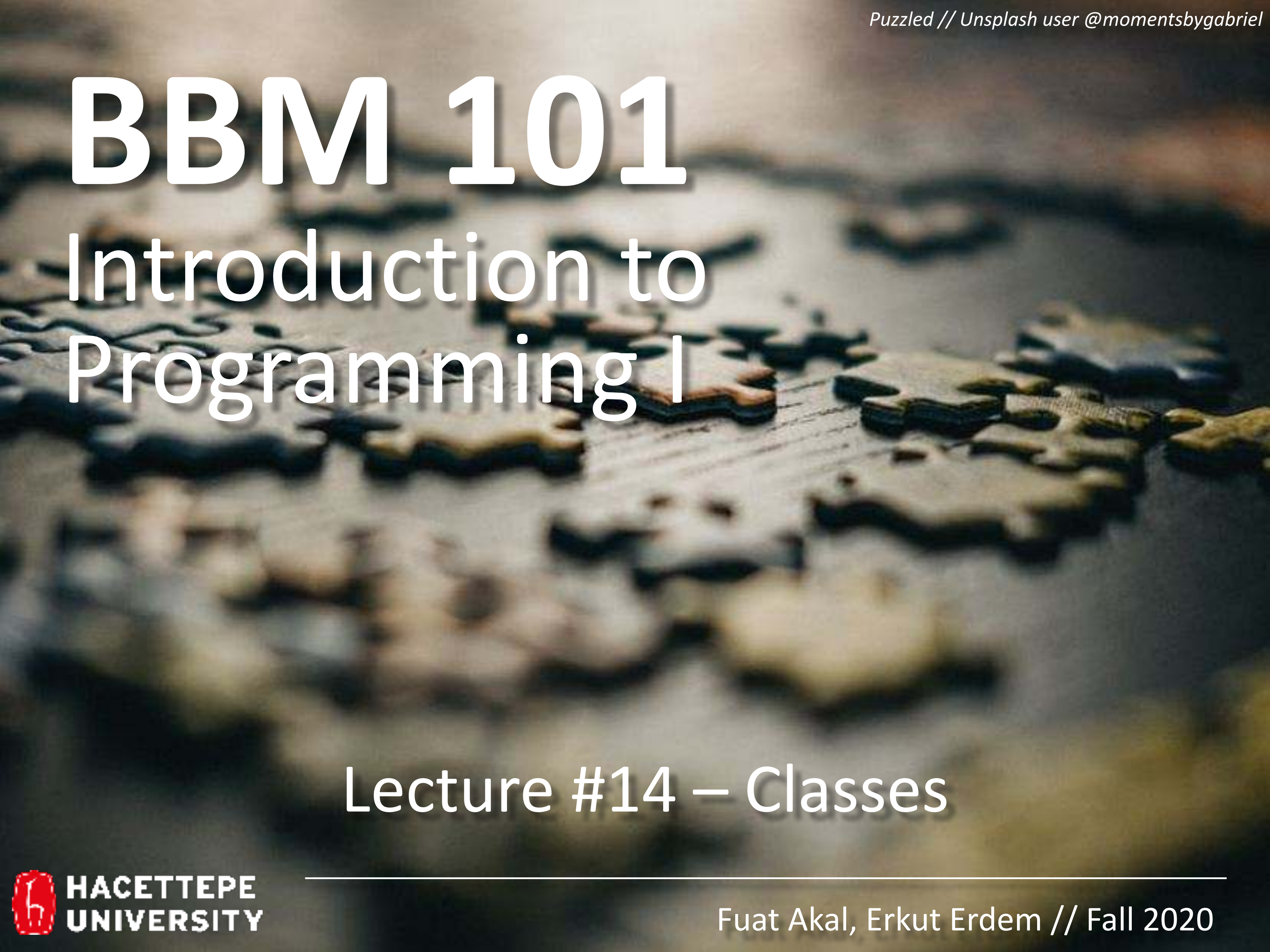


Puzzled // Unsplash user @momentsbygabriel

BBM 101

Introduction to Programming I

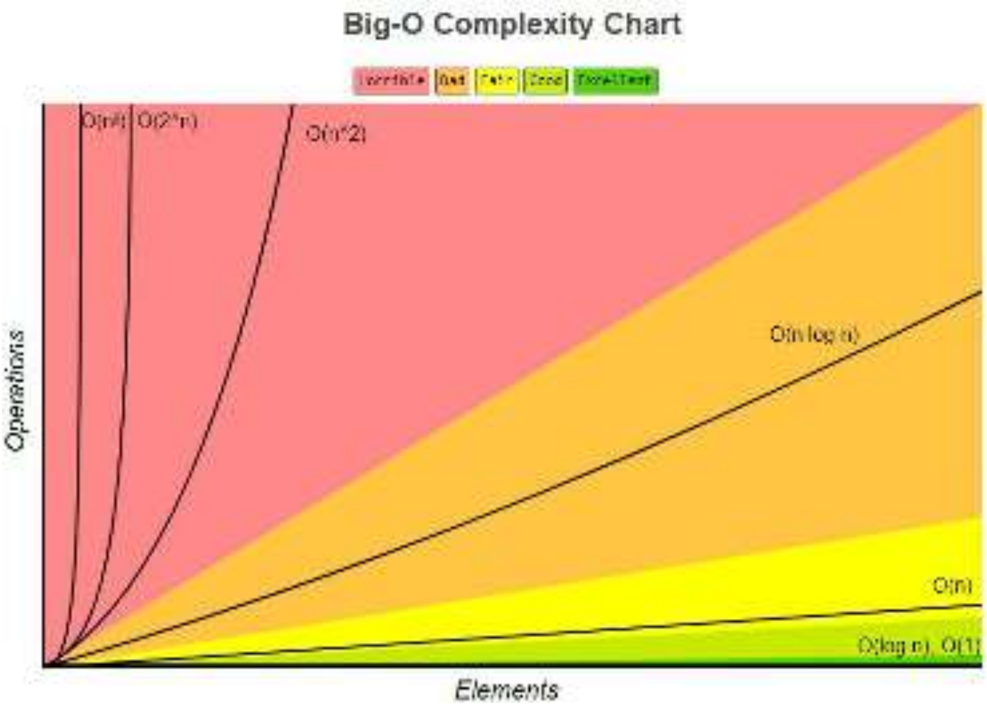
Lecture #14 – Classes

HACETTEPE UNIVERSITY

Fuat Akal, Erkut Erdem // Fall 2020

Last time… **Algorithmic Speed**

- ***O(1)*** denotes constant running time
- ***O(log n)*** denotes logarithmic running time
- ***O(n)*** denotes linear running time
- ***O(n log n)*** denotes log-linear running time
- ***O(n^c)*** denotes polynomial running time
  (*c* is a constant)
- ***O(c^n)*** denotes exponential running time
  (*c* is a constant being raised to a power based on size of input)



Lecture Overview

- Classes
  - Object Oriented Programming
  - Class Statements
  - Methods
  - Attributes
  - Inheritence

Disclaimer: Much of the material and slides for this lecture were borrowed from John DeNero’s Berkeley CS 61A

Lecture Overview

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Object-Oriented Programming

- A method for organizing programs
  - Data abstraction
  - Bundling together information and related behavior

- A metaphor for computation using distributed state Each object has its own local state
  - Each object also knows how to manage its own local state, based on method calls
  - Method calls are messages passed between objects
  - Several objects may all be instances of a common type
  - Different types may relate to each other

- Specialized syntax & vocabulary to support this metaphor

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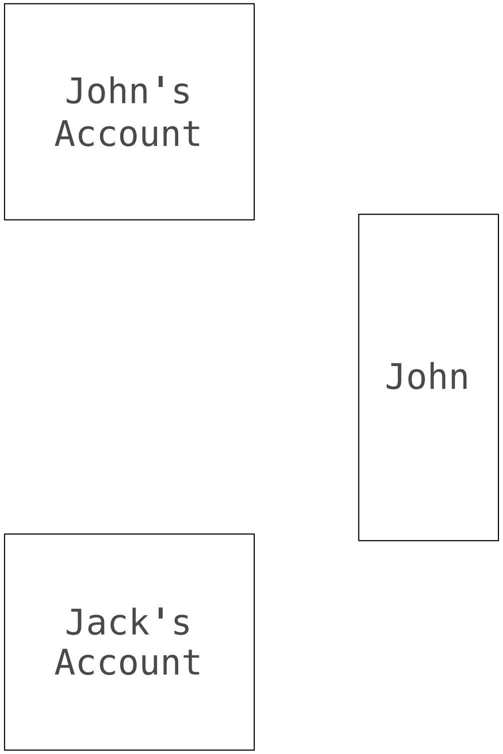

