

Smalltalk Lecture 9

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Metaclasses in 7 points

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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

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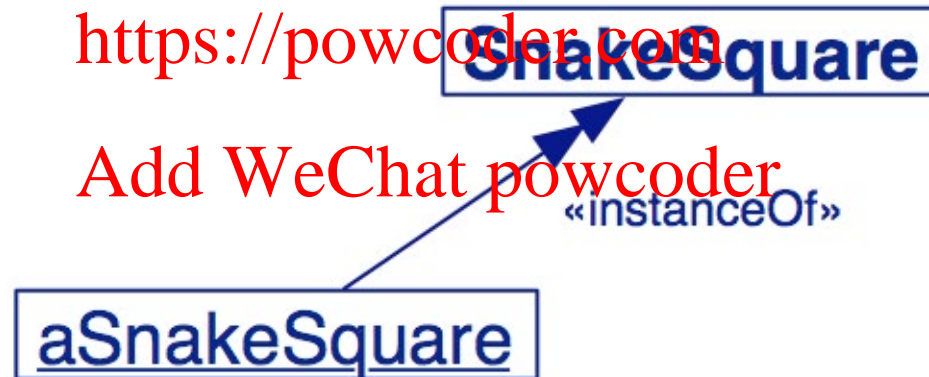
1. Every object is an instance of a class

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2. Every class inherits from Object

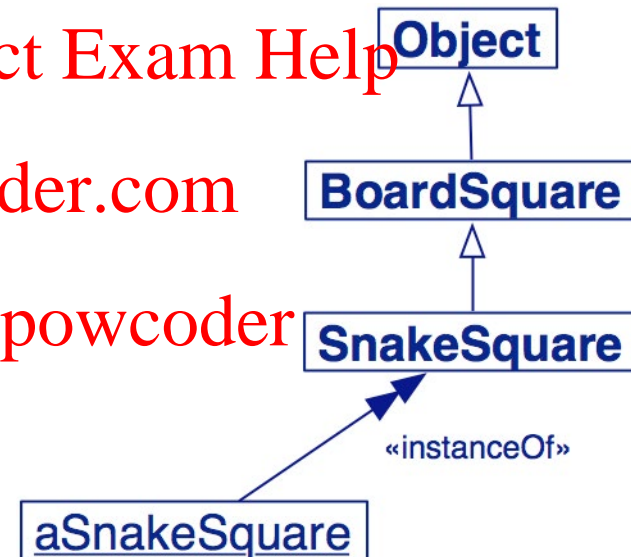
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> **Every object is-an Object =**

- The class of every object ultimately inherits from Object

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aSnakeSquare is-a SnakeSquare
and is-a BoardSquare
and is-an Object



Caveat: in some Smalltalk systems, Object has a superclass called ProtoObject

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The Meaning of is-a

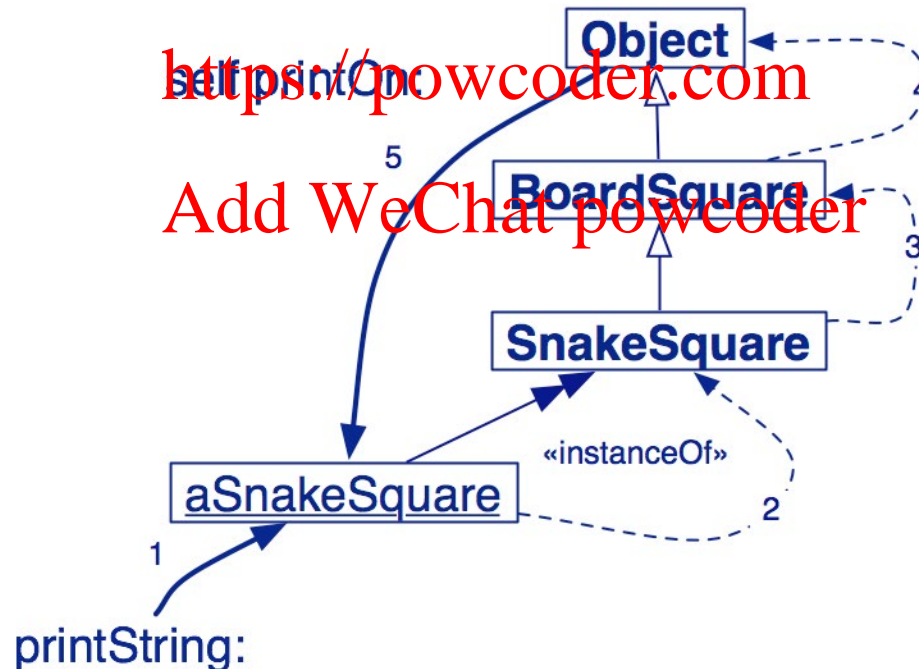
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- > When an object receives a message, the method is looked up in the method dictionary of its class, and, if necessary, its superclasses, up to Object.

