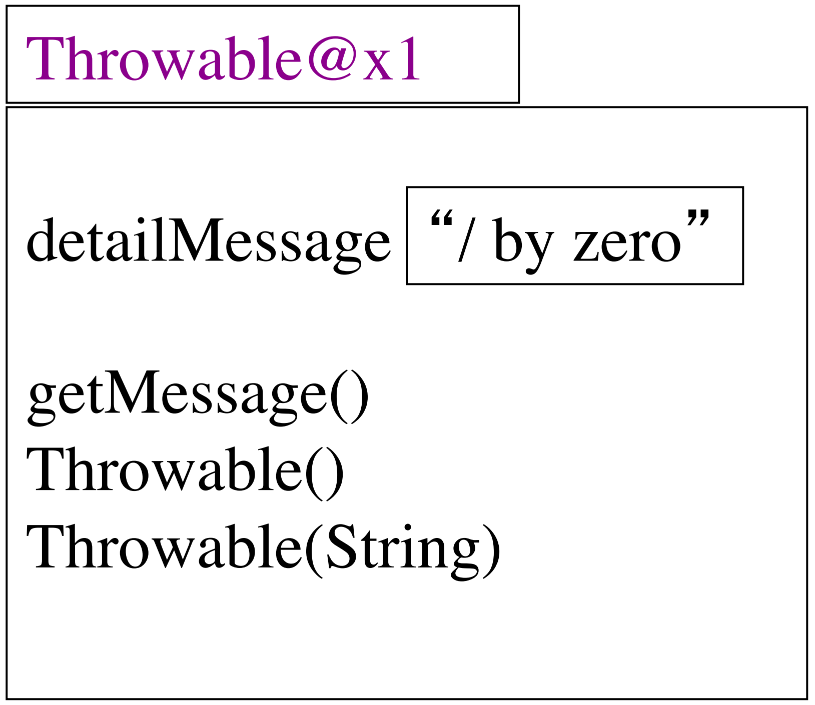
called from line 458

Found error on line 48

See stack of calls that are not completed!

Exceptions and Errors

In package java.lang: class Throwable:



When some kind of error occurs, an exception is "thrown" —you'll see what this means later.

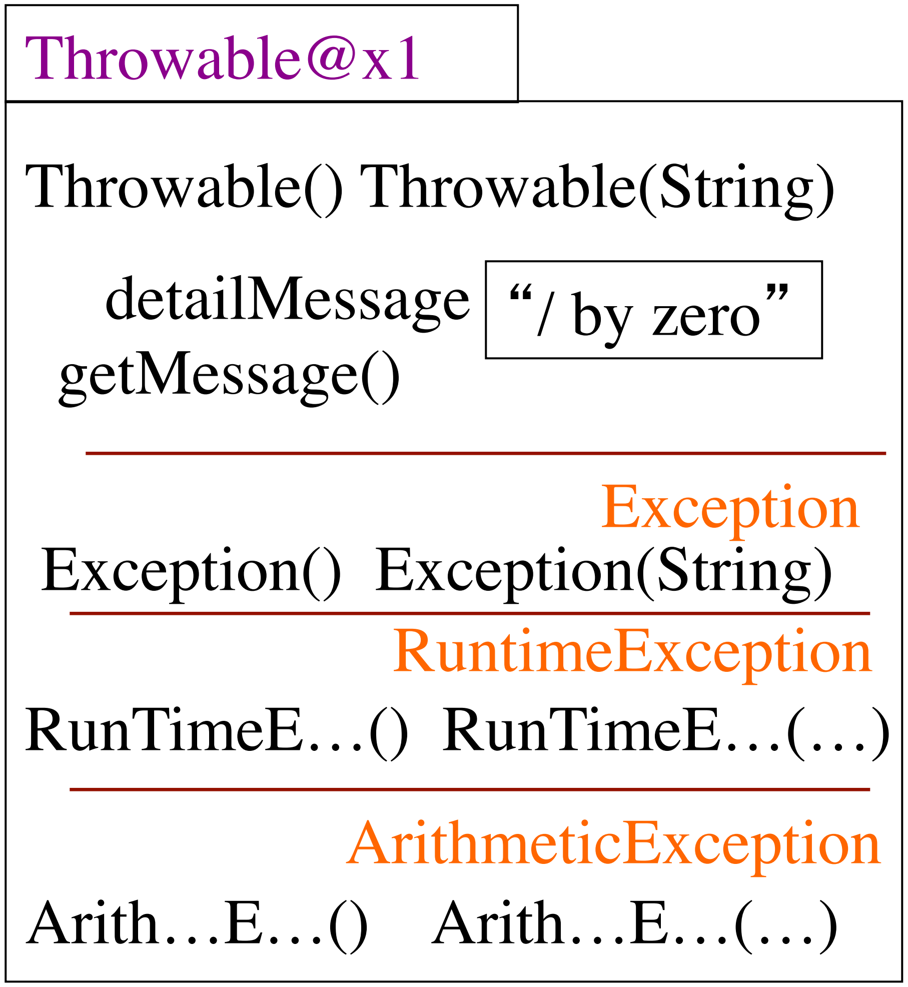
An exception is an instance of class Throwable

