Metaclasses in 7 Steps

Classes are objects too...
Classes are instances of other classes
...
One model applied twice

Metaclasses in 7 points

1. Every object is an instance of a class
2. Every class eventually inherits from Object
3. Every class is an instance of a metaclass
4. The metaclass hierarchy parallels the class hierarchy
5. Every metaclass inherits from Class and Behavior
6. Every metaclass is an instance of Metaclass
7. The metaclass of Metaclass is an instance of Metaclass

Adapted from Goldberg & Robson, *Smalltalk-80 — The Language*

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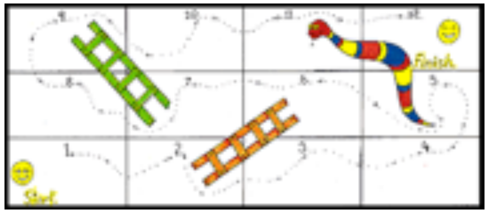
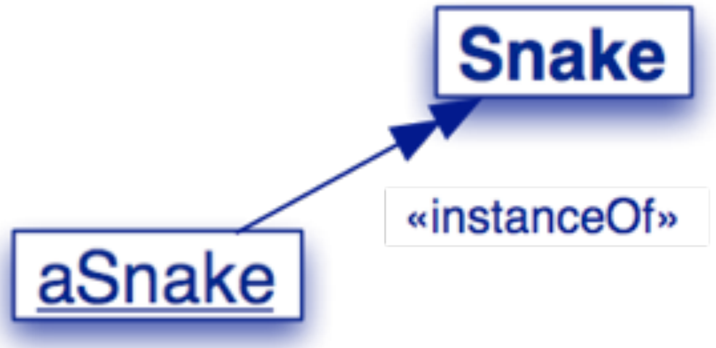
1. Every object is an instance of a class





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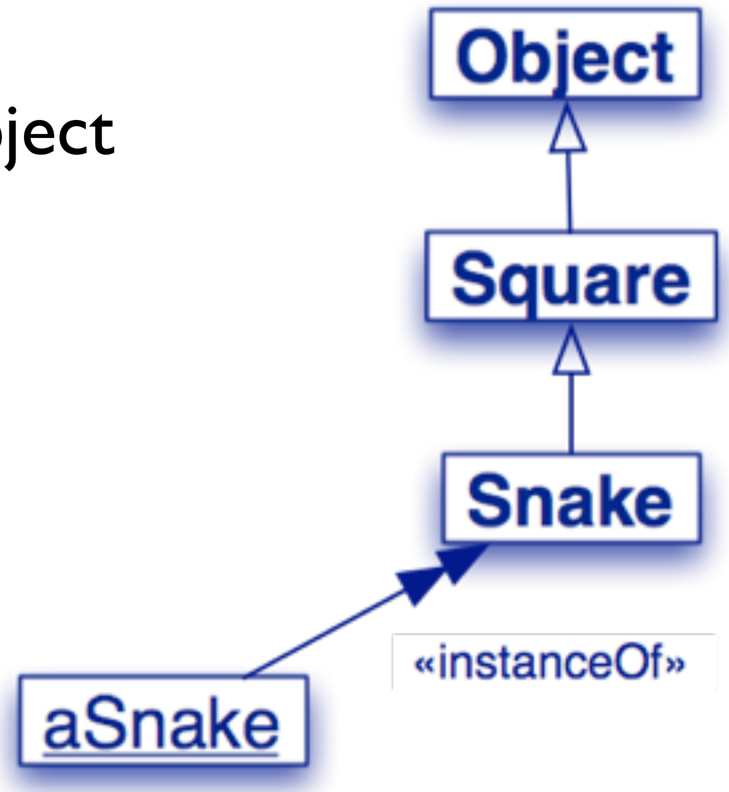
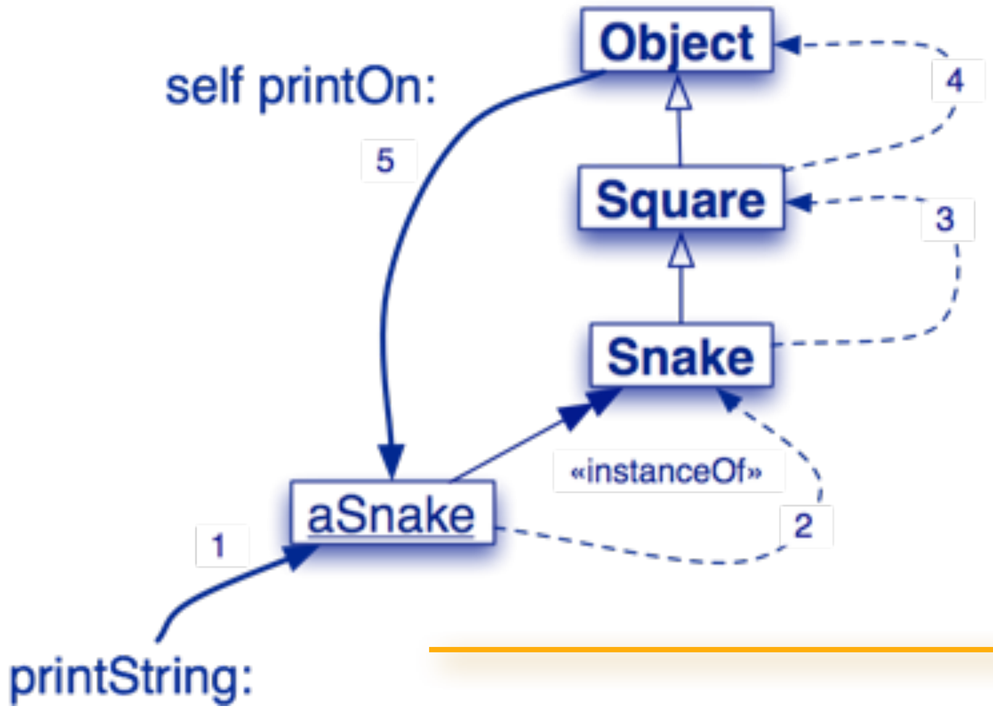
2. Every class inherits from Object