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Responsibilities of Object

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- > **Object** <https://powcoder.com>
 - represents the common object behavior
 - *error-handling, halting ...*
 - all classes should inherit ultimately from `Object`

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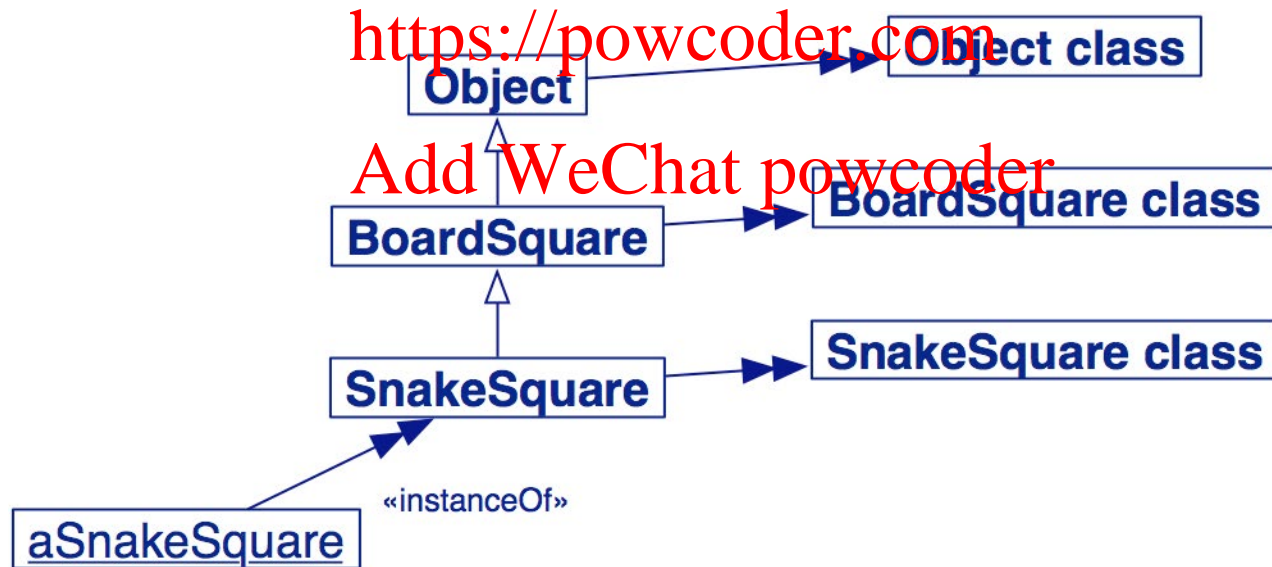
3. Every class is an instance of a metaclass

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> ***Classes are objects too!***

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

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Metaclasses are implicit

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- > ***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

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```
345 class
SmallInteger superclass
Integer allSubclasses
```

```
Integer canUnderstand: #append:
Integer canUnderstand: #binomial
Integer selectors
```

Class methods are instance methods of the metaclass.

Class variables are NOT instance variables of the metaclass.

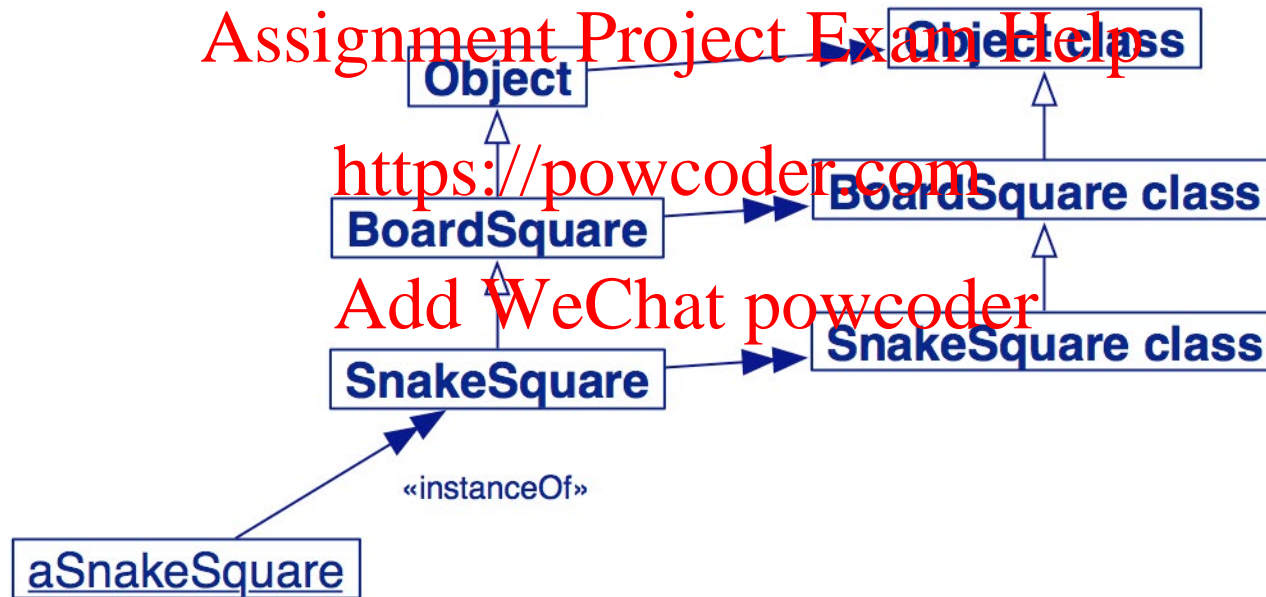
Class instance variables are a new concept not found in C++/Java.