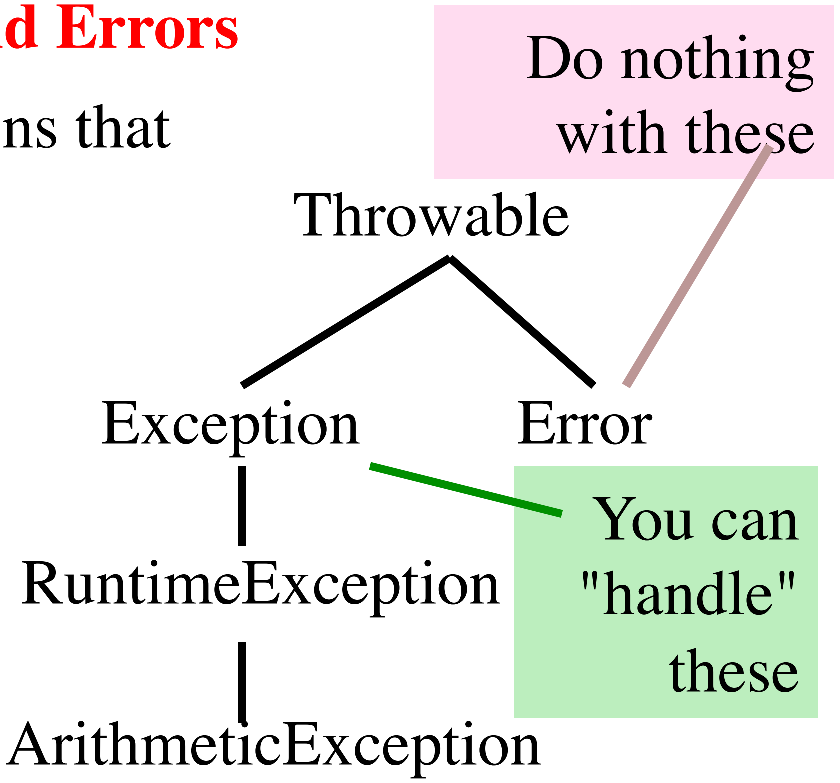
(or one of its subclasses)

Two constructors in class Throwable. Second one stores its String parameter in field detailMessage.

Exceptions and Errors

So many different kind of exceptions that we have to organize them.



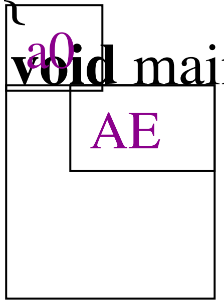


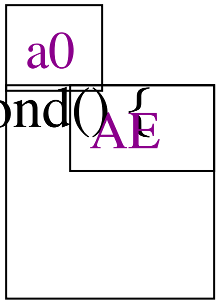
Subclass always has: 2 constructors, no fields, no other methods.
Constructor calls superclass constructor.