Every object is-an Object
The class of every object
ultimately inherits from Object



The Meaning of is-a

When an object receives a message, the method is looked up in the method dictionary of its class, and, if necessary, its superclasses, up to Object



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Responsibilities of Object

`Object`

- represents the common object behavior
  - error-handling, halting …
- all classes should inherit ultimately from `Object`

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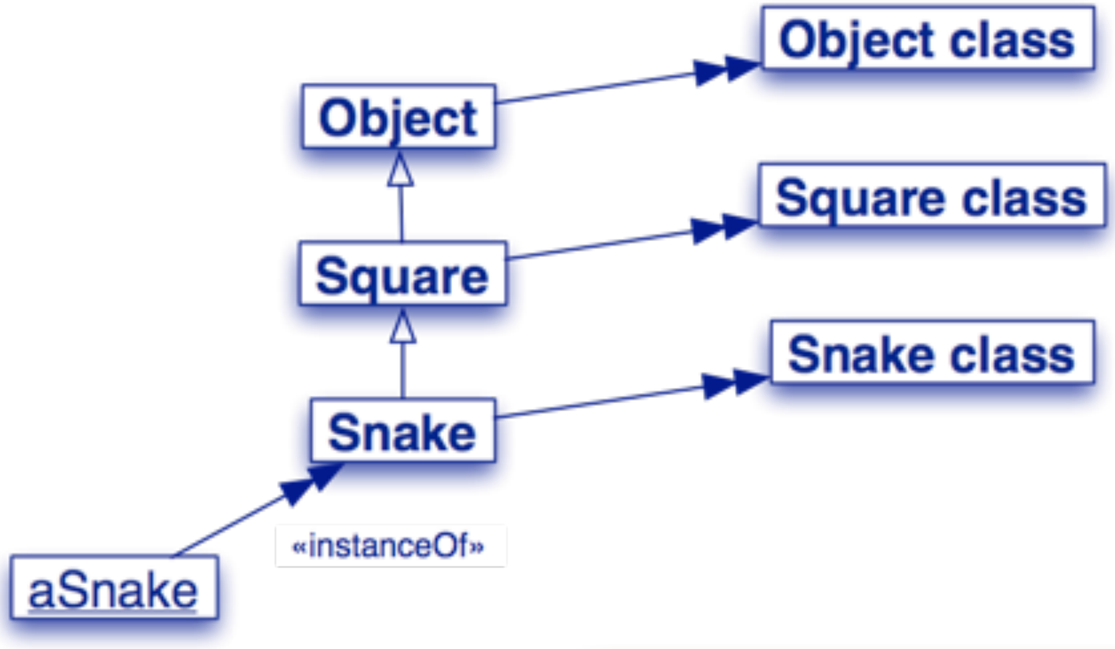
3. Every class is an instance of a metaclass

Classes are objects too!

