7. Understanding Classes and Metaclasses

Roadmap

- Metaclasses in 7 points
- Indexed Classes
- Class Instance Variables
- Class Variables
- Pool Dictionaries

Selected material courtesy Stéphane Ducasse

Roadmap

- **Metaclasses in 7 points**
- Indexed Classes
- Class Instance Variables
- Class Variables
- Pool Dictionaries

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

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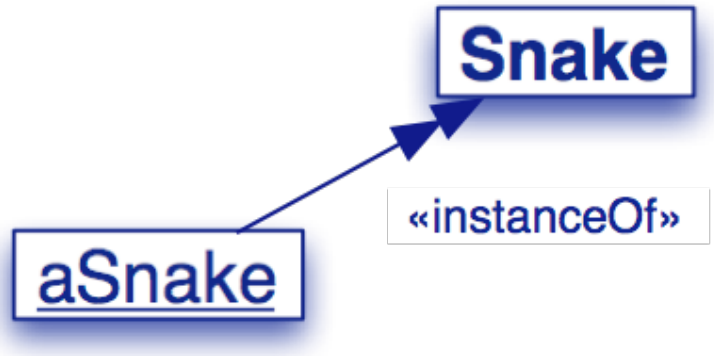
1. Every object is an instance of a class



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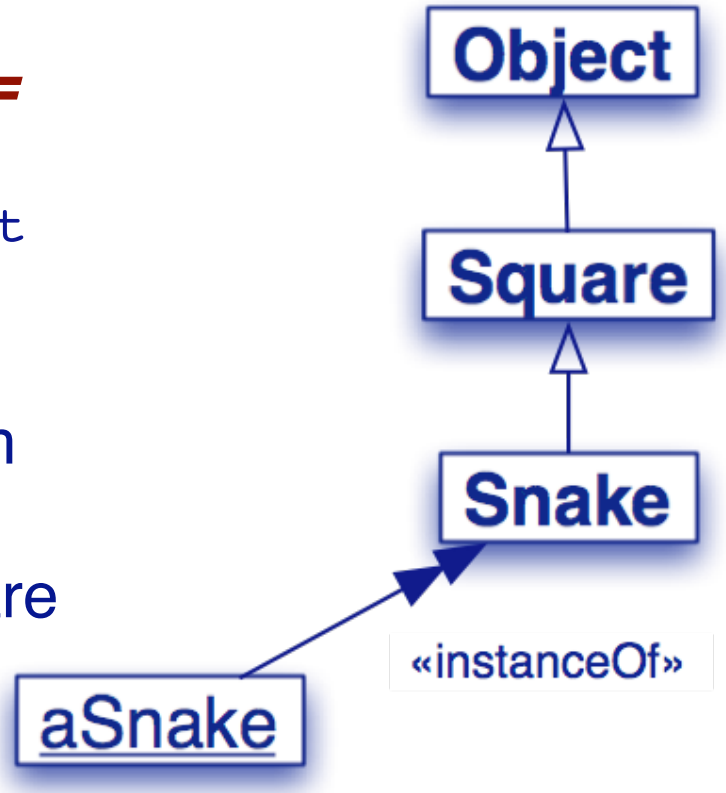
2. Every class inherits from Object

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

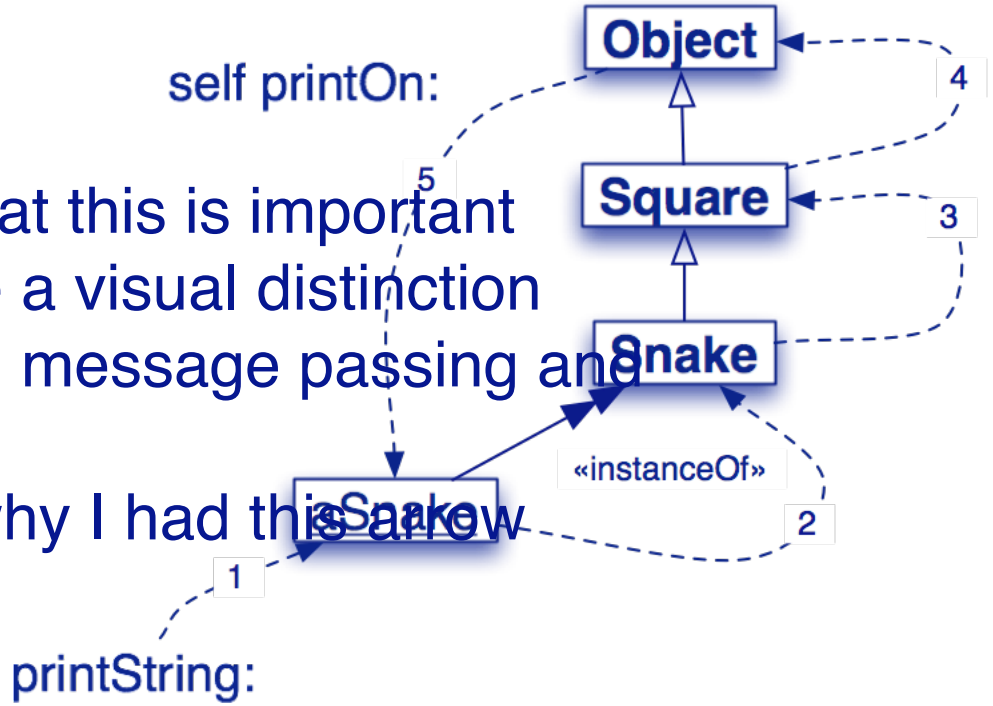
@@ Why not ColoredSnake inherits from Snake
Snake inheriting from square
Hurts me :_)



Caveat: in Squeak, `Object` has a superclass called `ProtoObject`

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



I think that this is important
To make a visual distinction
Between message passing and lookup
This is why I had this arrow thingie