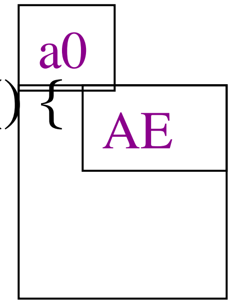
Creating and throwing and Exception

Class:

```
03 public class Ex {
04     public static void main(…) {
05         second();
06     }
07
08     public static void second() {
09         third();
10     }
11
12     public static void third() {
13         int x= 5 / 0;
14     }
15 }
```







Call

Object a0 is thrown out to the call. Thrown to call of main: info printed

Ex.first(); Output

```
ArithmeticException: / by zero
  at Ex.third(Ex.java:13)
  at Ex.second(Ex.java:9)
  at Ex.main(Ex.java:5)
  at sun.reflect.NativeMethodAccessorImpl.invoke0(Native Method)
  at sun.reflect.NativeMethodAccessorImpl.invoke(…)
  at sun.reflect.DelegatingMethodAccessorImpl.invoke(…)
  at java.lang.reflect.Method.invoke(Method.java:585)
```

Throw statement

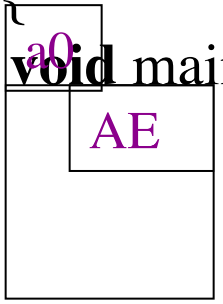
Class:

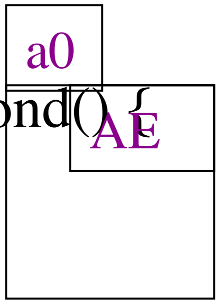
Call

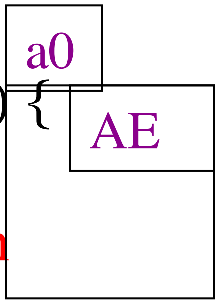
Ex.first();

Same thing, but with an explicit throw statement

```
03 public class Ex {
04     public static void main(…) {
05         second();
06     }
07
08     public static void second() {
09         third();
10     }
11
12     public static void third() {
13         throw new
               ArithmeticException
                   (“I threw it”);
14     }
15 }
```







Output

```
ArithmeticException: / by zero
  at Ex.third(Ex.java
  at Ex.second(Ex.java:9)
  at Ex.main(Ex.java:5)
  at sun.reflect.NativeMethodAccessorImpl.invoke0(Native Method)
  at sun.reflect.NativeMethodAccessorImpl.invoke(…)
  at sun.reflect.DelegatingMethodAccessorImpl.invoke(…)
  at java.lang.reflect.Method.invoke(Method.java:585)
```

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();
    }
}
```

The “throws” clause

Throw Exception that is not subclass of RuntimeException? May need throws clause

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

If Java asks for a throws clause, insert it. Otherwise, don’t be concerned with it.

Try statement: catching a thrown exception

```
try {
   statements
}
catch  (class-name  e) {
   statements
}
```

try-block

catch-block

class-name that is a subclass of Throwable

Assume statement occurs in a method m

Execution: Execute the try-block. Three cases arise: The try-block:

1. Does not throw an exception: End of execution.

2. Throws a class-name exception: execute the catch-block statements, with e containing the thrown exception.

3. Throws other exception: throw the object to the statement that called m.

Junit testing class

A Junit testing class is a class that contains procedures that are called to do “unit testing”. The units are generally methods in objects.

Eclipse has a simple way to create such a class:

1. In Package Explorer, select src directory for project
2. Use menu item File → New → Junit Test Case
3. If the class you are texting is C, name the file Ctester

Junit testing class looks like this:

```
import static org.junit.Assert.*;
import org.junit.Test;

public class CTester {

  @Test
  public void test() {

}
```

Put as many different test() method, with mnemonically chosen names.

To call *all* such methods, select file CTester in the Package Explorer and then use menu item Run→ Run

What to put in a test method

```
…
public class CTester {
    @Test
    public void testFail() {
        fail("Not yet implemented");

    @Test
    public void testM() {
        assertEquals(5, C.m(30));
        assertEquals(20, C.m(0));
```

Causes execution of method call to abort with a message

Testing 2 calls on static method m of C.
Put in as many tests as you need

assertEquals(expected value, computed value);