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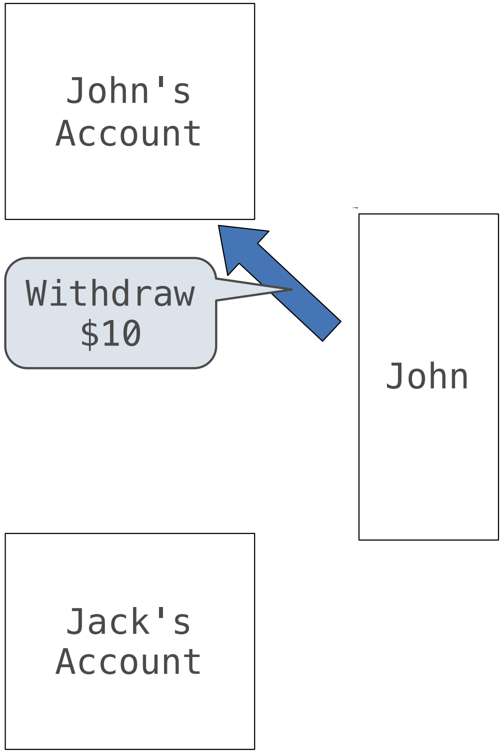

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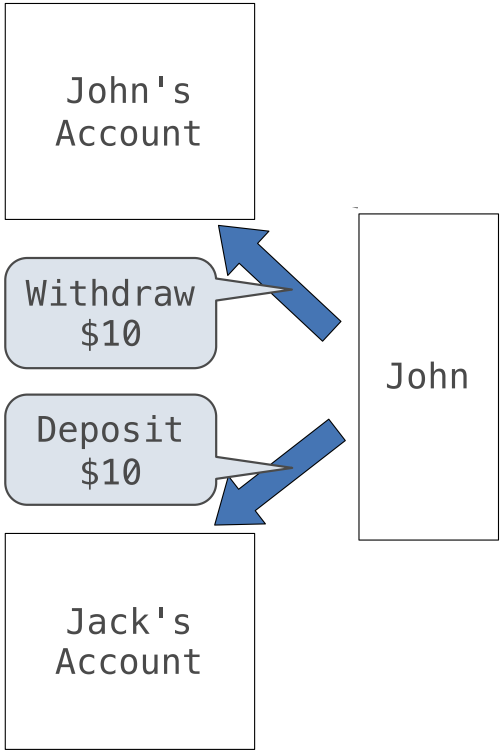

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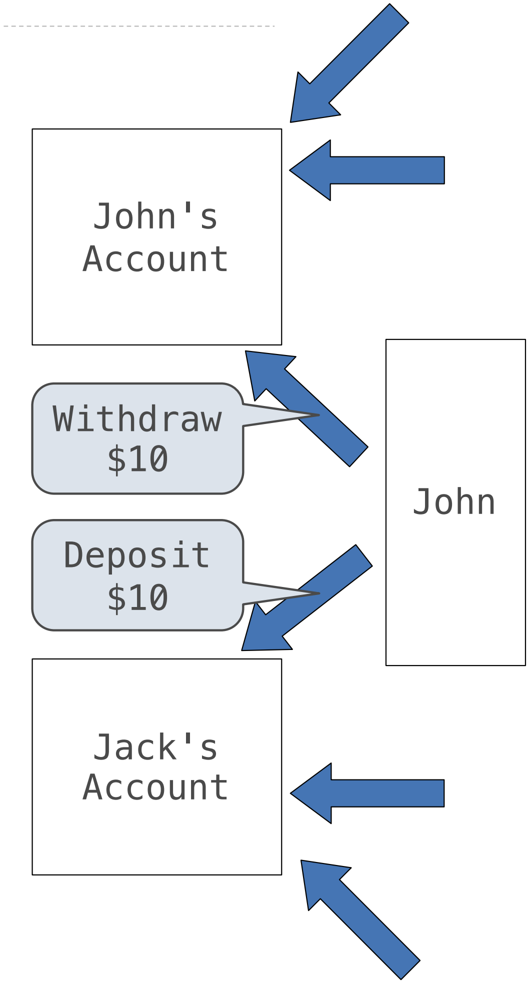

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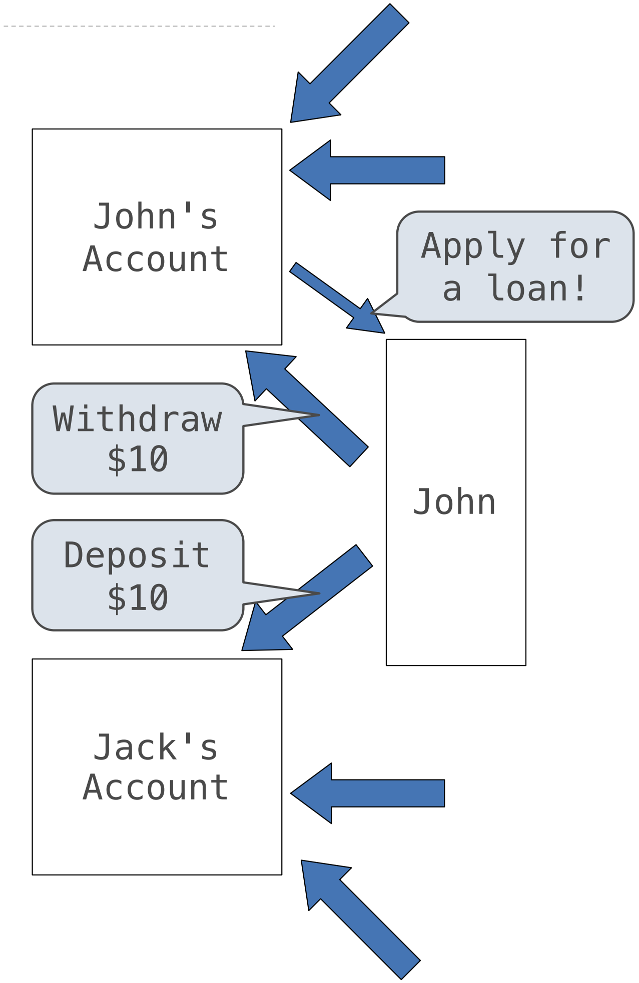

Classes

- A class serves as a template for its instances

Idea: All bank accounts have a `balance` and an account `holder`; the `Account` class should add those attributes to each newly created instance

```
>>> a = Account('John’)
>>> a.holder
'John'
>>> a.balance
0
```

Idea: All bank accounts should have `withdraw` and `deposit` behaviors that all work in the same way

```
>>> a.deposit(15)
15
>>> a.withdraw(10)
5
>>> a.balance
5
>>> a.withdraw(10)
'Insufficient funds'
```

Better idea: All bank accounts share a `withdraw` method and a `deposit` method

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The Class Statement

```
class <name>:
    <suite>
```

The `suite` is executed when
the class statement is executed.

- A `class` statement creates a new class and binds that class to `<name>` in the first frame of the current environment
- Assignment & `def` statements in `<suite>` create attributes of the class (not names in frames)

```
>>> class Clown:
...     nose = 'big and red'
...     def dance():
...         return 'No thanks’
...
>>> Clown.nose
'big and red’
>>> Clown.dance()
'No thanks'
>>> Clown
<class '__main__.Clown'>
```

Object Construction

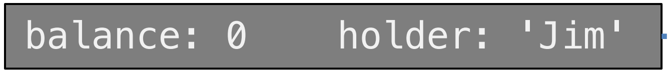
- **Idea**: All bank accounts have a `balance` and an account `holder`; the `Account` class should add those attributes to each of its instances

```
>>> a = Account('Jim’)
>>> a.holder
'Jim'
>>> a.balance
0
```

- When a class is called:

1. A new instance of that class is created:
2. The `__init__` method of the class is called with the new object as its first argument (named `self`), along with any additional arguments provided in the call expression

An account instance



balance: 0   holder: 'Jim'

```
class Account:
    def __init__(self, account_holder):
     ▷self.balance = 0
     ▷self.holder = account_holder
```

__init__ is called a constructor

Object identity

- Every object that is an instance of a user-defined class has a unique identity:

```
>>> a = Account('John’)
>>> b = Account('Jack’)
>>> a.balance
0
>>> b.holder
'Jack'
```

Every call to `Account` creates a new `Account` instance. There is only one `Account` class.