```
SmallInteger
Integer
Set (LargePositiveInteger LargeNegativeInteger
LargeInteger SmallInteger LargeZeroInteger)
false
true
Set (#binomial: #truncated #anyMask: #digitAt:
#clearBit: #ceilingLog: #timesRepeat:
#numerator #denominator #hash
#printPaddedWith:to:base: #printPaddedWith:to:
#gcd: #setBit: #noMask: #bitClear: #ceiling
#lcm: #storeOn:base: #isBitSet: #even
#estimatedLog #printOn: #printStringRadix:
#storeString #floor #replace:withStringBase:
#storeLiteralOn: #rounded #factorial #allMask:
#floorLog: #coerce: #odd #isInteger
#displayString #printString
#printOn:paddedWith:to:base: #bitAt:
#bitInvert #highBit #alignTo:
#printOn:paddedWith:to: #asCharacter
#displayOn: #printOn:base: #printString:
#isRational #bitAt:put: #asFraction
#asScaledDecimal: #radix: #lowBit #storeOn:
#isLiteralObject )
```

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4. The metaclass hierarchy parallels the class hierarchy

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- > Classes are objects too, so ...

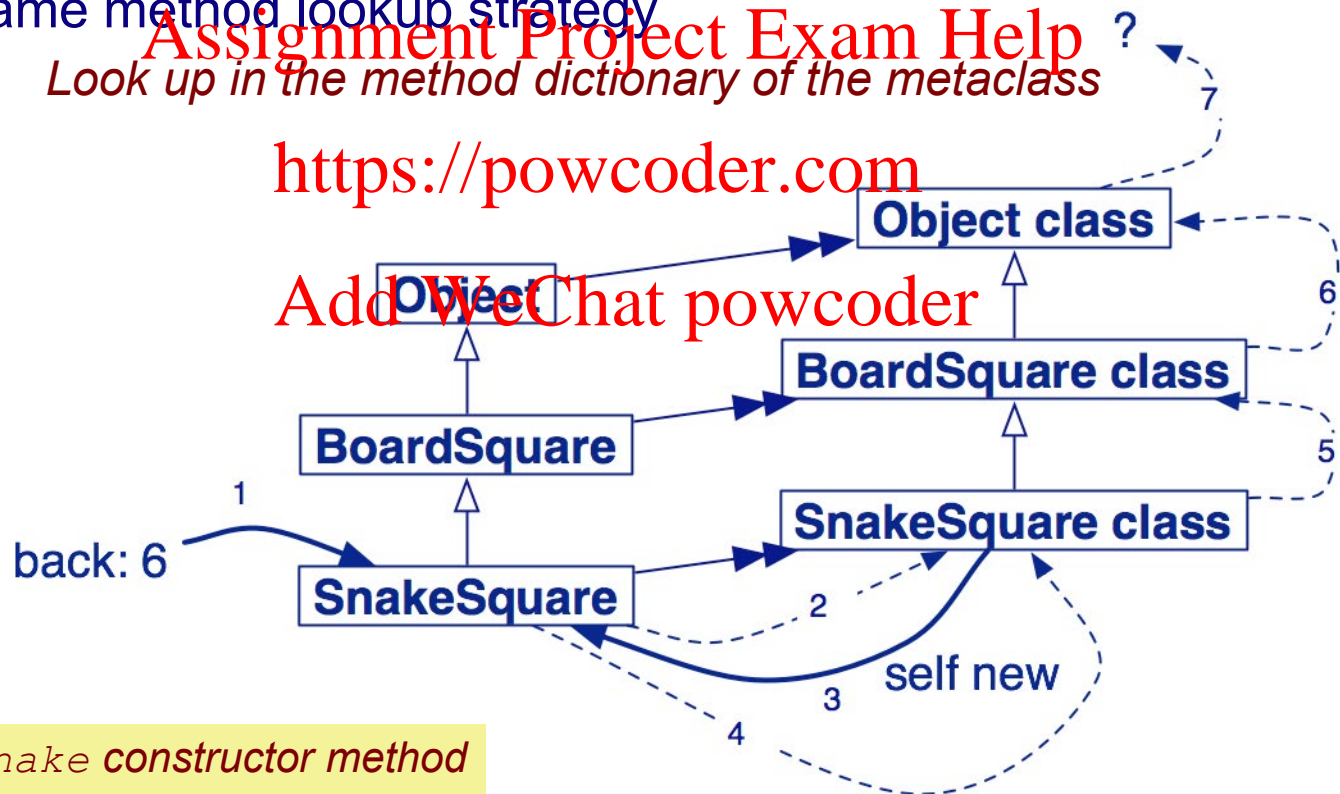
- Everything that holds for objects holds for classes as well

- Same method lookup strategy