```
}
```

To test a new class

To test a class, it is best to

1. Write a method a test procedure to test whether the constructor sets *all* fields properly, so that the class invariant is true. This will also test the getters. (see next slide)
2. Write a test procedure to test whether the setters do their job correctly.
3. Write a test procedure to test whether toString() is correct.
4. Write a separate method for each of the other constructors (if there are more)
5. Write other test procedures as is necessary to test other methods.

Testing a constructor

```
…
public class CTester {
    @Test
    public void testConstructor() {
        C c1= new C(5, 7);
        assertEquals(5, c1.getF1());
        assertEquals(7, c1.getF2());
        assertEquals(20, c1.getF3());
    }
```

Note: purpose of procedure is to test constructor, but the method also tests the getter methods.

Assume C has 3 fields, f1, f2, and f3, with appropriate getter methods.

Assume the 5 is for f1, the 7 is for f2, and f3 is to be initialized to 20.

This code creates a new objects and tests whether *all* fields are properly set.

Testing setter methods

```
…
public class CTester {
   @Test
   public void testSetters() {
      C c1= new C(5, 7);
      c1.setF1(6);
      assertEquals(6, c1.getF1());

      c1.setF2(-5);
      assertEquals(-5, c1.getF2());
}
```

Assume C has 3 fields, f1, f2, and f3, with appropriate getter and setter methods.

Warning: don’t use static components

While it is possible to use fields or static variables in a Junit test class, we advise against it at this point. You do not know when they are initialized (before the call of *each* test procedure, or once when you use Run → Run, or once when class if first created, whatever).

Just use local variables where needed in a testing class.

Enums (or enumerations)

An enum: a class that lets you create mnemonic names for entities instead of having to use constants like 1, 2, 3, 4

The declaration below declares a class Suit.
After that, in any method, use Suit.Clubs, Suit.Diamonds, etc. as constants.

$$\underbrace{\textbf{public}}_{\text{could be private, or any access modifier}}\ \underbrace{\textbf{enum}}_{\text{new keyword}}\ \text{Suit}\ \{\underbrace{\text{Clubs, Diamonds, Hearts, Spades}}_{\text{The constants of the class are Clubs, Diamonds, Hearts, Spades}}\}$$

Testing for an enum constant

public enum Suit {Clubs, Diamonds, Hearts, Spades}

Suit s= Suit.Clubs;
Then
s == Suit.Clubs is true   s == Suit.Hearts is false

```
switch(s) {
   case Clubs:
   case Spades:
      color= "black"; break;
   case Diamonds:
   case Hearts:
      color= "red"; break;
}
```

Can use a switch statement

Type of s is Suit.

You cannot write Suit.Hearts instead of Hearts

Miscellaneous points about enums

public enum Suit {Clubs, Diamonds, Hearts, Spades}

This declaration is shorthand for a class that has a constructor, four constants (public static final variables), a static method, and some other components. Here are some points:

1. Suit is a subclass of Enum (in package java.lang)

2. It is not possible to create instances of class Suit, because its constructor is private!

3. It's as if Clubs (as well as the other three names) is declared within class Suit as

public static final Suit Clubs= **new** Suit(some values);

You don't care what values

Miscellaneous points about enums

public enum Suit {Clubs, Diamonds, Hearts, Spades}

4. Static function values() returns a Suit[] containing the four constants. You can, for example, use it to print all of them:

```
for (Suit s : Suit.values())
    System.out.println(s);
```

Output:

```
Clubs
Diamonds
Hearts
Spades
```

You can see that toString in object Clubs returns the string “Clubs”

5. Static function valueOf(String name) returns the enum constant with that name:

```
Suit c= Suit.valueOf(“Hearts”);
```

After the assignment, c contains (the name of) object Hearts

Miscellaneous points about enums

public enum Suit {Clubs, Diamonds, Hearts, Spades}

This declaration is shorthand for a class that has a constructor, four constants (public static final variables), a static method, and some other components. Here are some points:

6. Object Clubs (and the other three) has a function ordinal() that returns it position in the list

Suit.Clubs.ordinal()	is	0
Suit.Diamonds.ordinal()	is	1

We have only touched the surface of enums. E.g. in an enum declaration, you can write a private constructor, and instead of Clubs you can put a more elaborate structure. That's outside the scope of CS2110.