- Identity operators "is" and "is not" test if two expressions evaluate to the same object:

```
>>> a is a
True
>>> a is not b
True
```

- Binding an object to a new name using assignment does not create a new object:

```
>>> c = a
>>> c is a
True
```

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Methods

- Methods are functions defined in the suite of a class statement

```
class Account:
    def __init__(self, account_holder):
        self.balance = 0
        self.holder = account_holder
```

self should always be bound to an instance of the Account class

```
    def deposit(self, amount):
        self.balance = self.balance + amount
        return self.balance

    def withdraw(self, amount):
        if amount > self.balance:
            return 'Insufficient funds’
        self.balance = self.balance – amount
        return self.balance
```

- These def statements create function objects as always, but their names are bound as attributes of the class

Invoking Methods

- All invoked methods have access to the object via the self parameter, and so they can all access and manipulate the object's state

```
class Account:
    ...
    def deposit(self, amount):
        self.balance = self.balance + amount
        return self.balance
```

Defined with two parameters

- Dot notation automatically supplies the first argument to a method

```
>>> tom_account = Account('Tom')
>>> tom_account.deposit(100)
100
```

Bound to self

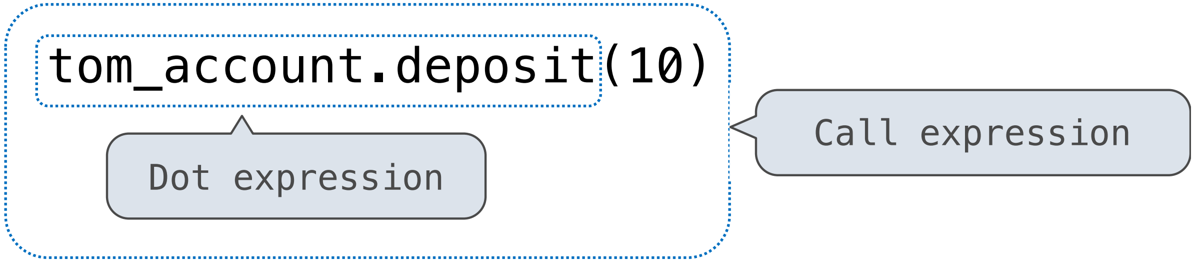
Invoked with one argument

Dot expressions

- Objects receive messages via dot notation
- Dot notation accesses attributes of the instance or its class

```
<expression>.<name>
```

- The <expression> can be any valid Python expression
- The <name> must be a simple name
- Evaluates to the value of the attribute looked up by <name> in the object that is the value of the <expression>



```
tom_account.deposit(10)
```

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Accessing Attributes

- Using getattr, we can look up an attribute using a string

```
>>> getattr(tom_account, 'balance’)
10
>>> hasattr(tom_account, 'deposit’)
True
```

- getattr and dot expressions look up a name in the same way
- Looking up an attribute name in an object may return:
  - One of its instance attributes, or
  - One of the attributes of its class

Methods and Functions

- Python distinguishes between:
- *Functions*, which we have been creating since the beginning of the course, and
- *Bound methods*, which couple together a function and the object on which that method will be invoked

Object + Function = Bound Method

```
>>> type(Account.deposit)
<class 'function'>
>>> type(tom_account.deposit)
<class 'method’>

>>> Account.deposit(tom_account, 1001)
1011
>>> tom_account.deposit(1004)
2015
```

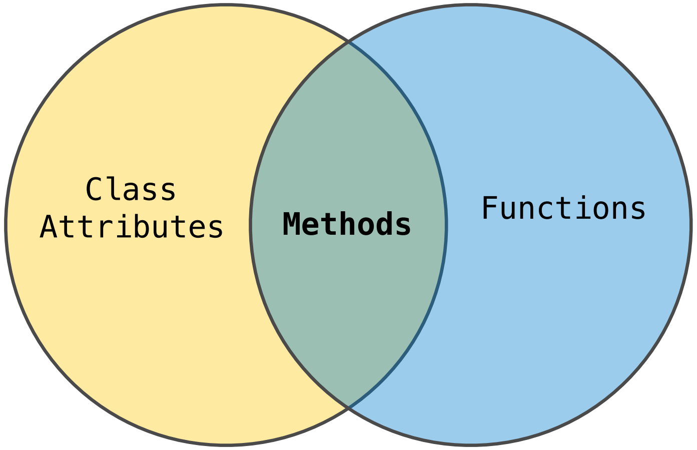
Function: all arguments within parentheses

Method: One object before the dot and other arguments within parentheses

Terminology: Attributes, Functions, and Methods

- All objects have attributes, which are name-value pairs
- Classes are objects too, so they have attributes
- Instance attribute: attribute of an instance
- Class attribute: attribute of the class of an instance

Terminology:



Python object system:

Functions are objects

Bound methods are also objects: a function that has its first parameter "self" already bound to an instance

Dot expressions evaluate to bound methods for class attributes that are functions

`<instance>.<method_name>`

Looking Up Attributes by Name

```
<expression>.<name>
```

To evaluate a dot expression:

1. Evaluate the `<expression>` to the left of the dot, which yields the object of the dot expression
2. `<name>` is matched against the instance attributes of that object; if an attribute with that name exists, its value is returned
3. If not, `<name>` is looked up in the class, which yields a class attribute value
4. That value is returned unless it is a function, in which case a bound method is returned instead

Class Attributes

- Class attributes are "shared" across all instances of a class because they are attributes of the class, not the instance

```
class Account:
    interest = 0.02 # A class attribute
    def __init__(self, account_holder):
    self.balance = 0
        self.holder = account_holder
    # Additional methods would be defined here
```

```
>>> tom_account = Account('Tom')
>>> jim_account = Account('Jim')
>>> tom_account.interest
0.02
>>> jim_account.interest
0.02
```

The **interest** attribute is ***not*** part of the instance; it's part of the class!

Assignment to Attributes

- Assignment statements with a dot expression on their left-hand side affect attributes for the object of that dot expression
  - If the object is a class, then assignment sets a class attribute
  - If the object is an instance, then assignment sets an instance attribute

```
class Account:
   interest = 0.02
   def __init__(self, holder):
       self.holder = holder
       self.balance = 0
...

tom_account = Account('Tom')
```

Class Attribute Assignment:

```
Account.interest = 0.04
```

Assignment to Attributes

- Assignment statements with a dot expression on their left-hand side affect attributes for the object of that dot expression
  - If the object is a class, then assignment sets a class attribute
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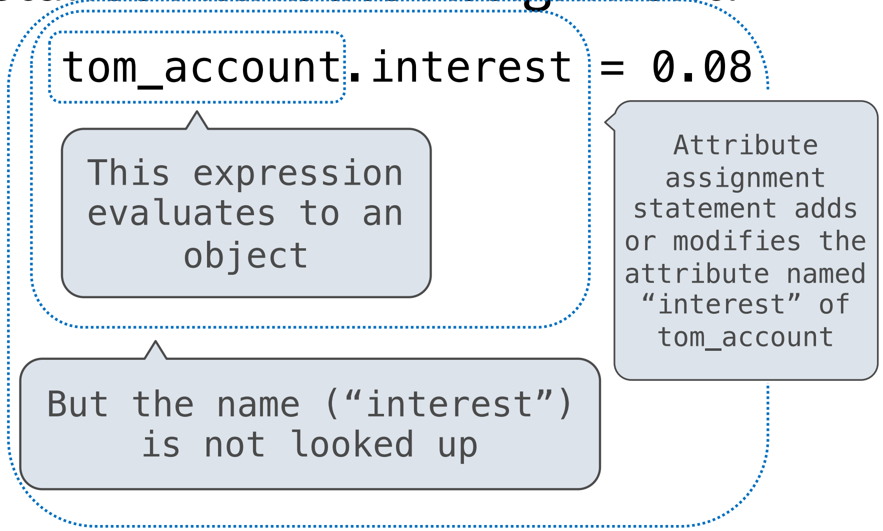
```
class Account:
   interest = 0.02
   def __init__(self, holder):
       self.holder = holder
       self.balance = 0
...

tom_account = Account('Tom')
```

Instance Attribute Assignment:



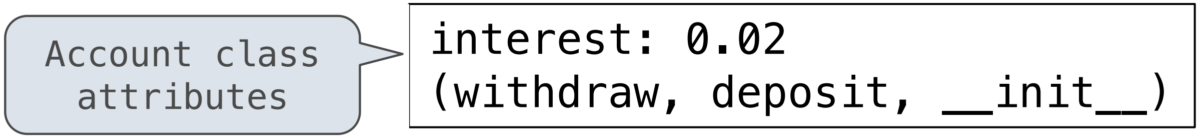
```
tom_account.interest = 0.08
```

This expression evaluates to an object

But the name ("interest") is not looked up

Attribute assignment statement adds or modifies the attribute named "interest" of tom_account

Attribute Assignment Statements

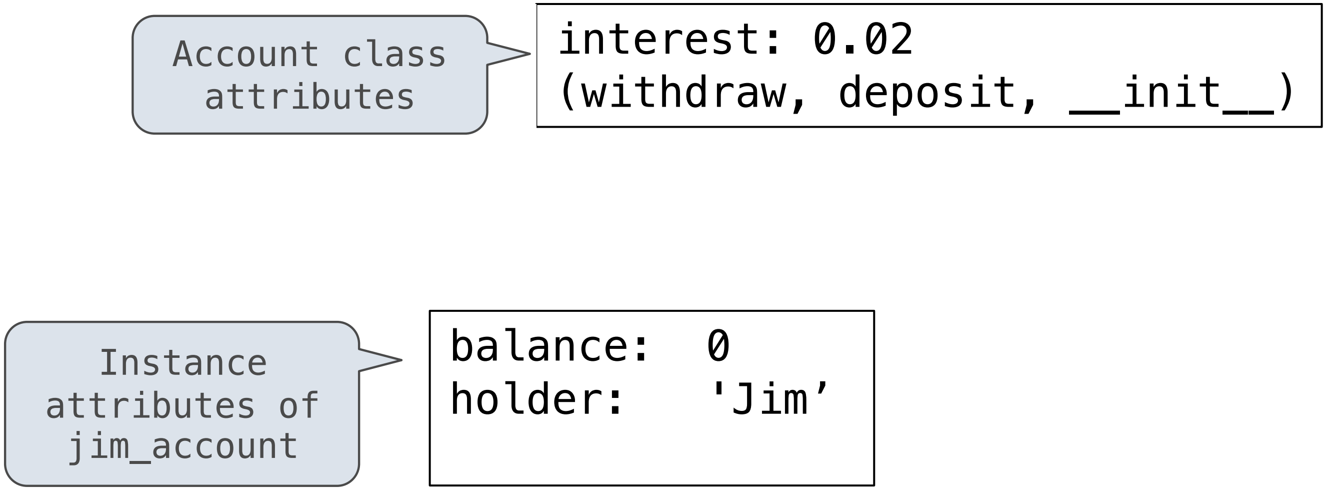


Account class attributes

```
interest: 0.02
(withdraw, deposit, __init__)
```

```
>>> jim_account = Account('Jim')
```