- Every class X is the unique instance of its metaclass, called X class



Metaclasses are implicit

There are no explicit metaclasses

- Metaclasses are created implicitly when classes are created
- No sharing of metaclasses (unique metaclass per class)

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Metaclasses by Example

```
Square allSubclasses
Snake allSubclasses

Snake allInstances
Snake instVarNames

Snake back: 5

Snake selectors

Snake canUnderstand: #new
```

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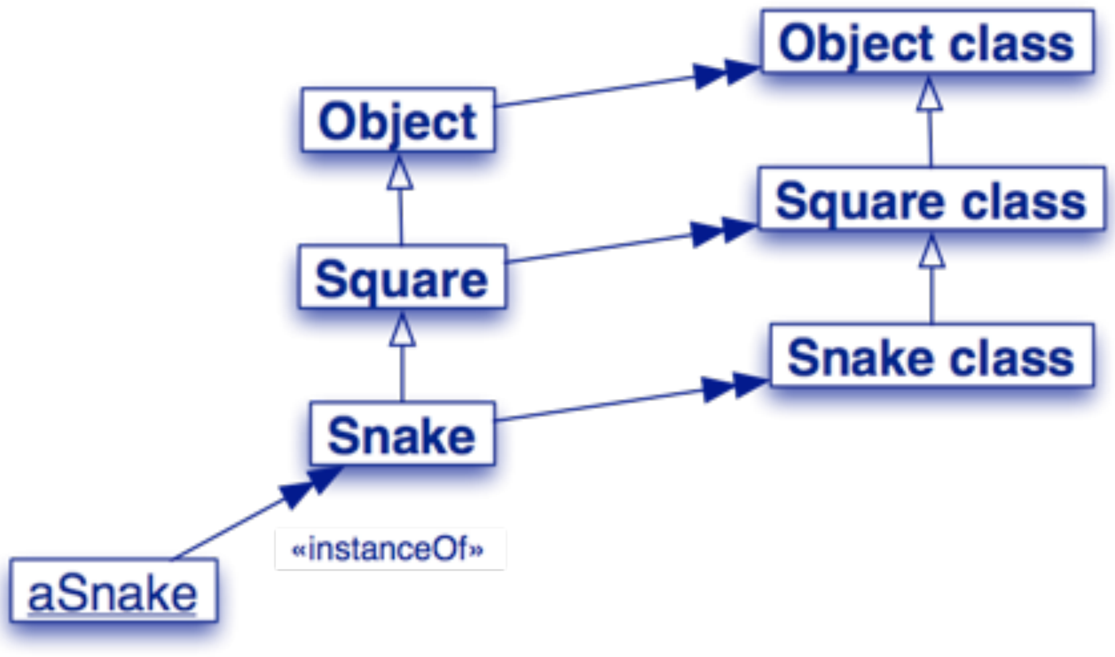
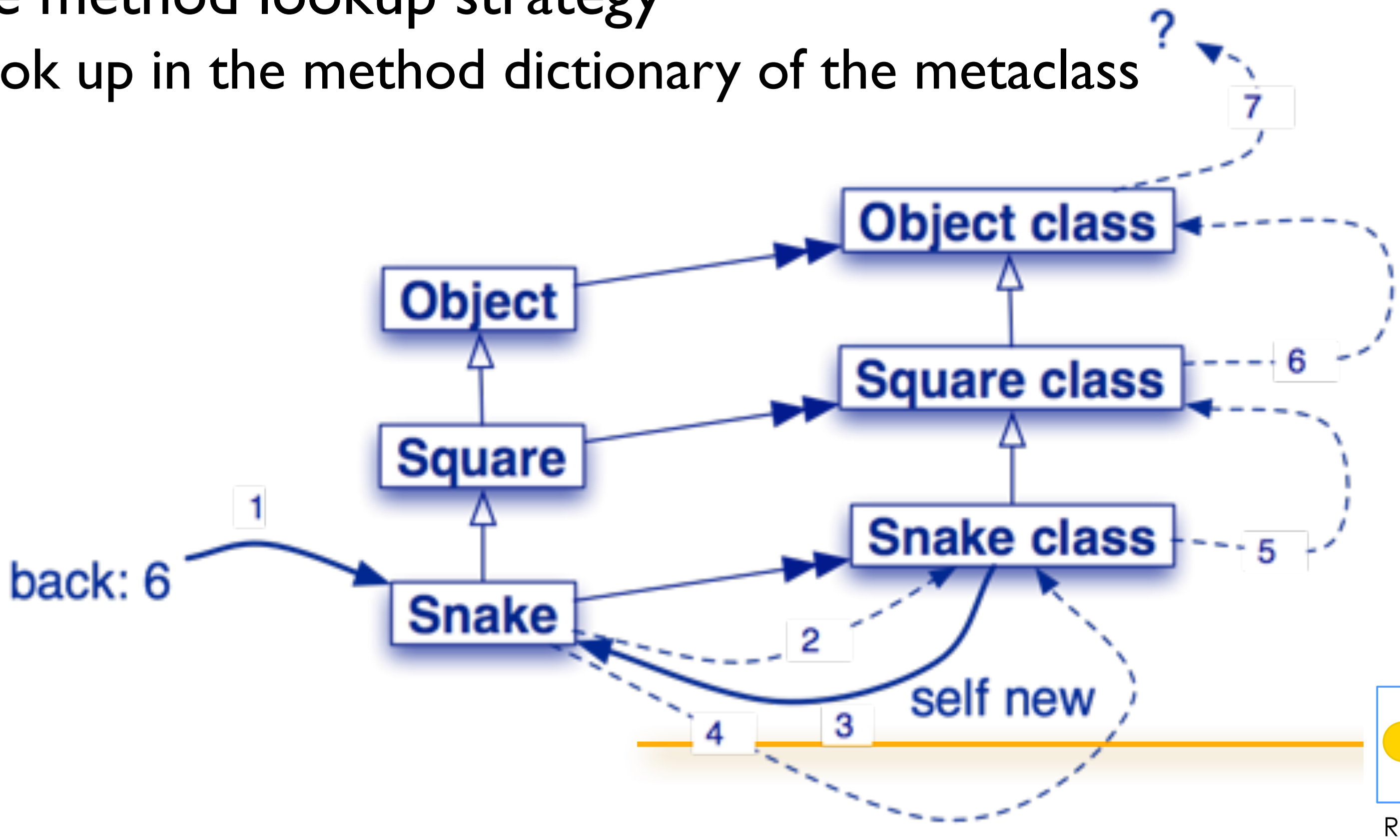
4. The metaclass hierarchy parallels the