- Look up in the method dictionary of the metaclass

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back: is a *Snake* constructor method

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5. Every metaclass inherits from Class and Behavior

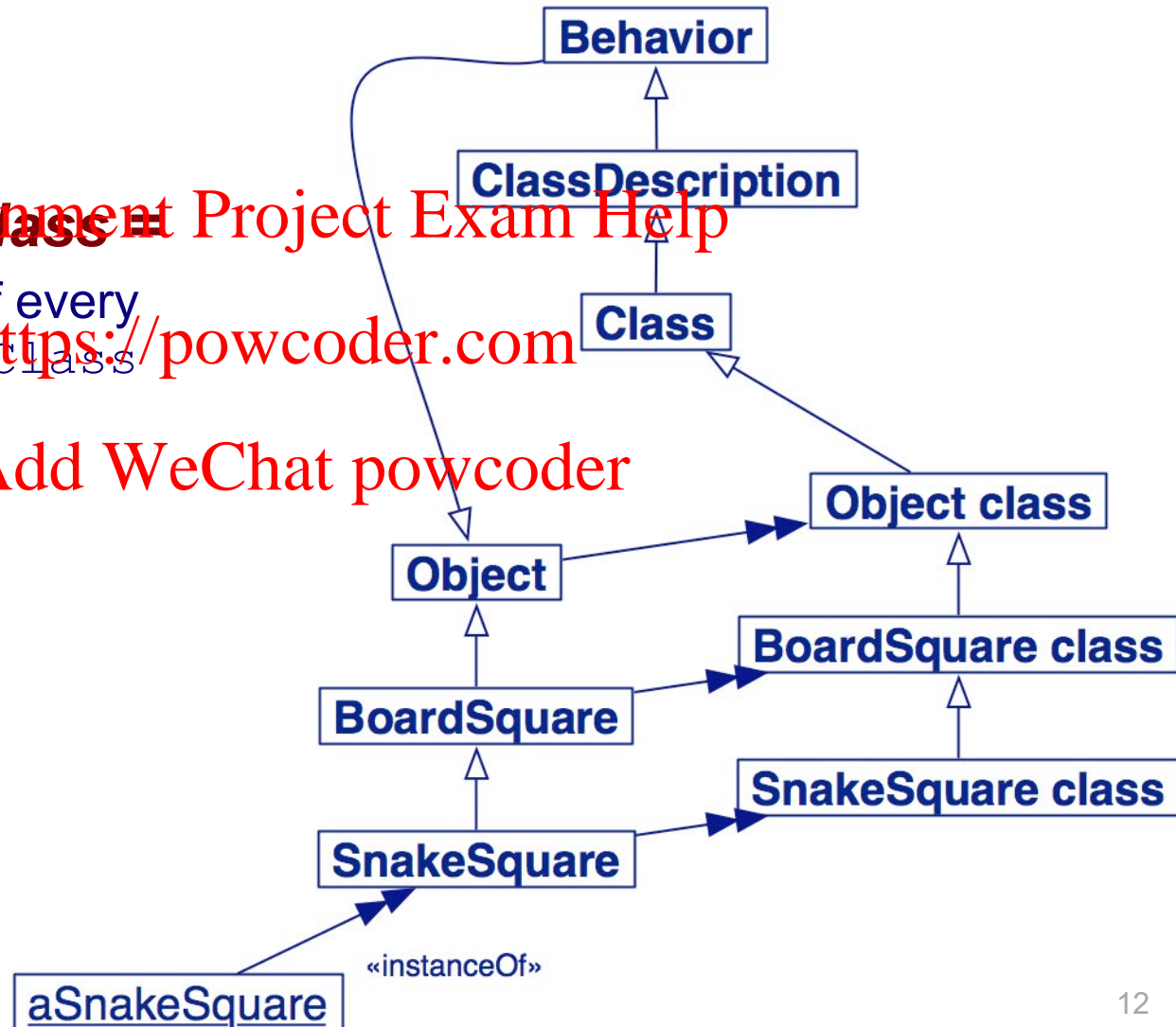
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Every class is a Class =

—The metaclass of every class inherits from Class

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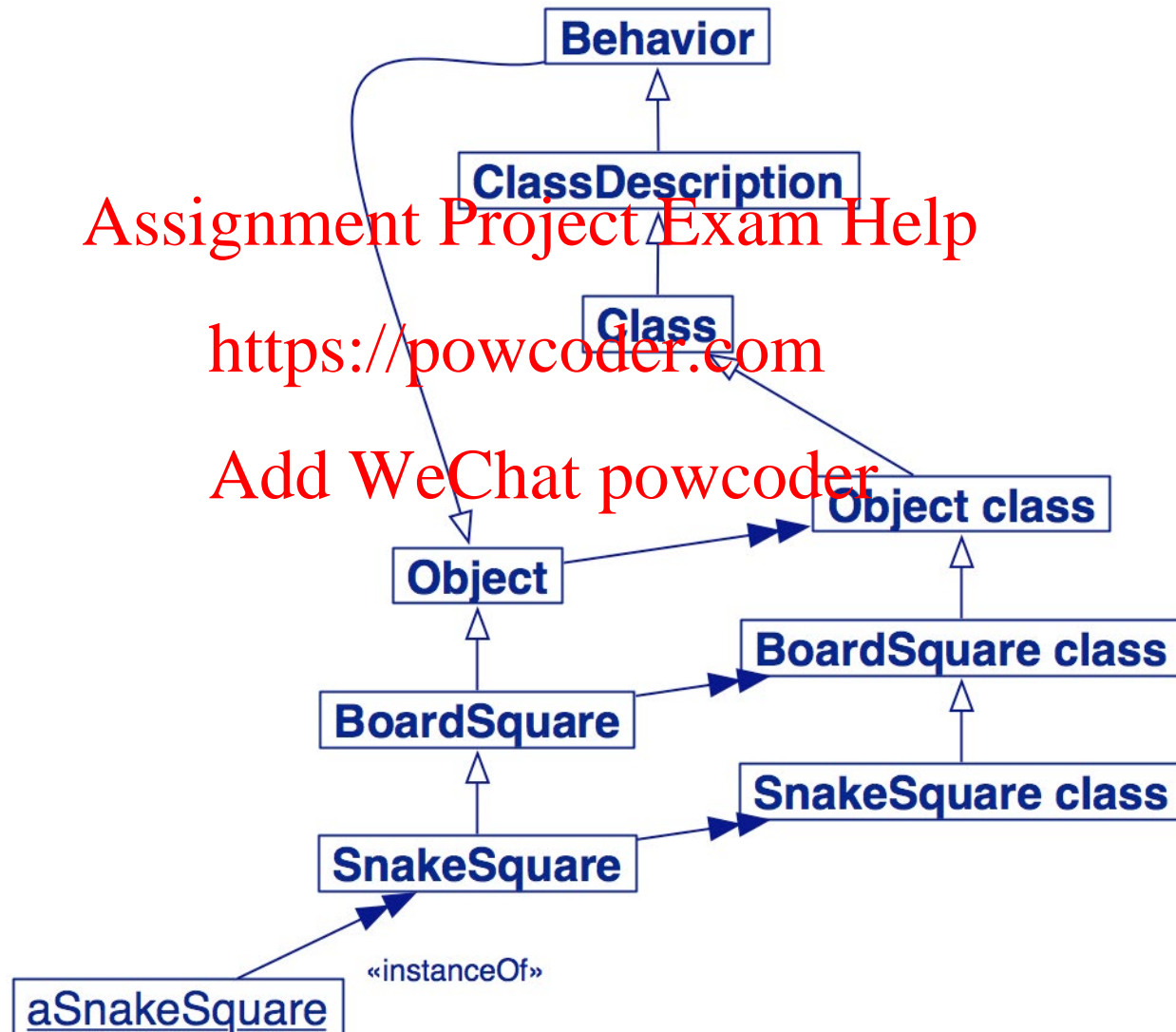
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Where is new defined?

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Responsibilities of Behavior

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> 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)*

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Responsibilities of `ClassDescription`

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> `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`.

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Responsibilities of Class

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- > **Class** Assignment Project Exam Help