Attribute Assignment Statements



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Instance attributes of jim_account

```
balance:  0
holder:   'Jim’
```

```
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```

Attribute Assignment Statements

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Instance attributes of jim_account

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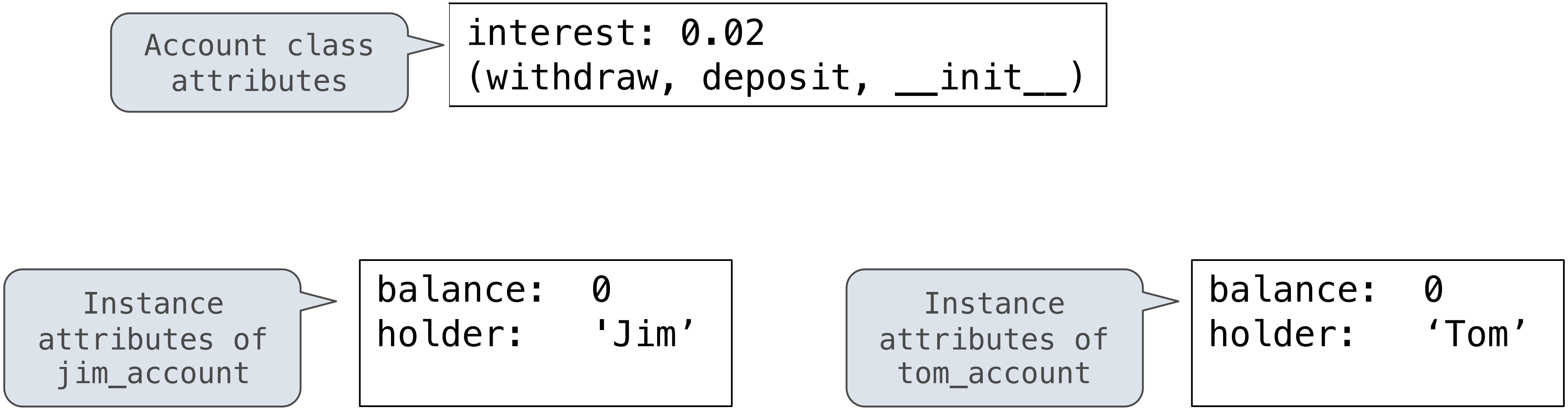
```

Attribute Assignment Statements



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Instance attributes of jim_account

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Instance attributes of tom_account

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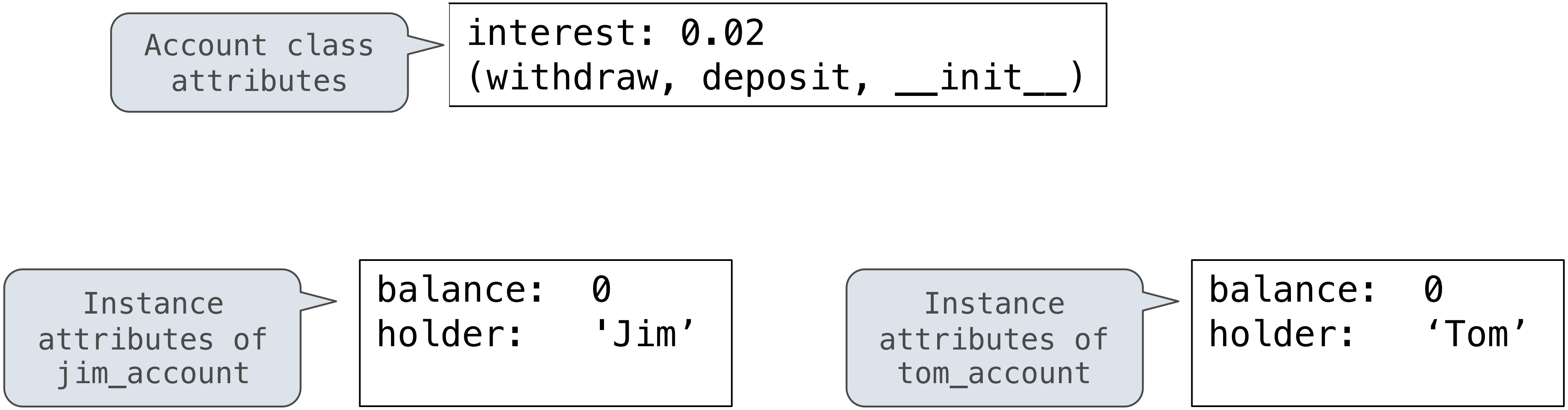

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Instance attributes of jim_account

balance: 0
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Instance attributes of tom_account