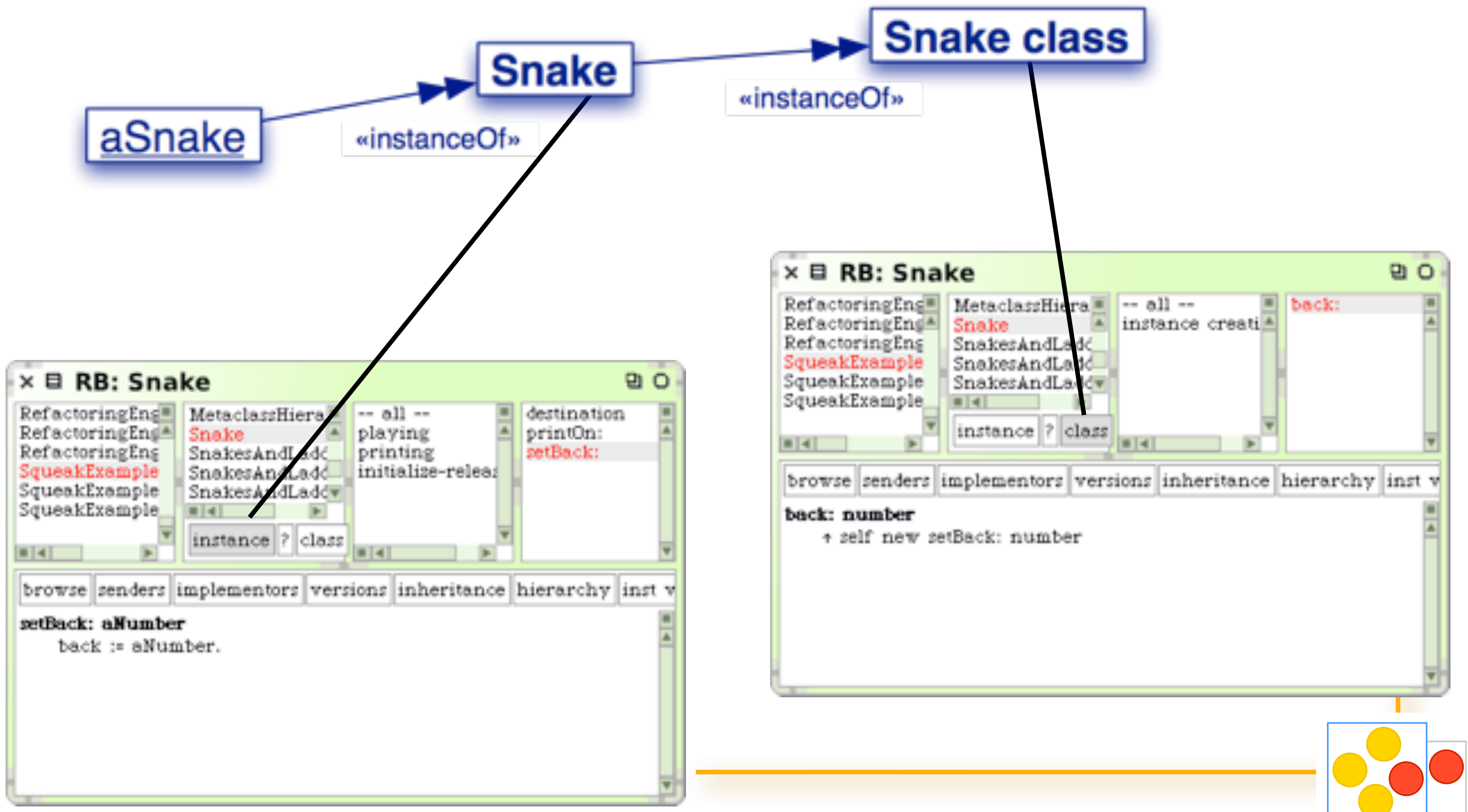


Uniformity between Classes and Objects

- Classes are objects too, so …
  - Everything that holds for objects holds for classes as well
  - Same method lookup strategy
    - Look up in the method dictionary of the metaclass