 - represents the common behavior of all classes
 - *name, compilation, method storing, instance variables ...*
 - representation for classVariable names and shared pool variables (`addClassName`, `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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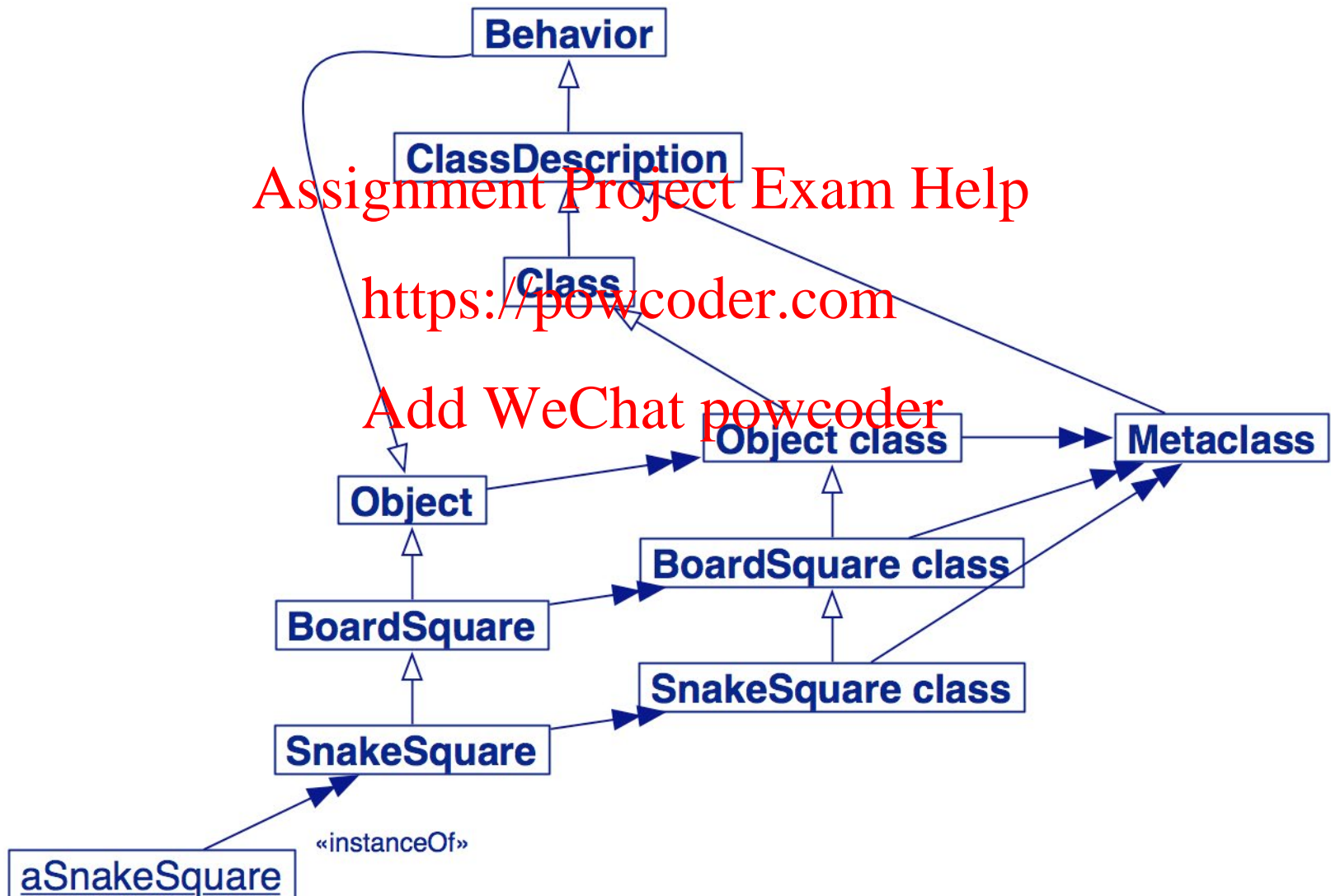
6. Every metaclass is an instance of Metaclass

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Metaclass Responsibilities

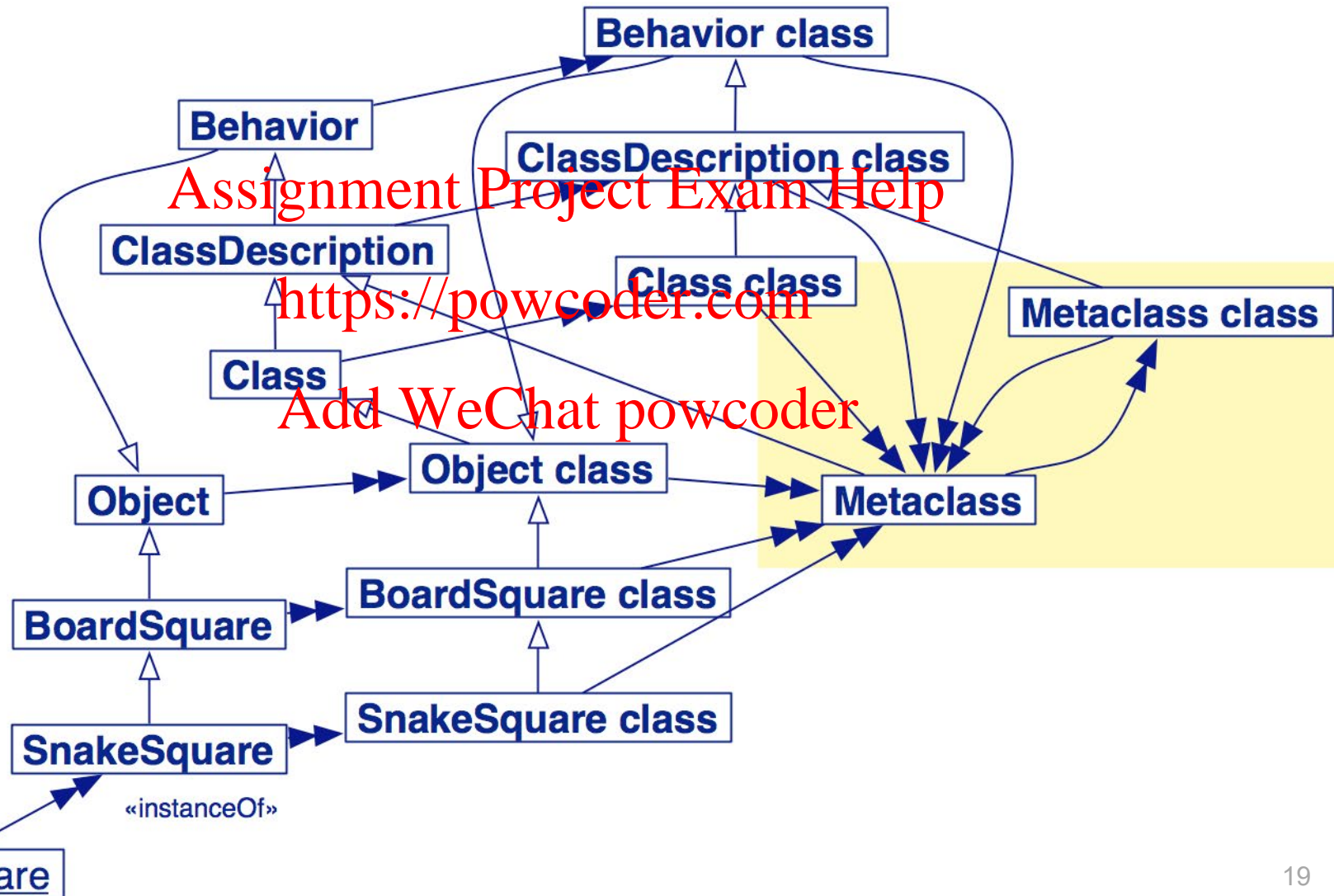
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- > **Metaclass**
- Represents common metaclass Behavior
 - *instance creation (subclassOf:)*
 - *creating initialized instances of the metaclass's sole instance*
 - *initialization of class variables*
 - *metaclass instance protocol (name:inEnvironment:subclassOf:....)*
 - *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

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Class Instance Variables

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- > 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.