balance: 0
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```
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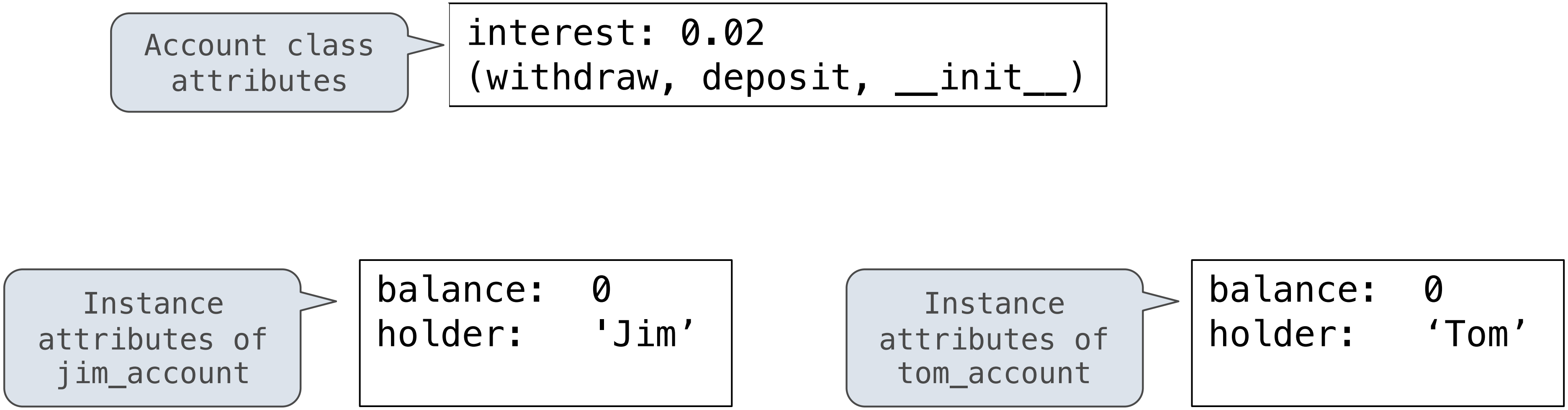
>>> tom_account = Account('Tom’)
>>> tom_account.interest
0.02
```

Attribute Assignment Statements



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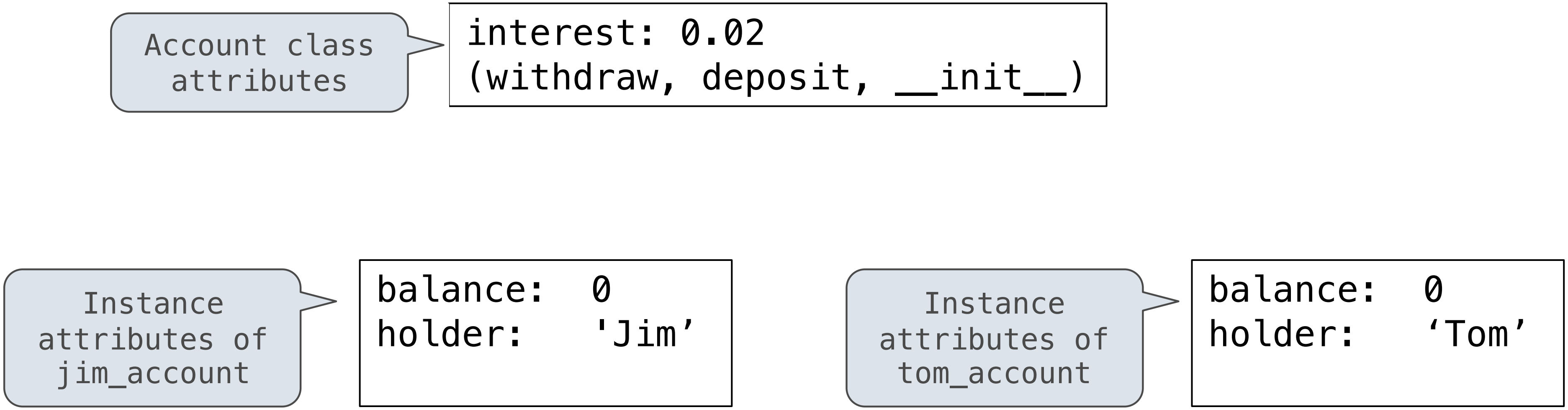

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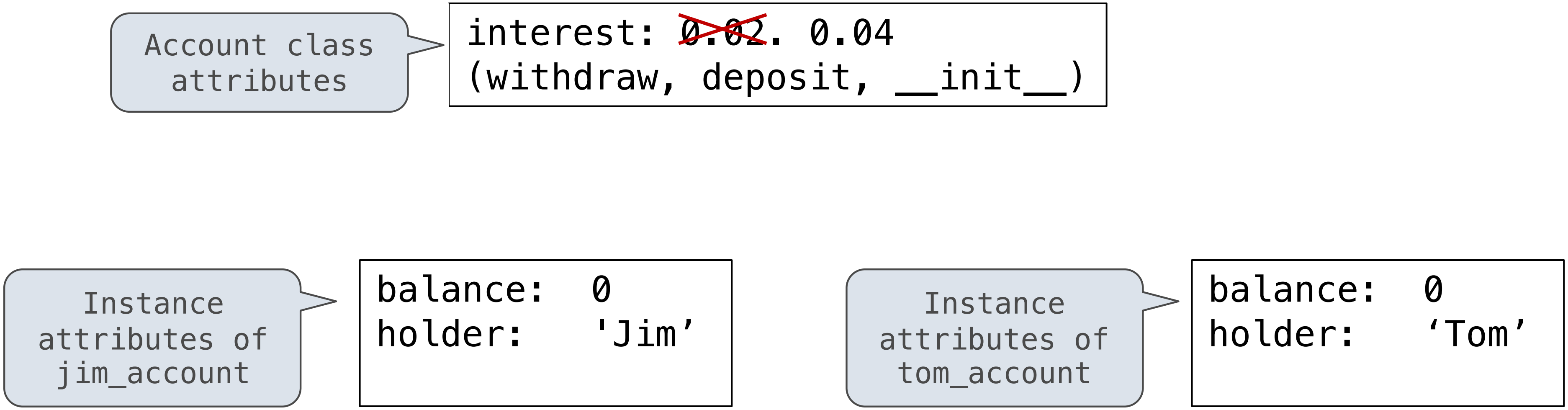

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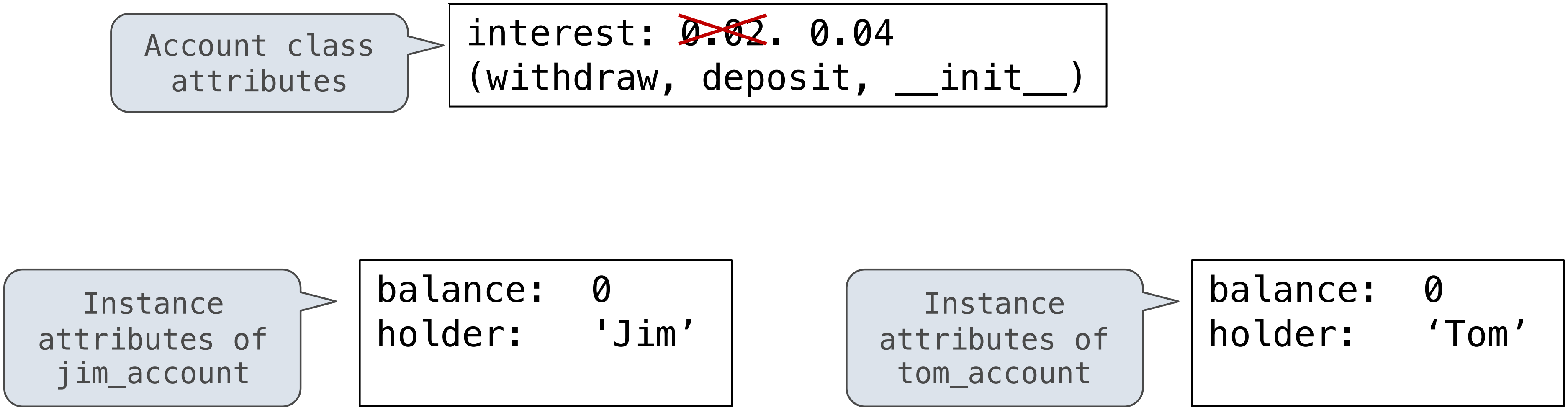

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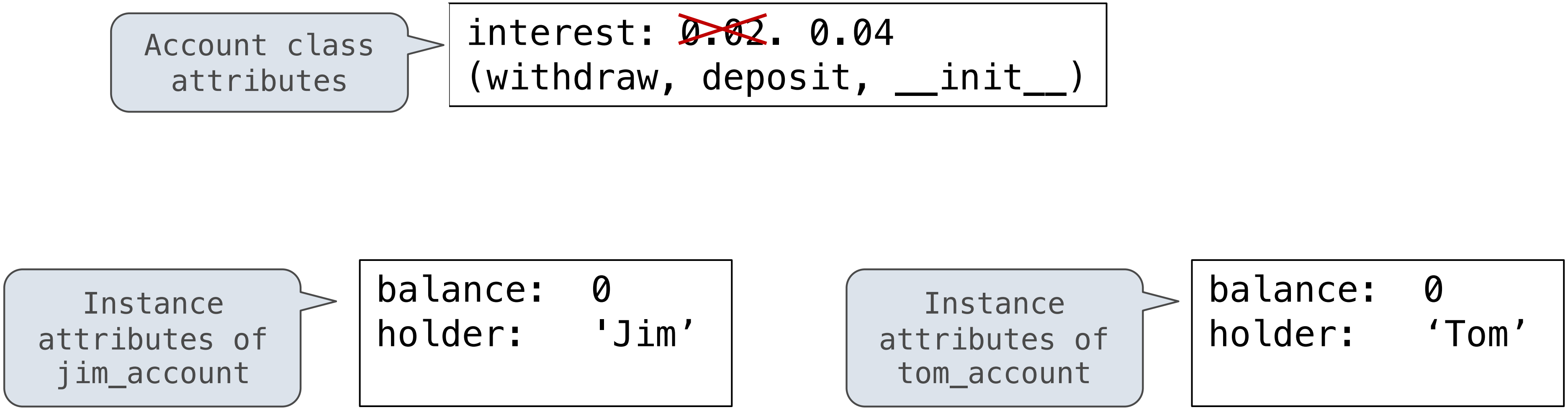

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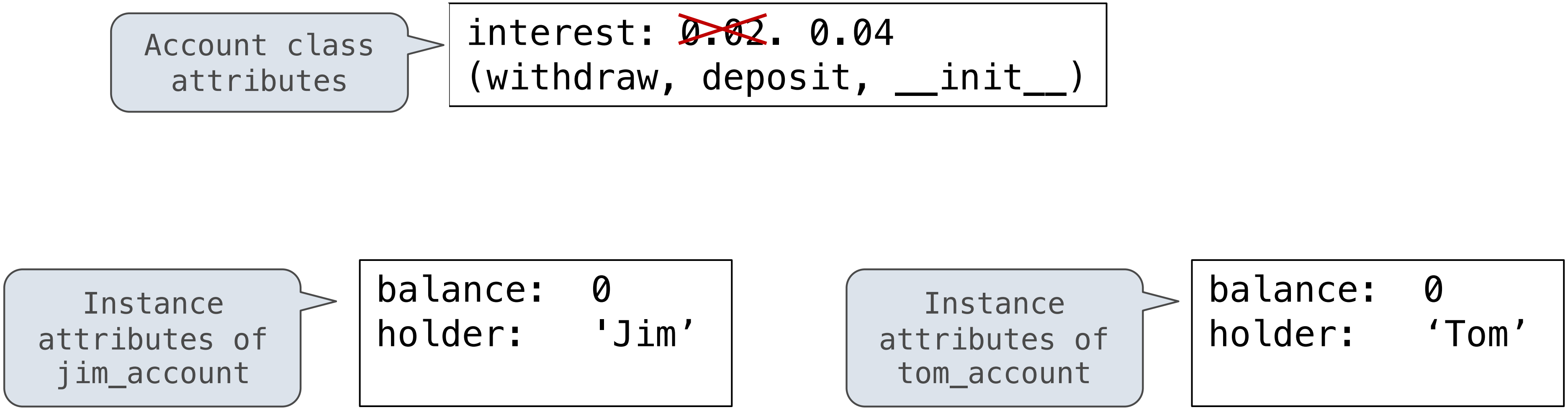

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```