Responsibilities of Object

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

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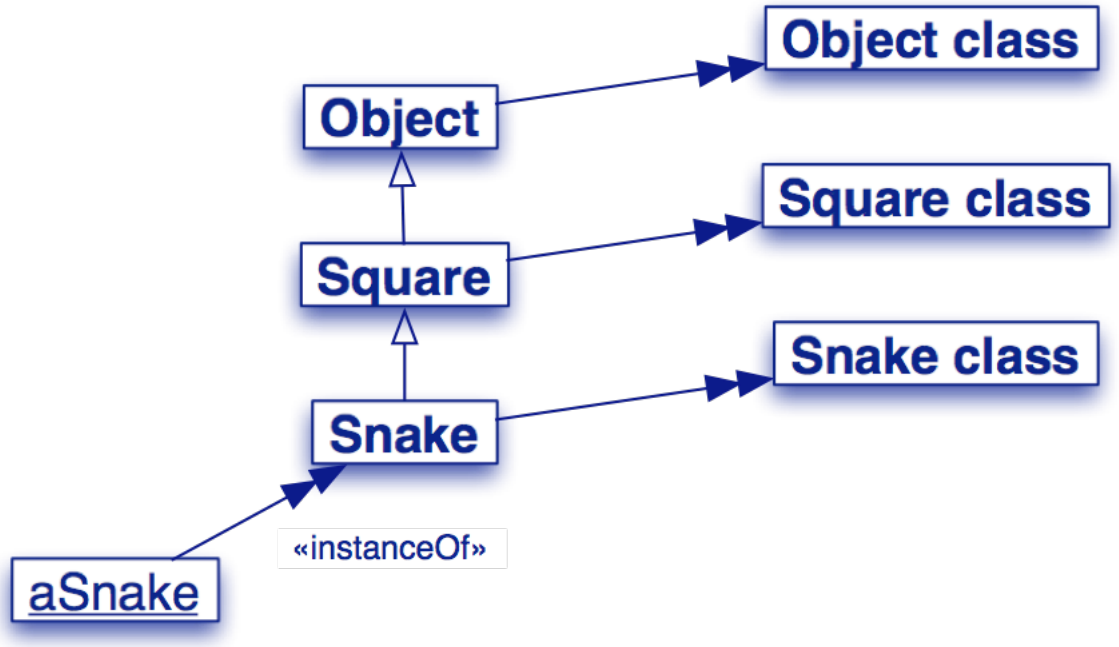
3. Every class is an instance of a metaclass

- 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)

Metaclasses by Example

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```
Square allSubclasses
Snake allSubclasses

Snake allInstances
Snake instVarNames

Snake back: 5

Snake selectors

Snake canUnderstand: #new
Snake canUnderstand: #setBack:
```

```
a Set(Snake FirstSquare Ladder)
a Set()

an Array(<-6[11] <-2[6] <-4[11])
#('back')

<-5[nil]