 - *Be sure to distinguish whether you need a class variable or an instance variable or a class instance variable.*

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Example: the Singleton Design Pattern

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

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```
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 Variable = Shared Variable

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- > 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

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Initializing class variables

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- > Class variables should be initialized by an `initialize` method on the class side, or by lazy initialization

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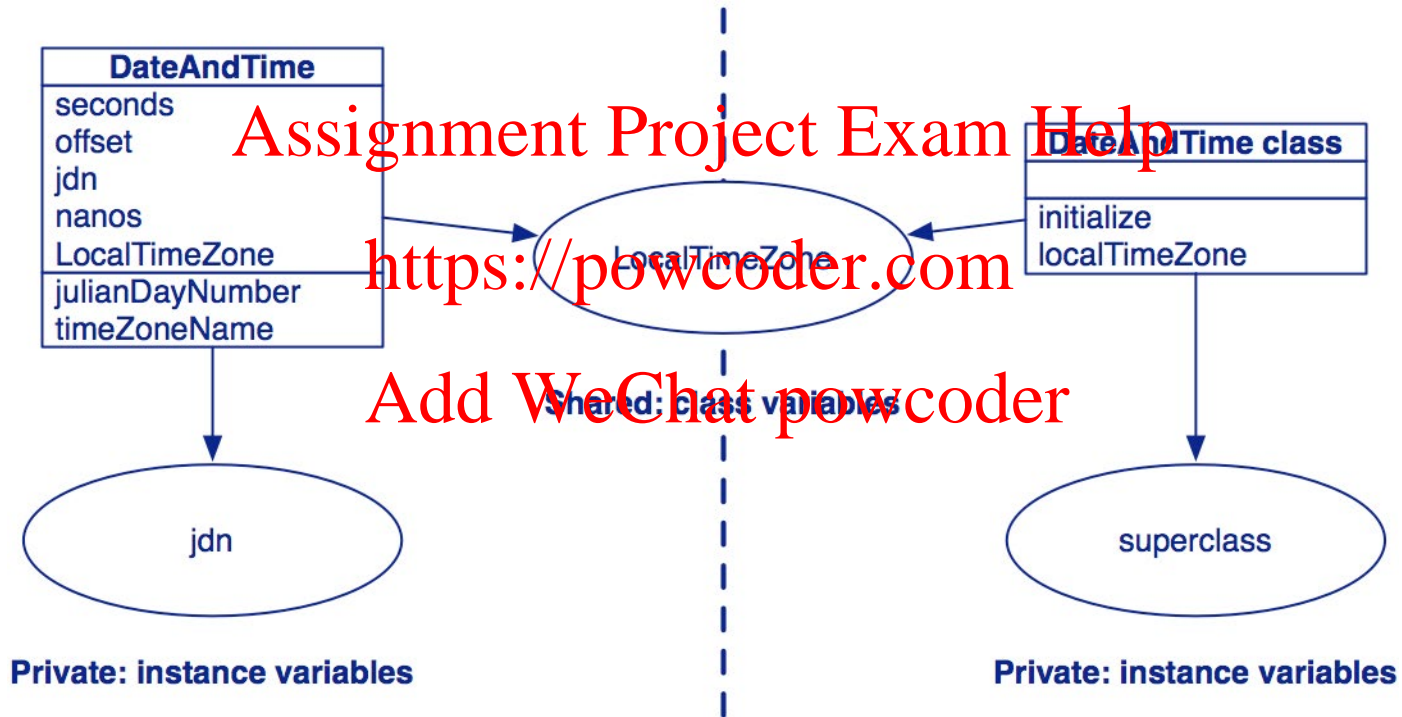
```
Magnitude subclass: #DateAndTime.  
DateAndTime instanceVariableNames: 'seconds offset jdn nanos'.  
DateAndTime addClassVarName: 'LocalTimeZone'.
```

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```
Date class>>localTimeZone  
    "Answer the local time zone"  
  
    ^ LocalTimeZone ifNil: [ LocalTimeZone := TimeZone default ]
```