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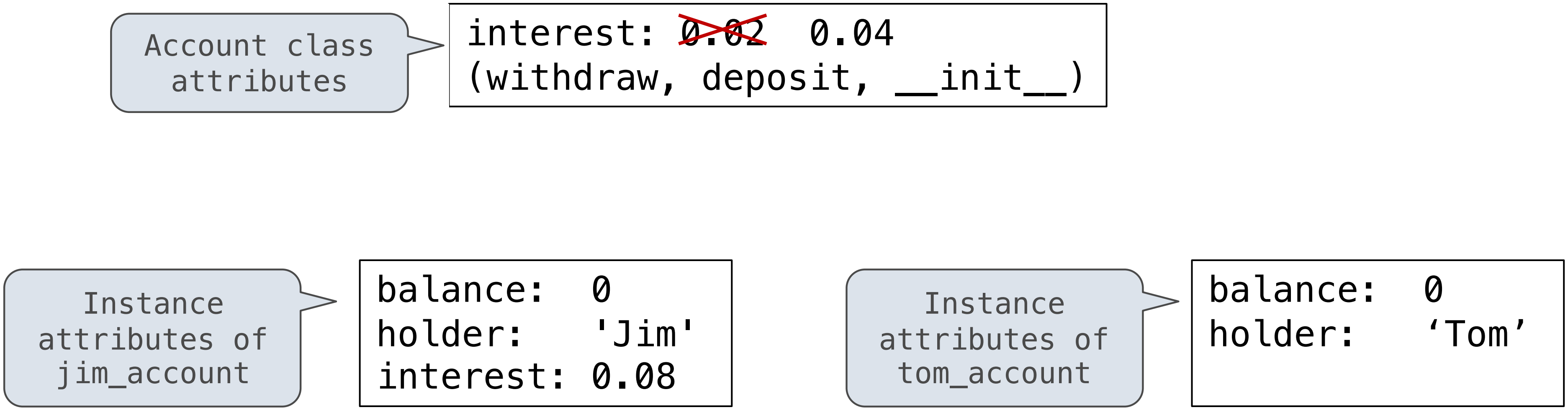
Attribute Assignment Statements



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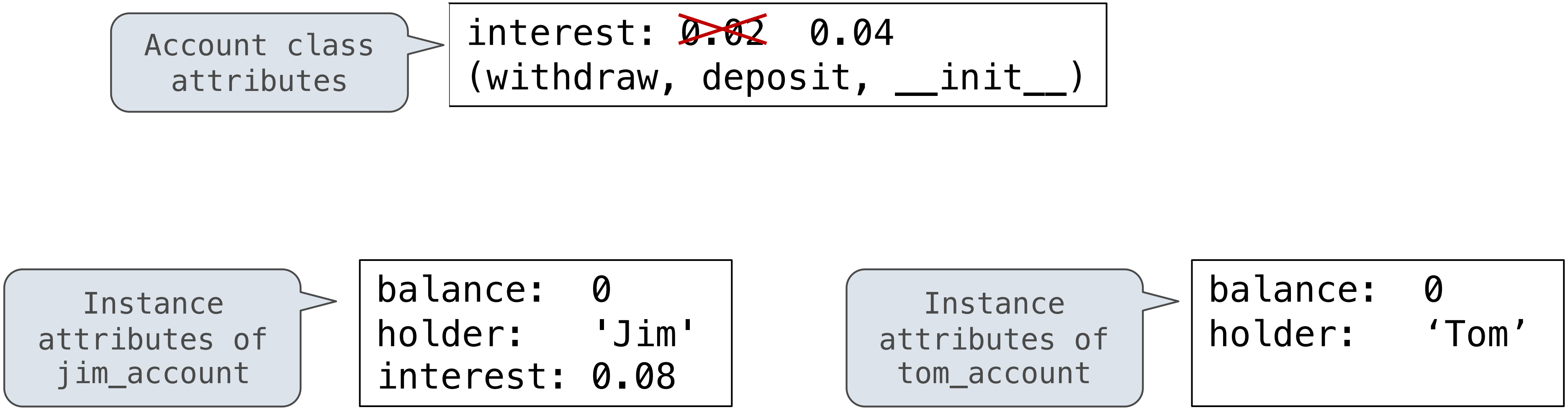
Attribute Assignment Statements



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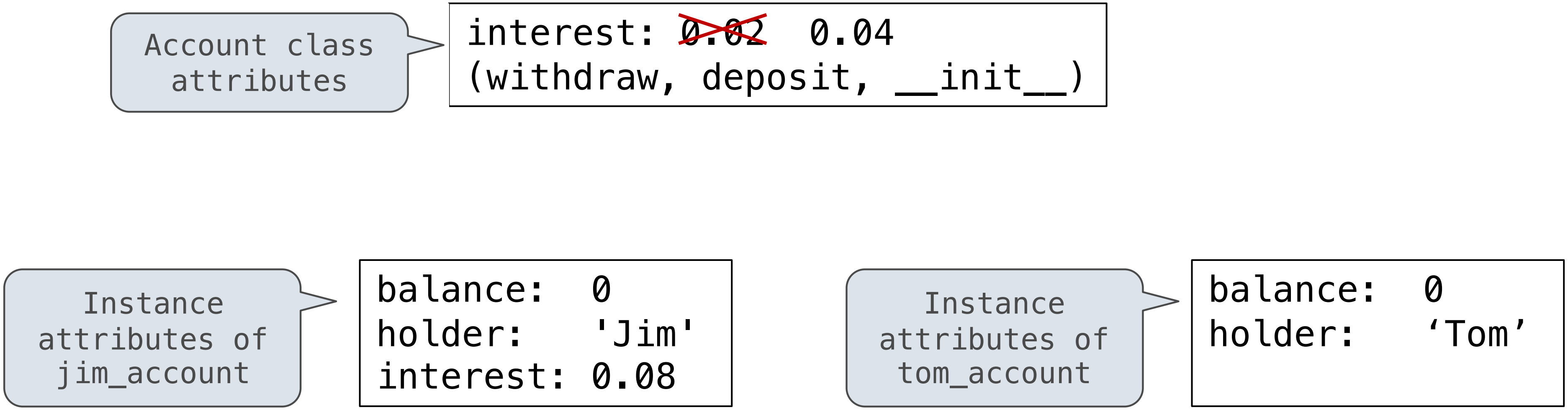
Attribute Assignment Statements



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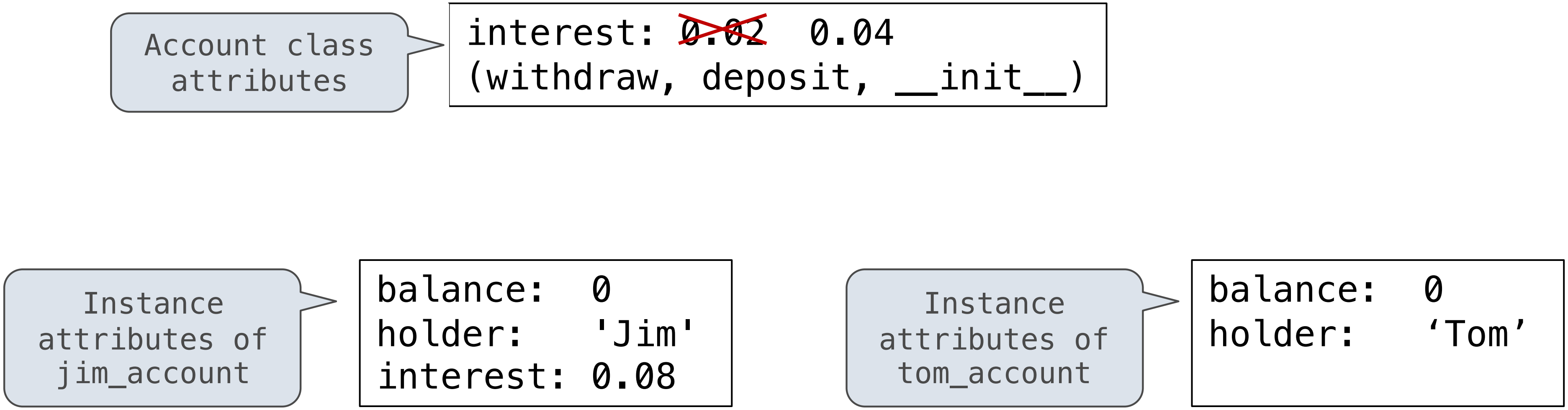
Attribute Assignment Statements



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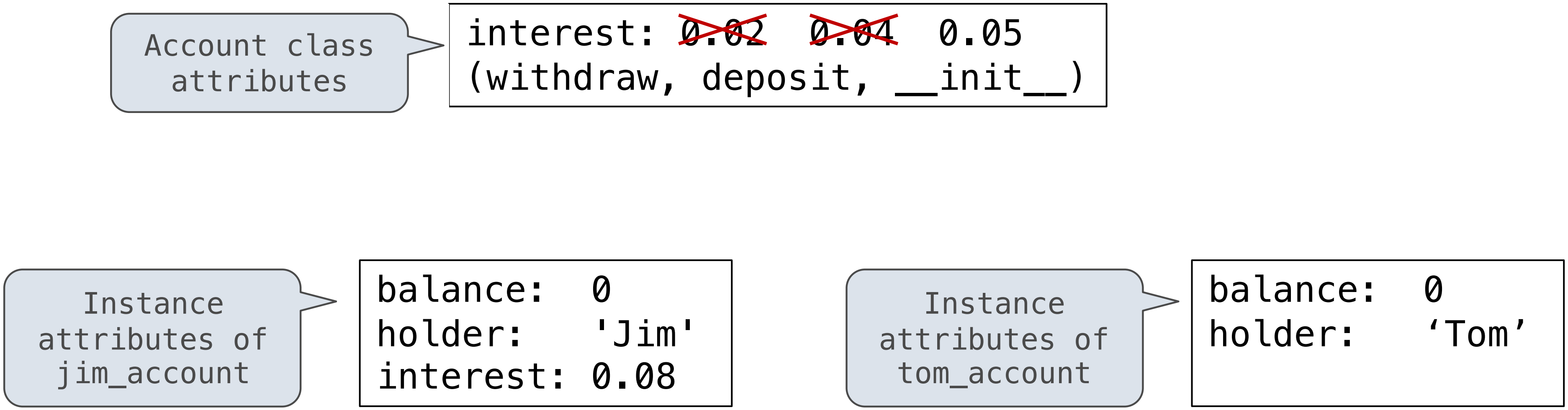
0.02
>>> Account.interest = 0.04
>>> tom_account.interest
0.04
>>> jim_account.interest
0.04
```

```
>>> jim_account.interest = 0.08
>>> jim_account.interest
0.08
>>> tom_account.interest
0.04
>>> Account.interest = 0.05
```