an IdentitySet(#printOn:
        #destination #setBack:)
false
true
```

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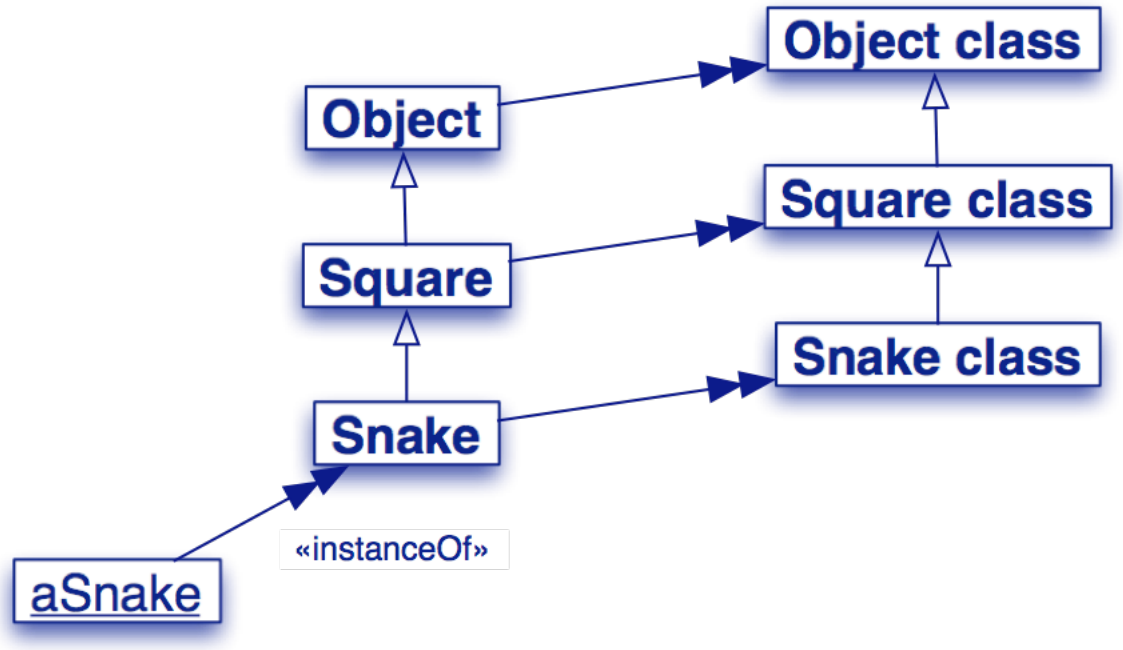
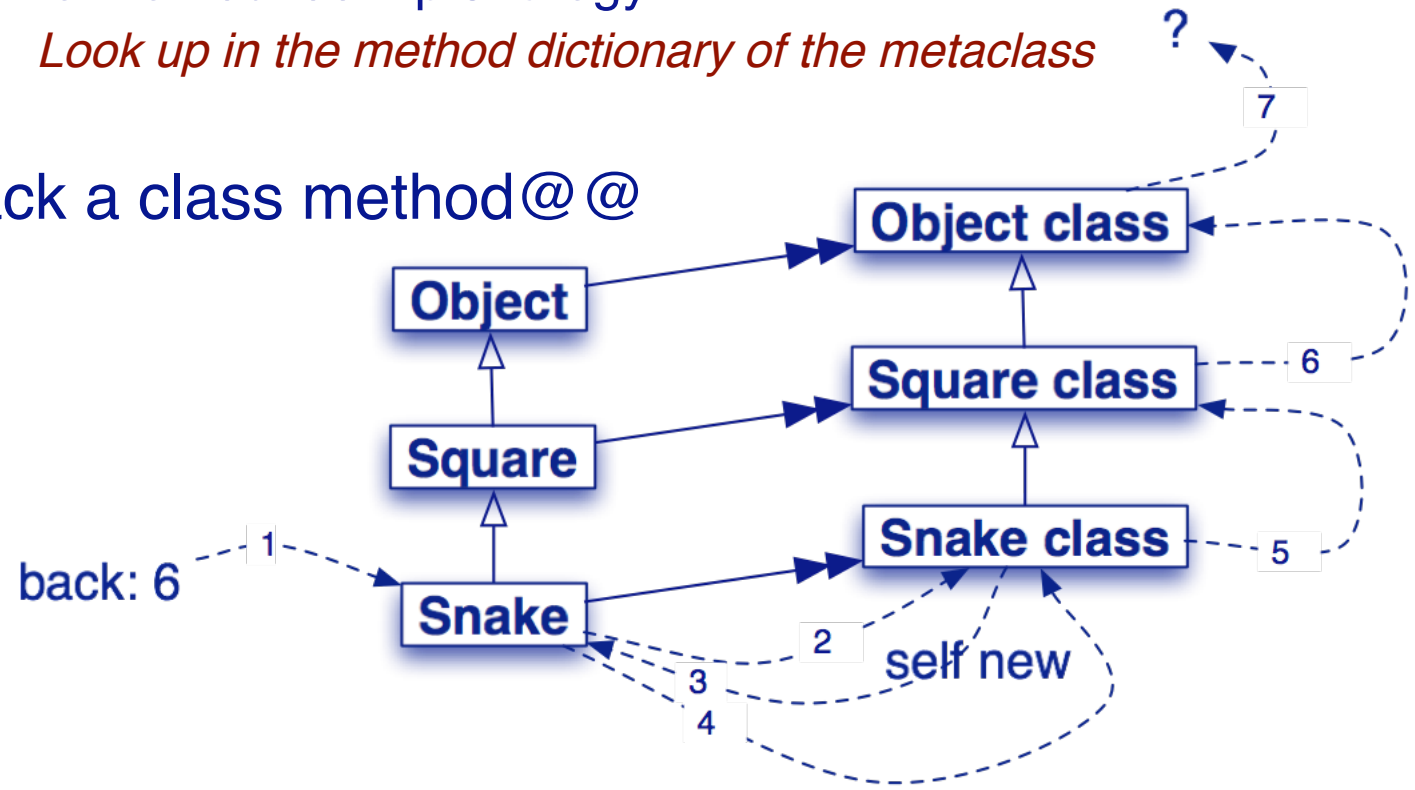
4. The metaclass hierarchy parallels the class hierarchy



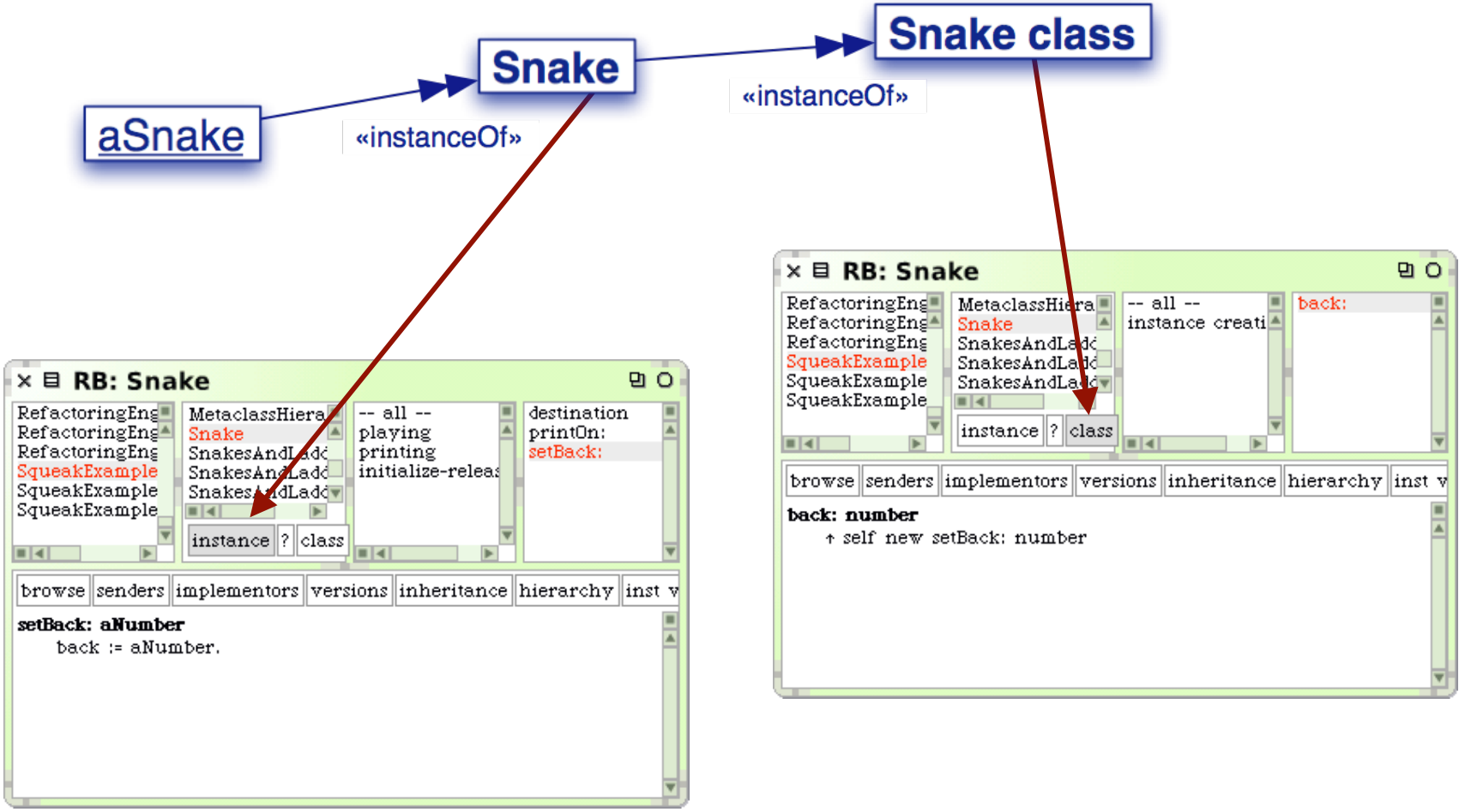
Uniformity between Classes and Objects

- 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*

@@Is back a class method@@