About the Buttons



```
setBack: aNumber
    back := aNumber.
```

```
back: number
    ↑ self new setBack: number
```

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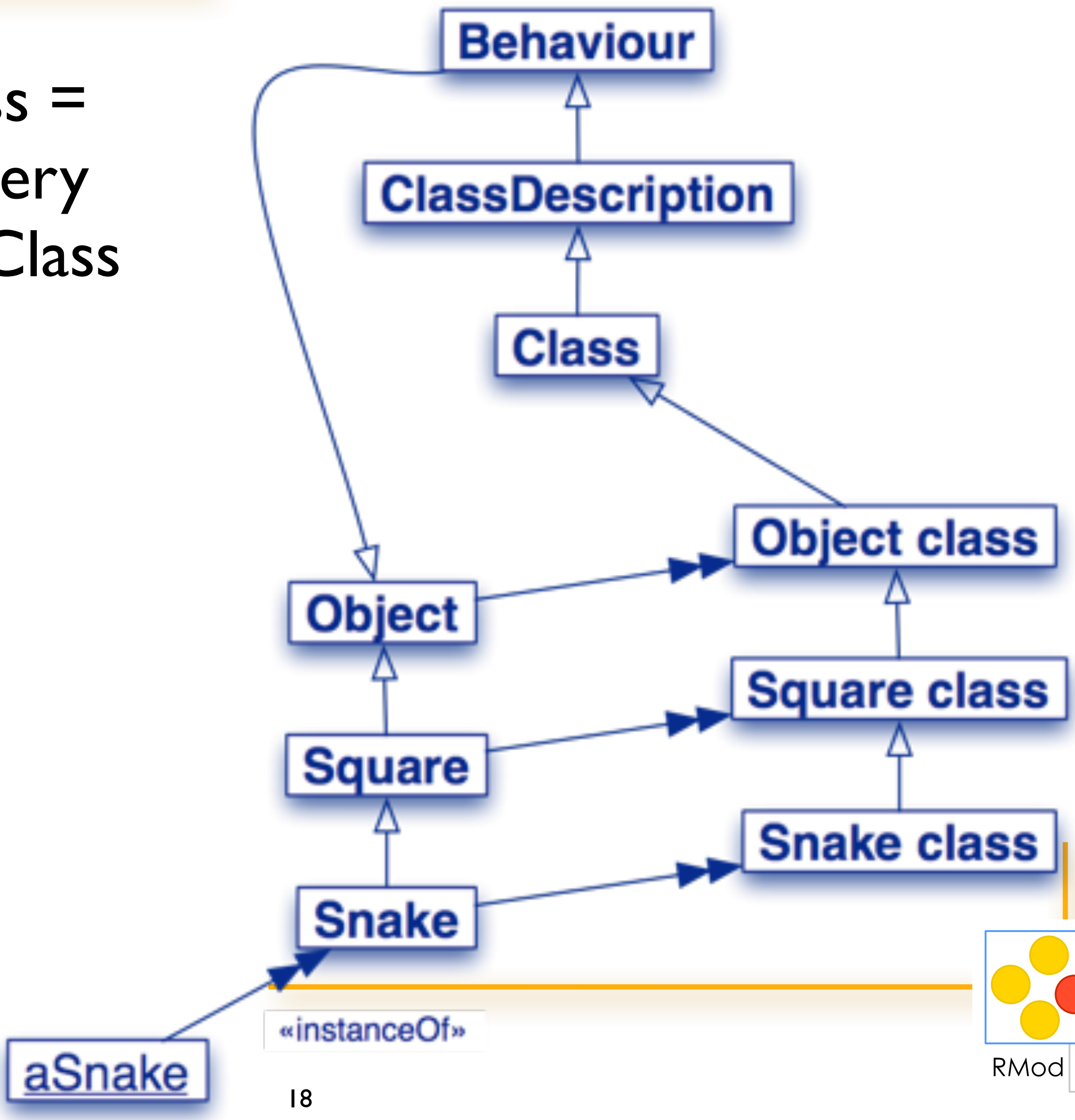
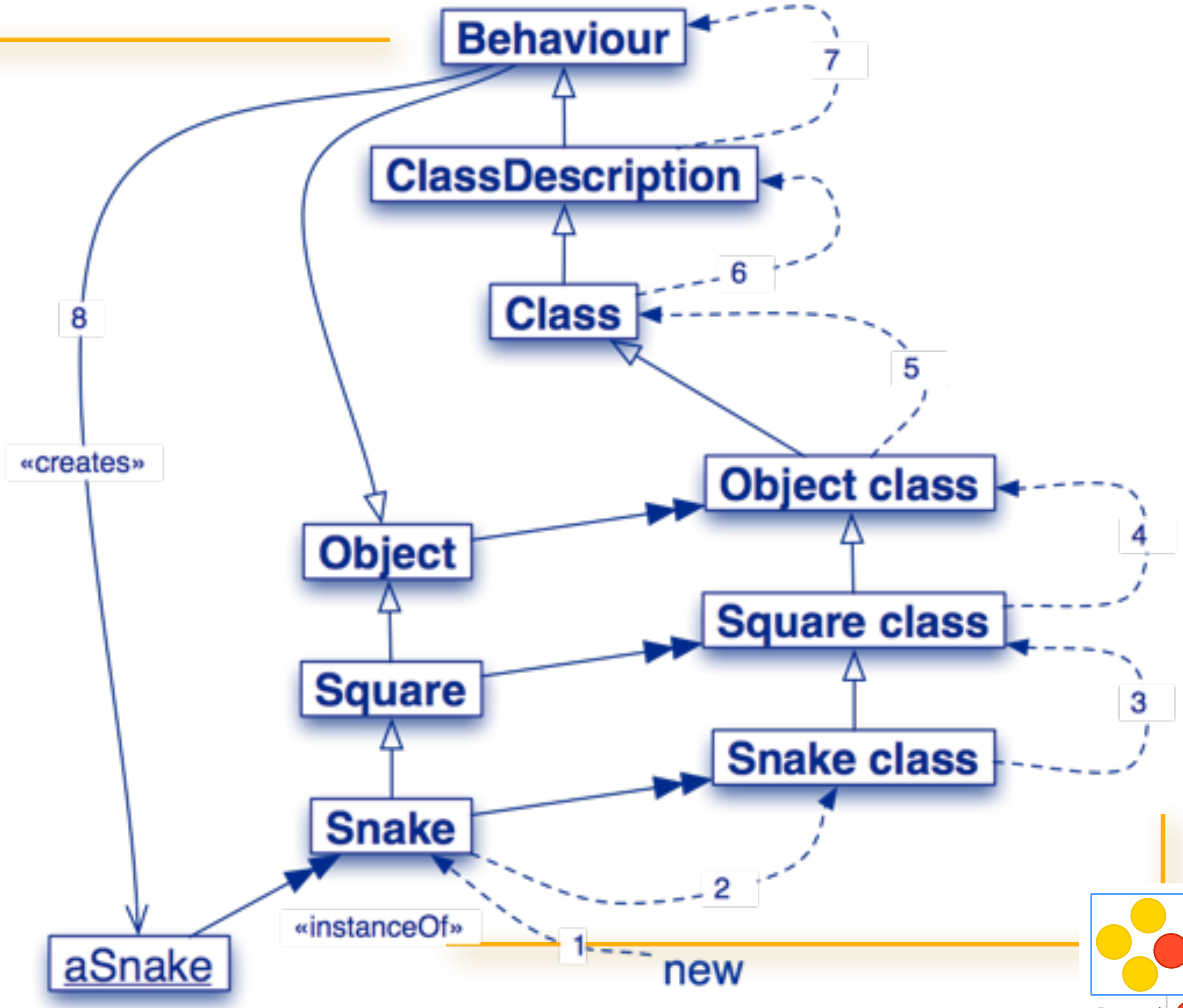
5. Every metaclass inherits from Class and