Attribute Assignment Statements



Account class attributes

interest: ~~0.02~~ ~~0.04~~ 0.05
(withdraw, deposit, __init__)

Instance attributes of jim_account

balance: 0
holder: 'Jim'
interest: 0.08

Instance attributes of tom_account

balance: 0
holder: ‘Tom’

```
>>> jim_account = Account('Jim')
>>> tom_account = Account('Tom')
>>> tom_account.interest
0.02
>>> jim_account.interest
0.02
>>> Account.interest = 0.04
>>> tom_account.interest
0.04
>>> jim_account.interest
0.04
```

```
>>> jim_account.interest = 0.08
>>> jim_account.interest
0.08
>>> tom_account.interest
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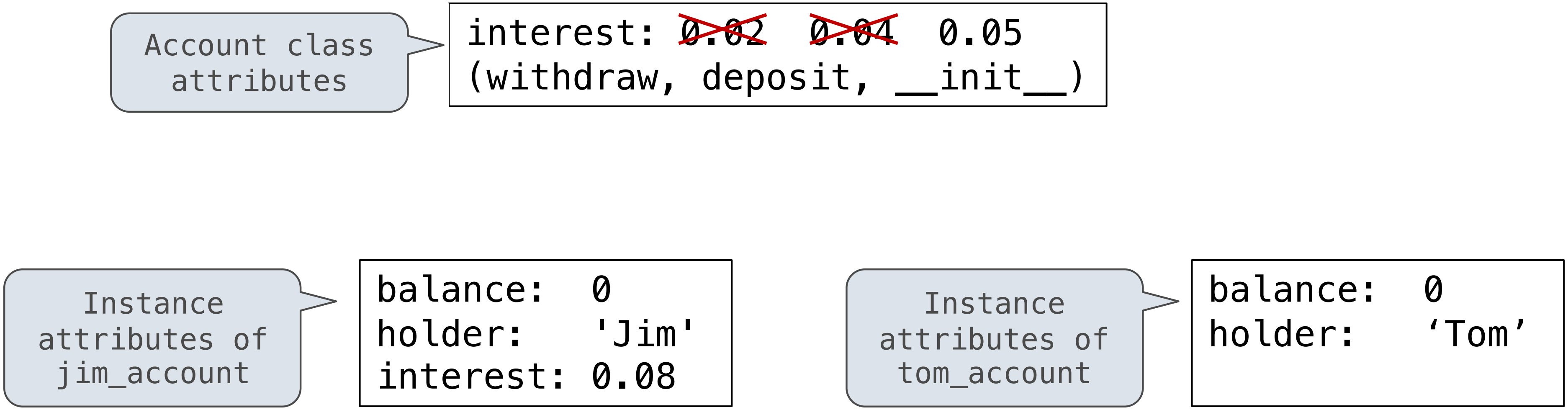
>>> Account.interest = 0.05
```

Attribute Assignment Statements



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holder: 'Jim'
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balance: 0
holder: ‘Tom’

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0.02
>>> jim_account.interest
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>>> tom_account.interest
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>>> jim_account.interest
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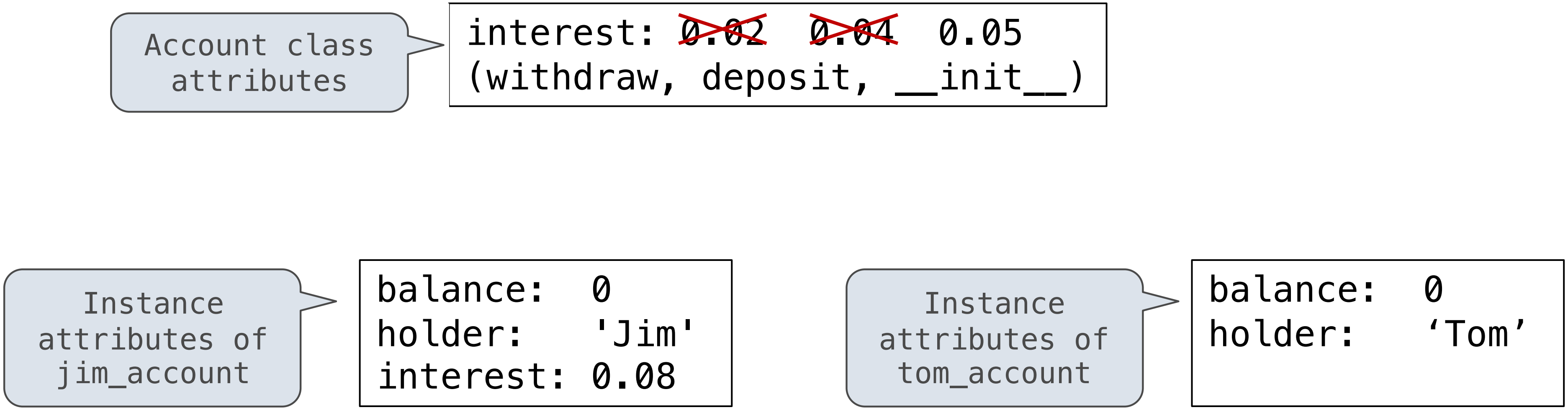
```

```
>>> jim_account.interest = 0.08
>>> jim_account.interest
0.08
>>> tom_account.interest
0.04
>>> Account.interest = 0.05
>>> tom_account.interest
0.05
```

Attribute Assignment Statements



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(withdraw, deposit, __init__)

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balance: 0
holder: ‘Tom’

```
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>>> tom_account.interest
0.02
>>> jim_account.interest
0.02
>>> Account.interest = 0.04
>>> tom_account.interest
0.04
>>> jim_account.interest
0.04
```

```
>>> jim_account.interest = 0.08
>>> jim_account.interest
0.08
>>> tom_account.interest
0.04
>>> Account.interest = 0.05
>>> tom_account.interest
0.05
>>> jim_account.interest
0.08
```

Lecture Overview

- Classes
  - Object Oriented Programming
  - Class Statements
  - Methods
  - Attributes
  - Inheritence

Inheritance

- Inheritance is a technique for relating classes together
- A common use: Two similar classes differ in their degree of specialization
- The specialized class may have the same attributes as the general class, along with some special-case behavior

```
class <Name>(<Base Class>):
   <suite>
```

- Conceptually, the new subclass inherits attributes of its base class
- The subclass may override certain inherited attributes
- Using inheritance, we implement a subclass by specifying its differences from the the base class

Inheritance Example

- A CheckingAccount is a specialized type of Account

```
>>> ch = CheckingAccount('Tom’)
>>> ch.interest     # Lower interest rate for checking accounts
0.01
>>> ch.deposit(20)  # Deposits are the same
20
>>> ch.withdraw(5)  # Withdrawals incur a $1 fee
14
```

- Most behavior is shared with the base class Account

```
class CheckingAccount(Account):
    """A bank account that charges for withdrawals."""
    withdraw_fee = 1
    interest = 0.01
    def withdraw(self, amount):
        return Account.withdraw(self, amount + self.withdraw_fee)
```

Inheritance Example

- A CheckingAccount is a specialized type of Account

```
>>> ch = CheckingAccount('Tom’)
>>> ch.interest     # Lower interest rate for checking accounts
0.01
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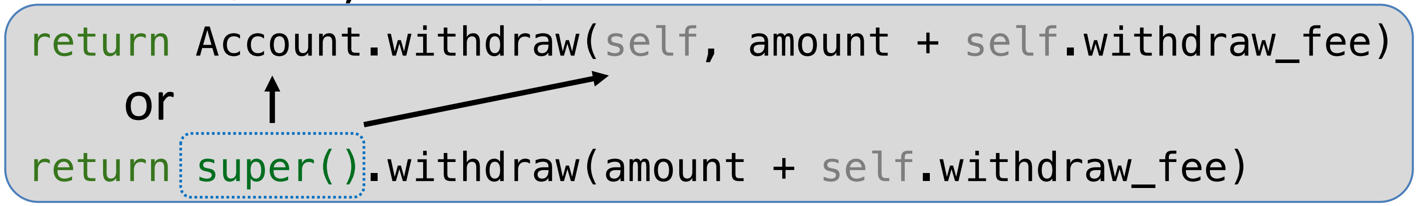
- Most behavior is shared with the base class Account

```
class CheckingAccount(Account):
    """A bank account that charges for withdrawals."""
    withdraw_fee = 1
    interest = 0.01
    def withdraw(self, amount):
```



```
        return Account.withdraw(self, amount + self.withdraw_fee)
              or
        return super().withdraw(amount + self.withdraw_fee)
```