About the Buttons



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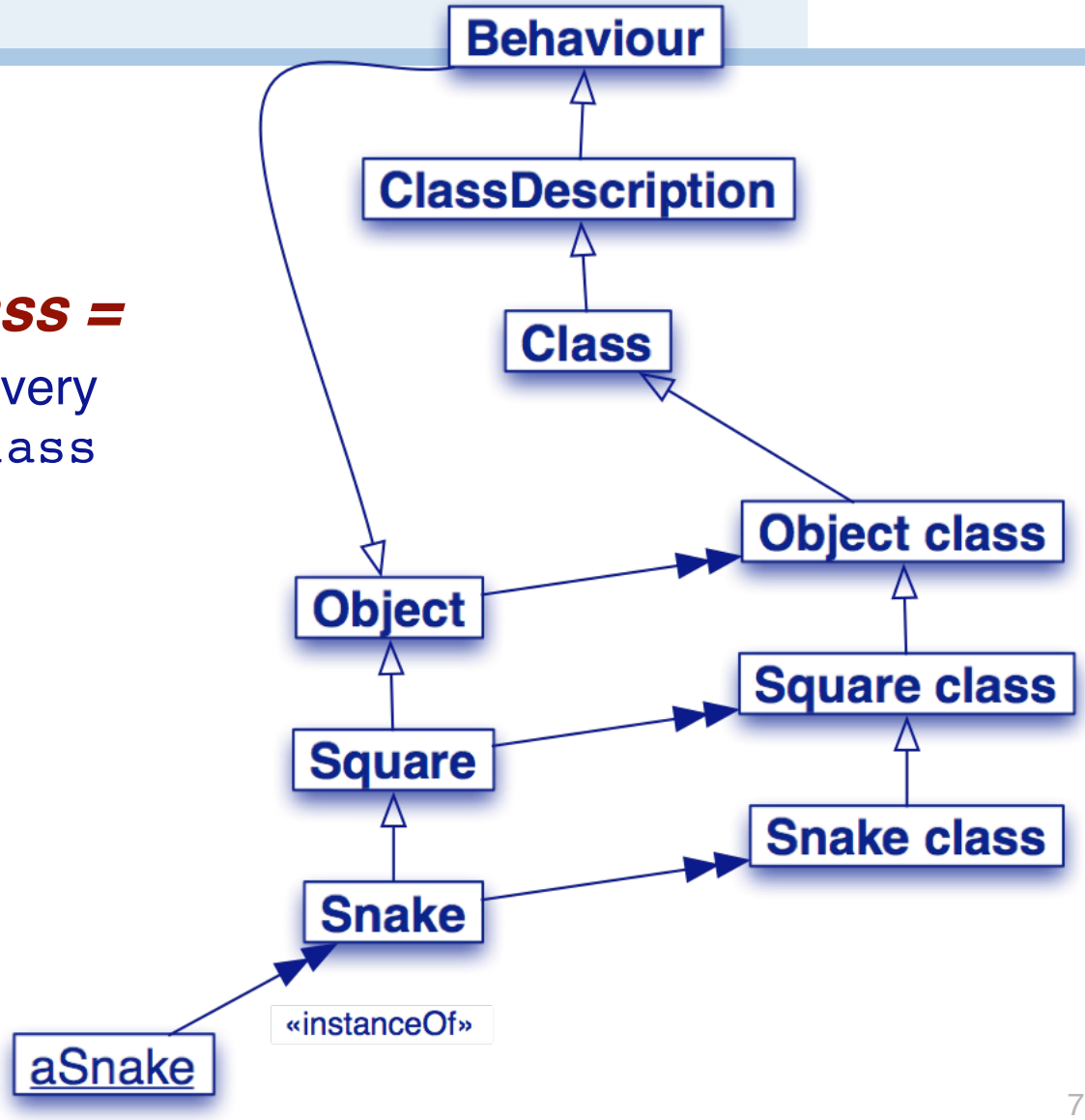
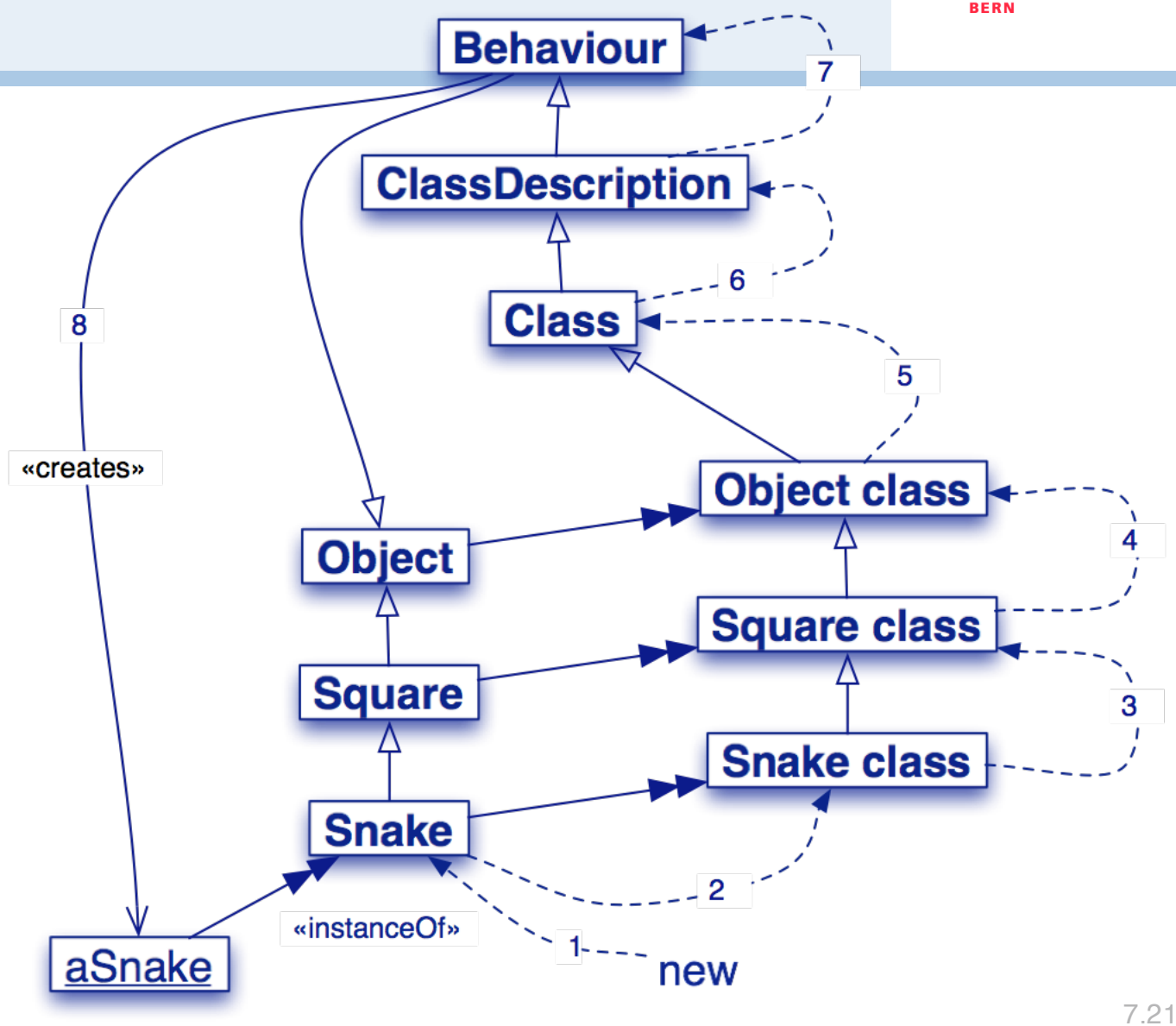
5. Every metaclass inherits from Class and Behavior

Every class is-a Class =

— The metaclass of every class inherits from `Class`



Where is new defined?



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)*
    - *accessing class hierarchy (superclass, subclasses)*