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Instance Variables vs. Class Variables vs. Class Instance Variables



Reflection, Introspection, Intercession, Reification (Meta-programming)

- > Reflection is the ability of a program to *manipulate as data* something representing the state of the program during its own execution.
 - Introspection is the ability for a program to *observe* and therefore *reason* about its own state.
 - Intercession is the ability for a program to *modify* its own execution state or *alter its own interpretation* or meaning.
- > Reification is the mechanism for encoding execution state as data

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The Essence of a Class

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1. A format <https://powcoder.com>
— I.e., a number of instance variables and types
2. A superclass Add WeChat powcoder
3. A method dictionary

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Behavior class>> new

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> In Pharo:

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```
Behavior class>>new
| classInstance |
classInstance := self basicNew.
classInstance methodDictionary:
    classInstance emptyMethodDictionary.
classInstance superclass: Object.
classInstance setFormat: Object format.
^ classInstance
```

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NB: not to be confused with Behavior>>new!

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The Essence of an Object

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1. Class pointer
 2. Values
- > Can be special:
- `SmallInteger`
 - Indexed rather than pointer values
 - Compact classes (`CompiledMethod`, `Array ...`)

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Metaobjects vs metaclasses

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- > Need distinction between metaclass and metaobject!
 - A metaclass is a class whose instances are classes
 - A metaobject is an object that describes or manipulates other objects
 - *Different metaobjects can control different aspects of objects*

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Some MetaObjects

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- > **Structure:**
 - Behavior, ClassDescription, Class, Metaclass, ClassBuilder
- > **Semantics:**
 - Compiler, Decompiler, IRBuilder
- > **Behavior:**
 - CompiledMethod, BlockContext, Message, Exception
- > **ControlState:**
 - BlockContext, Process, ProcessorScheduler
- > **Resources:**
 - WeakArray
- > **Naming:**
 - SystemDictionary
- > **Libraries:**
 - MethodDictionary, ClassOrganizer

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Accessing state

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> Object>>instVarNamed: aString
> Object>>instVarNamed: aString put: anObject
> Object>>instVarAt: aNumber
> Object>>instVarAt: aNumber put: anObject

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```
pt := 10@3.  
pt instVarNamed: 'x'.  
pt instVarNamed: 'x' put: 33.  
pt
```

```
10  
  
33@3
```

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Accessing meta-information

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- > `Object>>class`
- > `Object>>identityHash`

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```
'hello' class  
(10@3) class  
Smalltalk class  
Class class  
Class class class  
Class class class class
```

```
'hello' identityHash  
Object identityHash  
5 identityHash
```

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```
ByteString  
Point  
SystemDictionary  
Class class  
Metaclass  
Metaclass class
```

```
2664  
2274  
5
```


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Code metrics

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Collection allSuperClasses size.	2
Collection allSelectors size.	192
Collection allInstVarNames size.	0
Collection selectors size.	53
Collection instVarNames size.	0
Collection subclasses size.	4
Collection allSubclasses size.	43