Every class is-a Class =
The metaclass of every class inherits from Class



Where is new defined?



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Responsibilities of Behavior

- **`Behavior`**
  - Minimum state necessary for objects that have instances.
  - Basic interface to the compiler.
  - ***State:***
    - class hierarchy link, method dictionary, description of instances (representation and number)
  - ***Methods:***
    - creating a method dictionary, compiling method
    - instance creation (new, basicNew, new:, basicNew:)
    - class hierarchy manipulation (superclass:, addSubclass:)
    - accessing (selectors, allSelectors, compiledMethodAt:)
    - accessing instances and variables (allInstances, instVarNames)

Responsibilities of ClassDescription

`ClassDescription`

adds a number of facilities to basic Behavior:

- named instance variables
- category organization for methods
- the notion of a name (abstract)
- maintenance of Change sets and logging changes
- most of the mechanisms needed for fileOut

`ClassDescription` is an abstract class: its facilities are intended for inheritance by the two subclasses, `Class` and `Metaclass`.

Responsibilities of Class

`Class`

- represents the common behavior of all classes
  - name, compilation, method storing, instance variables …
- representation for classVariable names and shared pool variables (`addClassVarName:`, `addSharedPool:`, `initialize`)
- `Class` inherits from `Object` because `Class` is an `Object`
  - *`Class`* knows how to create instances, so all metaclasses should inherit ultimately from *`Class`*

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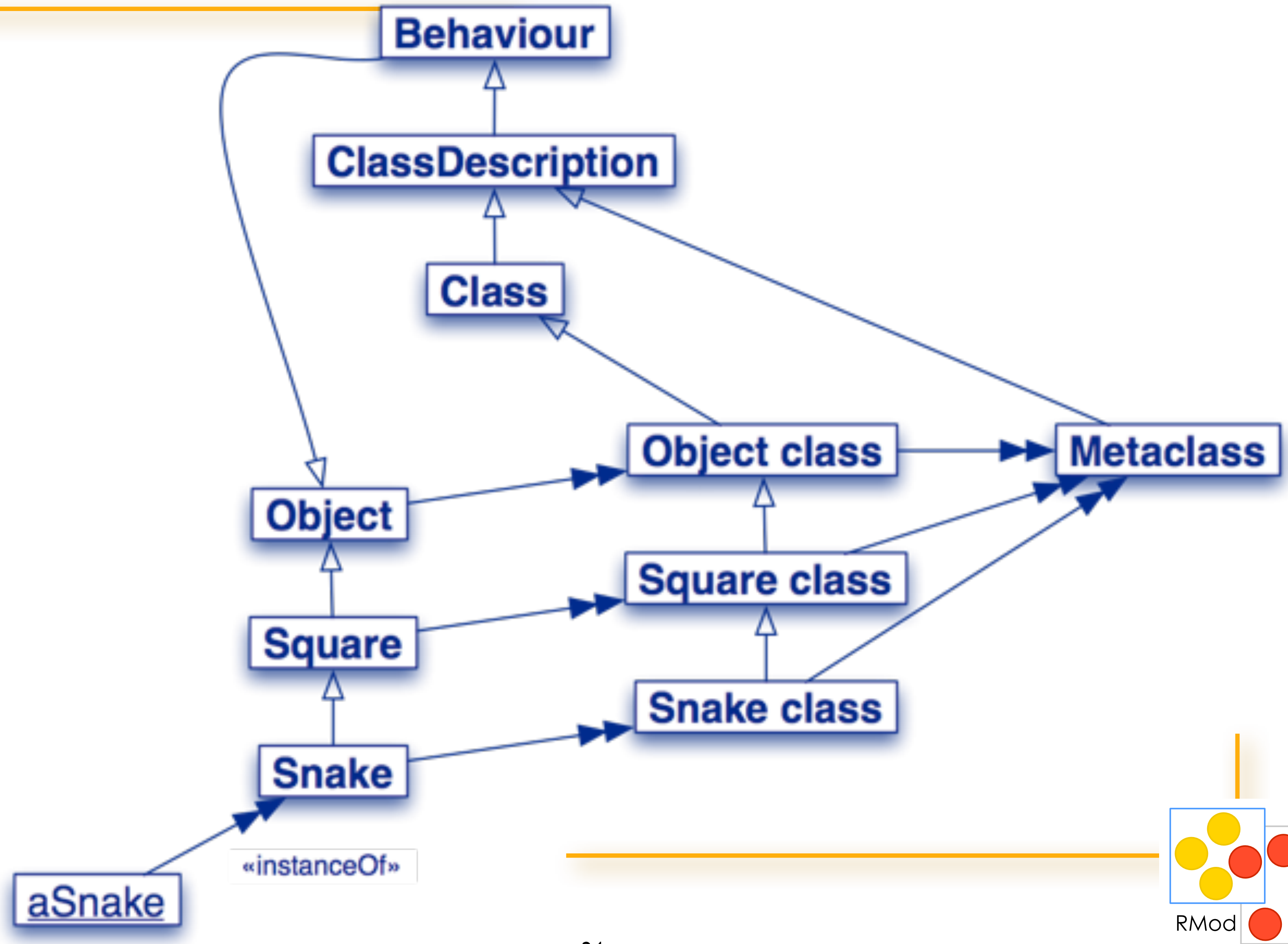

Metaclass Responsibilities

`Metaclass`

- Represents common metaclass Behavior
  - instance creation (subclassOf:)
  - creating initialized instances of the metaclass’s sole instance
  - initialization of class variables
  - metaclass instance protocol (name:inEnvironment:subclassOf:....)
  - method compilation (different semantics can be introduced)
  - class information (inheritance link, instance variable, ...)