    - *testing (hasMethods, includesSelector, canUnderstand:, inheritsFrom:, isVariable)*

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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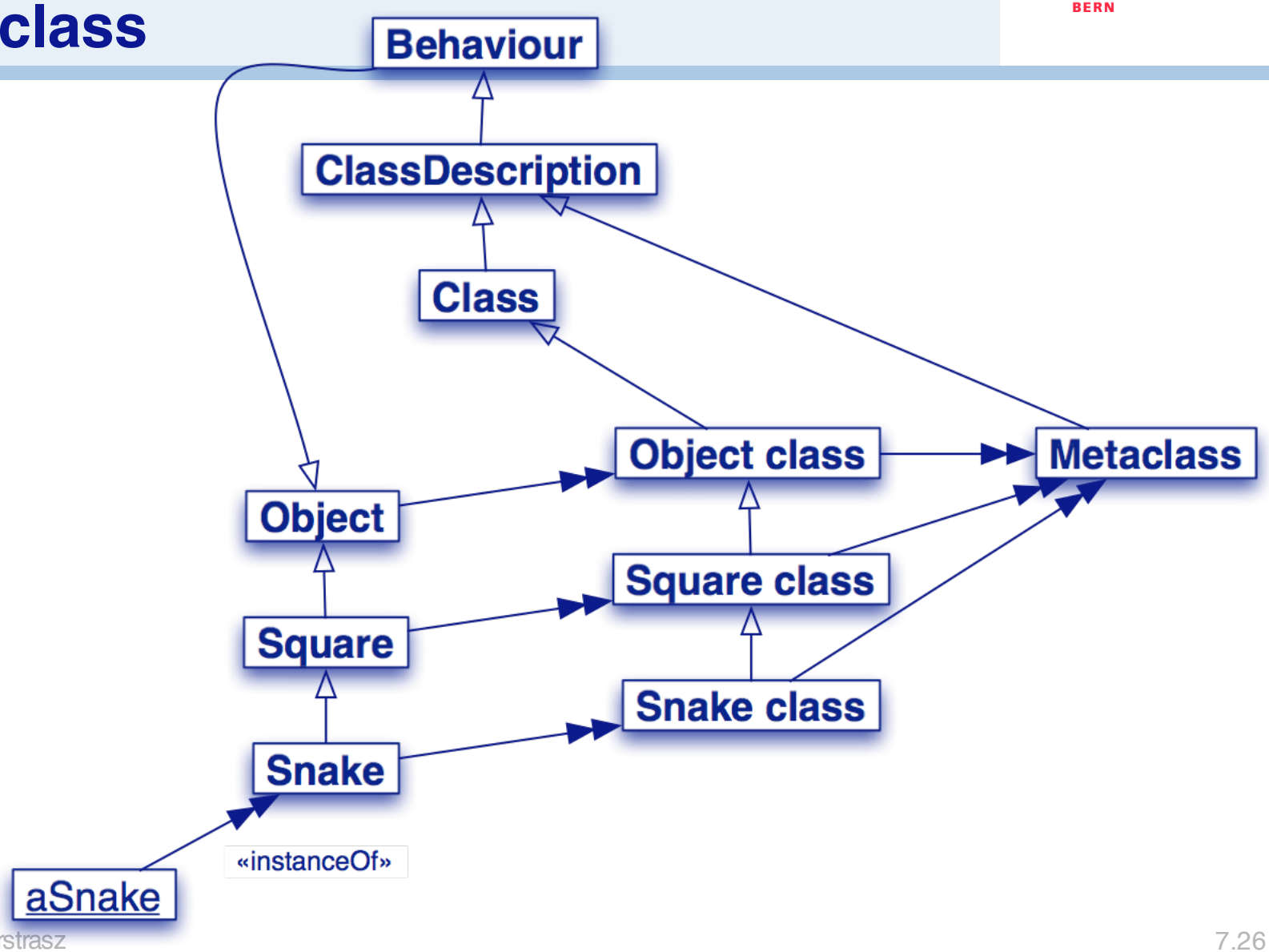
6. Every metaclass is an instance of Metaclass



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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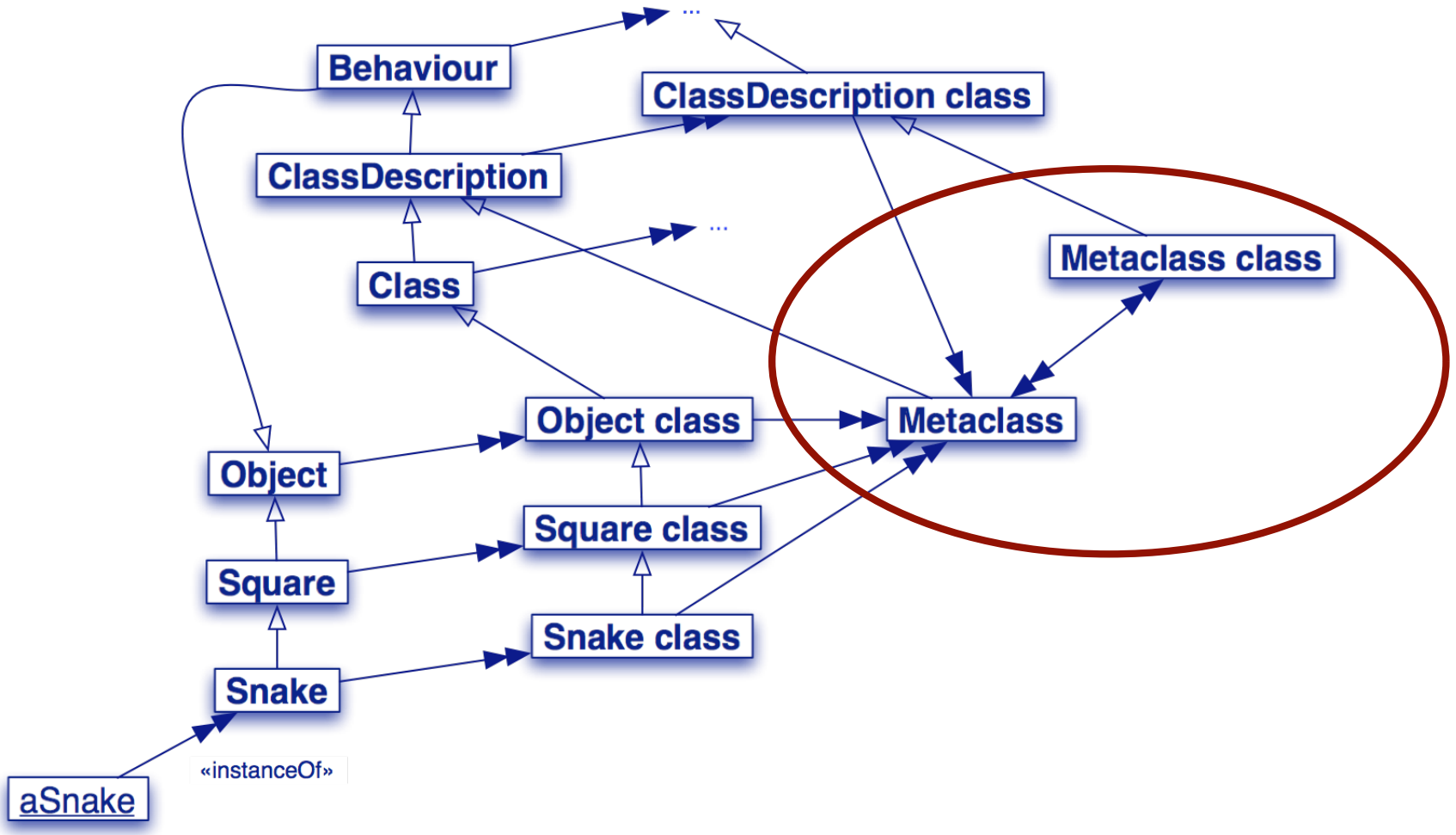

Navigating the metaclass hierarchy