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Recap: Classes are objects too

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> Object

- Root of inheritance
- Default Behavior
- Minimal Behavior

> Behavior

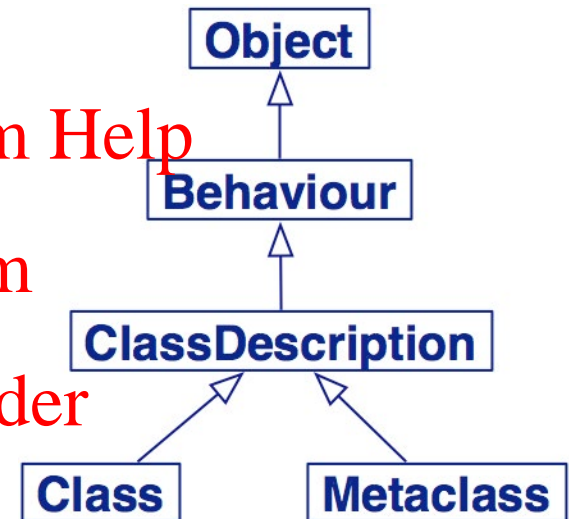
- Essence of a class
- Anonymous class
- Format, methodDict, superclass

> ClassDescription

- Human representation and organization

> Metaclass

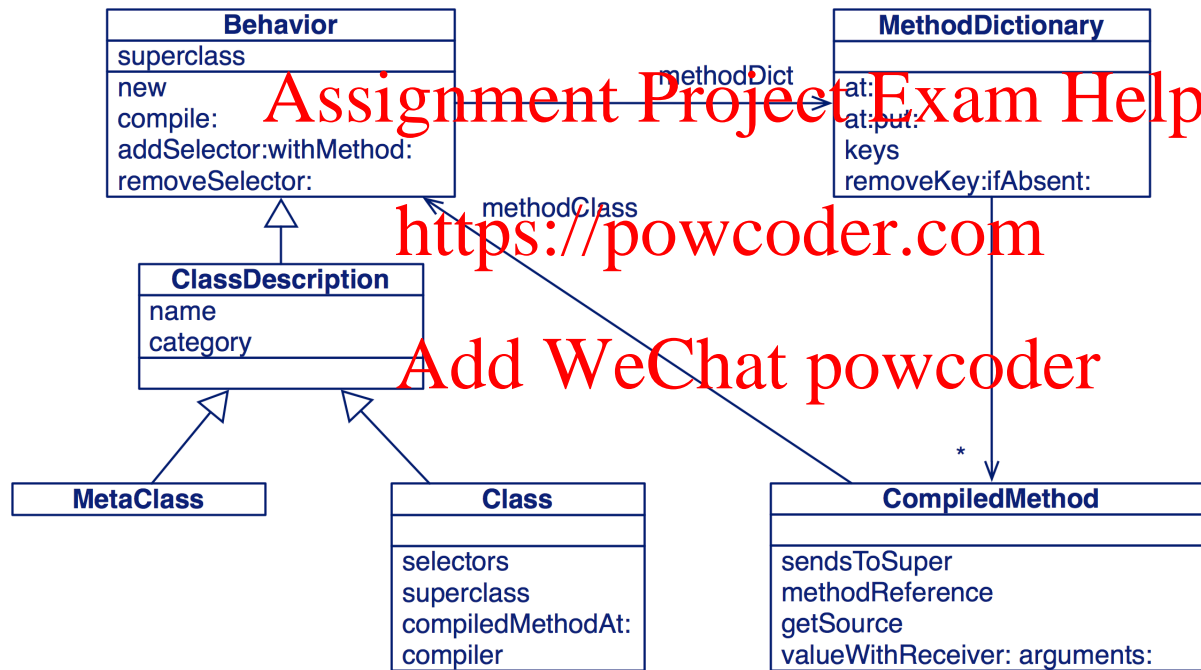
- Sole instance



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Classes are Holders of CompiledMethods

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Invoking a message by its name

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```
Object>>perform: aSymbol  
Object>>perform: aSymbol with: arg
```

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> Asks an object to execute a message

— Normal method lookup is performed

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```
5 factorial
```

```
120
```

```
5 perform: #factorial
```

```
120
```

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Executing a compiled method

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```
CompiledMethod>>valueWithReceiverArguments:
```

> No lookup is performed!

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```
(SmallInteger>>#factorial)  
valueWithReceiver: 5  
withArguments: #()
```

```
Error: key not found
```

```
(Integer>>#factorial)  
valueWithReceiver: 5  
withArguments: #()
```

```
120
```

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Example of class initialization

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- > MagnitudeAssignment: #DateProject Exam Help
- > instance variable names:
 - day
 - year
- > classVariableNames:
 - DaysInMonth
 - FirstDayOfMonth
 - MonthNames
 - SecondsInDay
 - WeekDayNames

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Date class>>initialize

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- > Date class>>initialize
- > "Initialize class variables representing the names of the months and
- > days and the number of seconds, days in each month, and first day of
- > each month. " <https://powcoder.com>
- > MonthNames := #(#January #February #March #April #May #June
- > #July #August #September #October #November #December).
- > SecondsInDay := 24 * 60 * 60.
- > DaysInMonth := #(31 28 31 30 31 30 31 31 30 31 30 31).
- > FirstDayOfMonth := #(1 32 60 91 121 152 182 213 244 274 305 335).
- > WeekDayNames := #(#Monday #Tuesday #Wednesday #Thursday
- > #Friday #Saturday #Sunday)