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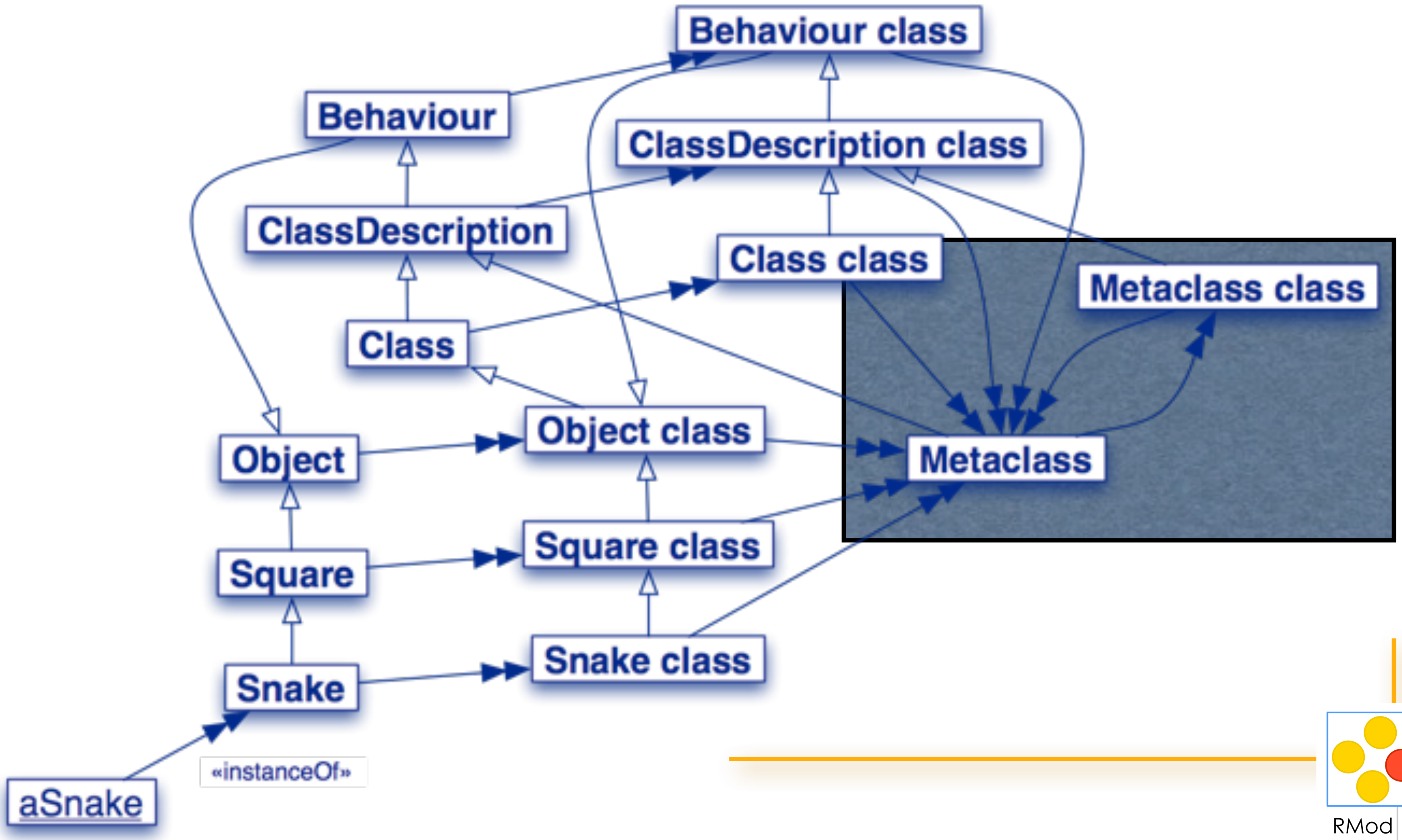
7. The metaclass of Metaclass is an instance of Metaclass



Navigating the metaclass hierarchy

```
MetaclassHierarchyTest>>testHierarchy
  "The class hierarchy"
  self assert: Snake superclass = Square.
  self assert: Square superclass = Object.
  self assert: Object superclass superclass = nil. "skip ProtoObject"
  "The parallel metaclass hierarchy"
  self assert: Snake class name = 'Snake class'.
  self assert: Snake class superclass = Square class.
  self assert: Square class superclass = Object class.
  self assert: Object class superclass superclass = Class.
  self assert: Class superclass = ClassDescription.
  self assert: ClassDescription superclass = Behavior.
  self assert: Behavior superclass = Object.
  "The Metaclass hierarchy"
  self assert: Snake class class = Metaclass.
  self assert: Square class class = Metaclass.
  self assert: Object class class = Metaclass.
  self assert: Class class class = Metaclass.
  self assert: ClassDescription class class = Metaclass.
  self assert: Behavior class class = Metaclass.
  self assert: Metaclass superclass = ClassDescription.
  "The fixpoint"
  self assert: Metaclass class class = Metaclass.
```

Summary

Just one model applied systematically.

The key: messages sent to an object are looked in its class then in the superclass.