```
MetaclassHierarchyTest>>testHierarchy
    "The class hierarchy"
    self assert: Snake name = 'Snake'.
    self assert: Snake superclass name = 'Square'.
    self assert: Snake superclass superclass name = 'Object'.

    "The parallel metaclass hierarchy"
    self assert: Snake class name = 'Snake class'.
    self assert: Snake class superclass name = 'Square class'.
    self assert: Snake class superclass superclass name = 'Object class'.
    …
    self assert: Snake class superclass superclass superclass superclass
name = 'Class'.
    …
    self assert: Snake class superclass superclass superclass superclass
superclass superclass superclass name = 'Object'.

    "The Metaclass hierarchy"
    self assert: Snake class class name = 'Metaclass'.
    self assert: Snake class class class name = 'Metaclass class'.
    self assert: Snake class class class class name = 'Metaclass'.
```

Roadmap

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- **Indexed Classes**
- Class Instance Variables
- Class Variables
- Pool Dictionaries

Two ways to represent objects

- Named or indexed instance variables
  - Named: `name` of `GamePlayer`
  - Indexed: `#(Jack Jill) at: 1`
- Or looking at them in another way:
  - Objects with pointers to other objects
  - Objects with arrays of bytes (word, long)
  - Difference for efficiency reasons:
    - *arrays of bytes (like C strings) are faster than storing an array of pointers, each pointing to a single byte.*

Different methods to create classes

Indexed	Named Definition Method	Examples
No	Yes	`#subclass: …`
Yes	Yes	`#variableSubclass: …`
Yes	No	`#variableByteSubclass: …`

- See the subclass creation protocol of `Class`
- Constraints
  - *Pointer classes* defined using `#subclass:` support any kind of subclasses
  - *Byte classes* defined using `#variableSubclass:` can only have: `variableSubclass:` or `variableByteSubclass:` subclasses

Testing methods

- See testing protocols of `Behavior`:
  - #isPointers, #isBits, #isBytes, #isFixed, #isVariable
  - #kindOfSubclass

Defining Indexed Classes

- Example — instantiating an Array:

```
Array new: 4
```

```
#(nil nil nil nil)
```

```
ArrayedCollection variableSubclass: #Array
   instanceVariableNames: ''
   classVariableNames: ''
   poolDictionaries: ''
   category: 'Collections-Arrayed'
```

```
#(1 2 3 4) class isVariable
```

```
true
```

Defining an Indexed Class


```
Object variableSubclass: #IndexedObject
   instanceVariableNames: ''
   classVariableNames: ''
   poolDictionaries: ''
   category: ''
```

```
(IndexedObject new: 2)
   at: 1 put: 'Jack';
   at: 2 put: 'Jill';
   at: 1
```

'Jack'

Indexed Classes / Instance Variables

- An indexed variable is implicitly added to the list of instance variables
  - Only one indexed instance variable per class
  - Access with at: and at:put:
    - *NB: answers the value, not the receiver*
- Subclasses should also be indexed

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- **Class Instance Variables**
- Class Variables
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Class Instance Variables

- Class are objects too
  - Instances of their metaclass
    - *Methods looked up in the method dictionary of their metaclass*
  - Can also define instance variables
- When a metaclass defines a new instance variable, then its instance (a Class) gets a new variable
  - I.e., in addition to `subclass`, `superclasses`, `methodDict`...
- Use class instance variables to represent the private state of the class
  - E.g., number of instances, superclass etc.
    - *Not to represent information shared by all instances!*

Example: the Singleton Pattern

- A class having only one instance
  - We keep the unique instance created in an instance variable

```
WebServer class
   instanceVariableNames: 'uniqueInstance'

WebServer class>>new
   self error: 'Use uniqueInstance to get the unique instance'

WebServer class>>uniqueInstance
   uniqueInstance isNil
      ifTrue: [uniqueInstance := self basicNew initialize].
   ^ uniqueInstance
```

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- **Class Variables**
- Pool Dictionaries

Class Variable = Shared Variable

- To share information amongst all instances of a class, use a “class variable”
  - Shared and directly accessible by all the instances of the class and subclasses
  - Accessible to both instance and class methods
  - Begins with an uppercase letter

Initializing class variables

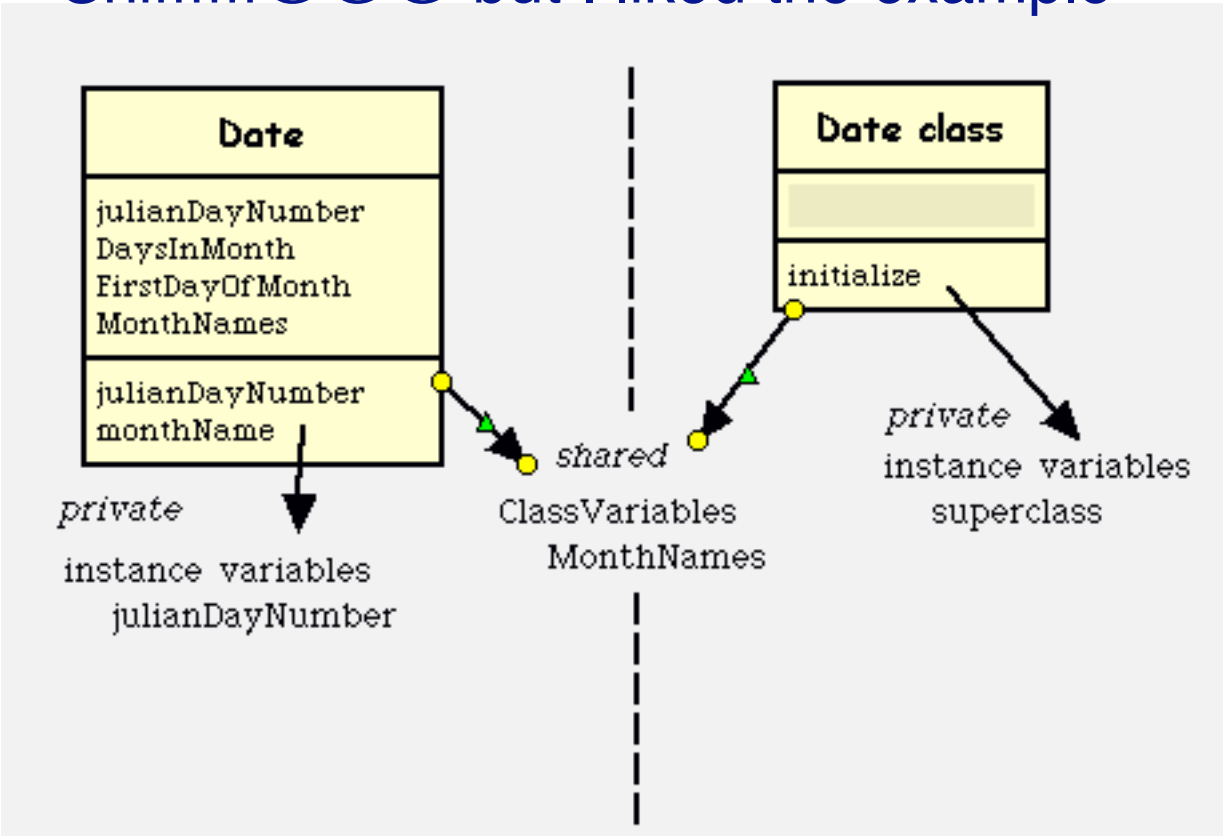
- Class variables should be initialized by an initialize method on the class side

```
Magnitude subclass: #Date
   instanceVariableNames: 'julianDayNumber '
   classVariableNames: 'DaysInMonth FirstDayOfMonth
      MonthNames SecondsInDay WeekDayNames '
   poolDictionaries: ''
   category: 'Kernel-Magnitudes'

Date class>>initialize
   ...
   WeekDayNames := #(Sunday Monday ...).
   MonthNames := #(January February ... ).
   DaysInMonth := #(31 28 31 30 31 30 31 31 30 31 30 31).
```

ClassVariables vs. Instance Variables

@@@This is not like that anymore in Squeak Snifffffff@@@ but I liked the example



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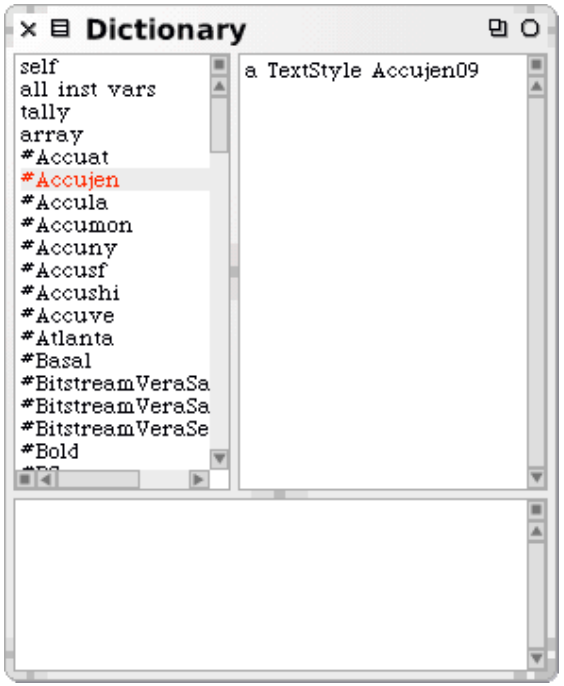
- Class Variables
- **Pool Dictionaries**

Pool Dictionaries

- A Pool Dictionary is a shared variable
  - Begins with a uppercase letter.
  - Shared by a group of classes not linked by inheritance.
- Each class possesses its own pool dictionary (containing pool variables).
  - They are not inherited.
- ***Don't use them!***

Examples of Pool Dictionaries


```
ArrayedCollection subclass: #Text
   instanceVariableNames: 'string runs'
   classVariableNames: ''
   poolDictionaries: 'TextConstants'
   category: 'Collections-Text'
```

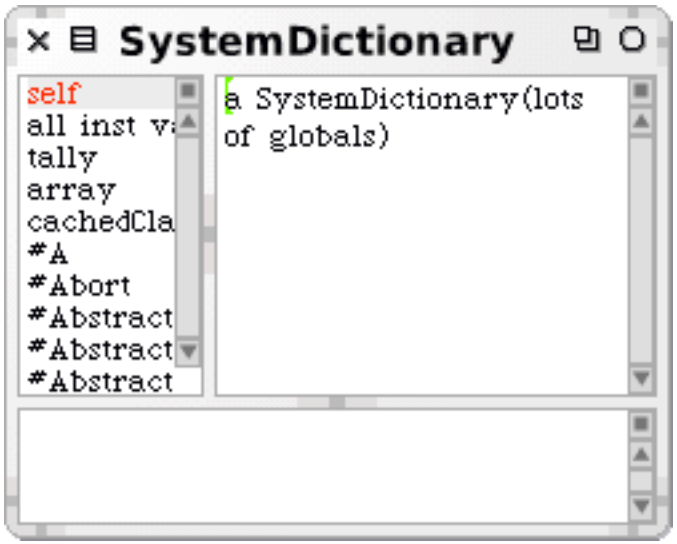


- Elements stored into TextConstants like `Ctrl`, `CR`, `ESC`, `Space` can be directly accessed from all the classes like `ParagraphEditor`....
- ***Hint:*** You can inspect any Pool Dictionary

Smalltalk System Dictionary

- Pool Dictionaries are stored in the Smalltalk system dictionary

```
Smalltalk inspect
```




```
(Smalltalk at: #TextConstants) at: #ESC
```

$

Accessing globals

> Use message-sending instead of directly accessing pool variables

```
stream nextPut: Lf "A pool variable visible to the class"
```

VS.

```
stream nextPut: Character lf
```

What you should know!

- *What does is-a mean?*
- *What is the difference between sending a message to an object and to its class?*
- *What are the responsibilities of a metaclass?*
- *What is the superclass of* `Object class`*?*
- *Where is* `new` *defined?*
- *What is the difference between class variables and class instance variables?*

Can you answer these questions?

- *Why are there no explicit metaclasses?*
- *When should you override* `new`*?*
- *Why don't metaclasses inherit from* `Class`*?*
- *Are there any classes that don't inherit from* `Object`*?*
- *Is* `Metaclass` *a* `Class`*? Why or why not?*
- *Where are the methods* `class` *and* `superclass` *defined?*
- *When should you define an indexed class?*
- *Are Java static variables just like class variables or class instance variables?*
- *Where is the* `SystemDictionary Smalltalk` *defined?*

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