Looking Up Attribute Names on Classes

- Base class attributes *aren't* copied into subclasses!
- To look up a name in a class:

1. If it names an attribute in the class, return the attribute value.
2. Otherwise, look up the name in the base class, if there is one.

```
>>> ch = CheckingAccount('Tom') # Calls Account.__init__
>>> ch.interest # Found in CheckingAccount
0.01
>>> ch.deposit(20) # Found in Account
20
>>> ch.withdraw(5) # Found in CheckingAccount
14
```

Designing for Inheritance

- Don't repeat yourself; use existing implementations
- Attributes that have been overridden are still accessible via class objects
- Look up attributes on instances whenever possible

```
class CheckingAccount(Account):
    """A bank account that charges for withdrawals."""
    withdraw_fee = 1
    interest = 0.01
    def withdraw(self, amount):
        return Account.withdraw(self, amount + self.withdraw_fee)
```

Attribute look-up on base class

Preferred to CheckingAccount.withdraw_fee to allow for specialized accounts

Inheritance and Composition

- Object-oriented programming shines when we adopt the metaphor
- Inheritance is best for representing is-a relationships
  - E.g., a checking account is a specific type of account
  - So, `CheckingAccount` inherits from `Account`
- Composition is best for representing has-a relationships
  - E.g., a bank **has a** collection of bank accounts it manages
  - So, A bank has a list of accounts as an attribute

Inheritance and Composition Example

- a bank **has a** collection of bank accounts it manages

```
class Bank:
    """A bank has accounts and pays interest."""
    def __init__(self):
        self.accounts = []

    def open_account(self, holder, amount, account_type=Account):
        """Open an account_type for holder and deposit amount."""
        account = account_type(holder)
        account.deposit(amount)
        self.accounts.append(account)
        return account

    def pay_interest(self):
        """Pay interest to all accounts."""
        for account in self.accounts:
            account.deposit(account.balance * account.interest)

    def too_big_too_fail(self):
          """Check whether the bank has more than 1 account or not."""
         return len(self.accounts) > 1
```

Inheritance and Composition Example

- a bank **has a** collection of bank accounts it manages

```
class Bank:
    """A bank has accounts and pays interest."""
    def __init__(self):
        self.account

    def open_account
        """Open an a
        account = ac
        account.depo
        self.account
        return accou

    def pay_interest
        """Pay inter
        for account
            account.

    def too_big_to_fail(self):
        """Check whether the bank has more than 1 account or not."""
        return len(self.accounts) > 1
```

```
>>> bank = Bank()
>>> john = bank.open_account('John', 10)
>>> jack = bank.open_account('Jack', 5, CheckingAccount)
>>> jack.interest
0.01
>>> john.interest = 0.06
>>> bank.pay_interest()
>>> john.balance
10.6
>>> jack.balance
5.05
>>> bank.too_big_to_fail()
True
```

Inheritance and Attribute Lookup

```
class A:
    z = -1
    def f(self, x):
        return B(x-1)

class B(A):
    n = 4
    def __init__(self, y):
        if y:
            self.z = self.f(y)
        else:
            self.z = C(y+1)

class C(B):
    def f(self, x):
        return x

>>> a = A()
>>> b = B(1)
>>> b.n = 5
```

```
>>> C(2).n

4

>>> a.z == C.z

True

>>> a.z == b.z

False
```

Which evaluates to an integer?

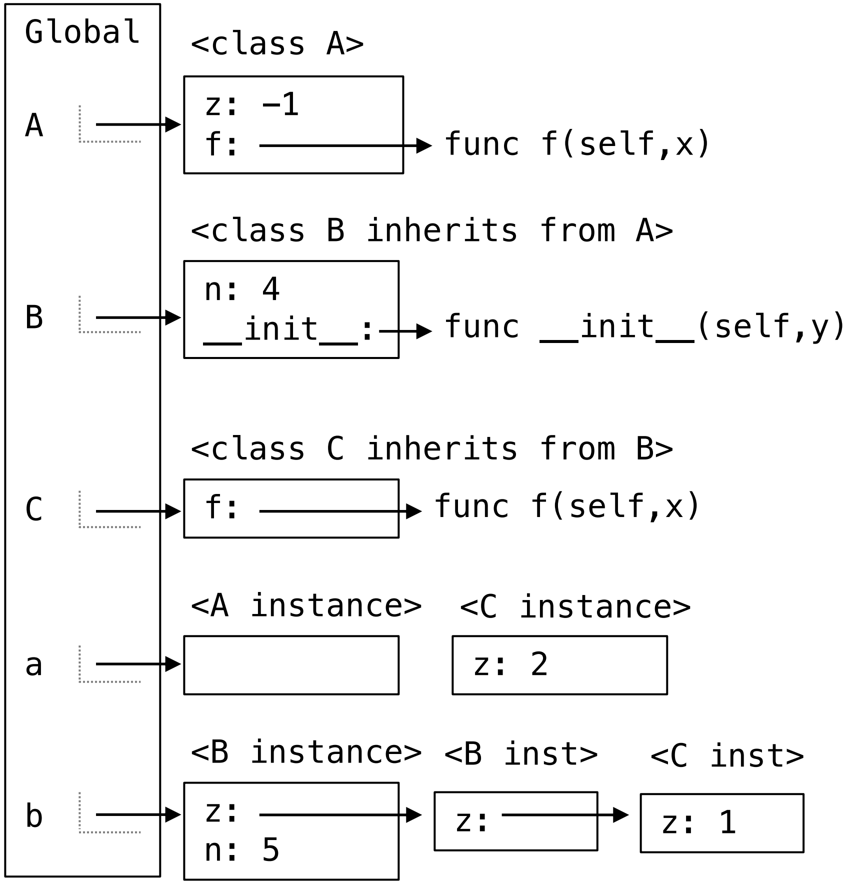
b.z

b.z.z

▷ b.z.z.z

b.z.z.z.z

None of these



Global

A

B

C

a

b

<class A>

z: -1

f: → func f(self,x)

<class B inherits from A>

n: 4

__init__: → func __init__(self,y)

<class C inherits from B>

f: → func f(self,x)

<A instance>

<C instance>

z: 2

<B instance>

z:

n: 5

<B inst>

z:

<C inst>

z: 1

Multiple Inheritance

```
class SavingsAccount(Account):
    deposit_fee = 2
    def deposit(self, amount):
        return Account.deposit(self, amount - self.deposit_fee)
```

- A class may inherit from multiple base classes in Python
- CleverBank marketing executive has an idea:
  - Low interest rate of 1%
  - A $1 fee for withdrawals
  - A $2 fee for deposits
  - A free dollar when you open your account

```
class AsSeenOnTVAccount(CheckingAccount, SavingsAccount):
    def __init__(self, account_holder):
        self.holder = account_holder
        self.balance = 1                 # A free dollar!
```

Multiple Inheritance

- A class may inherit from multiple base classes in Python

```
Class AsSeenOnTVAccount(CheckingAccount, SavingsAccount):
    def __init__(self, account_holder):
        self.holder = account_holder
        self.balance = 1 # A free dollar!
```

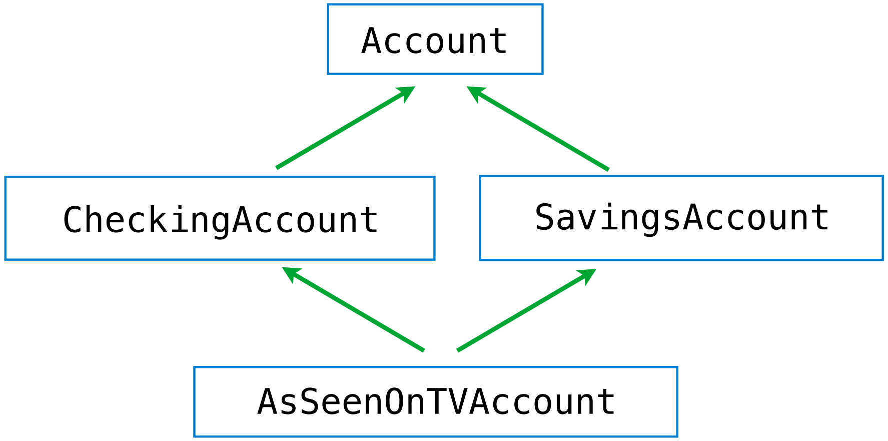
```
>>> such_a_deal = AsSeenOnTVAccount('John’)
>>> such_a_deal.balance
1
>>> such_a_deal.deposit(20)
19
>>> such_a_deal.withdraw(5)
13
```

Instance attribute

SavingsAccount method

CheckingAccount method

Resolving Ambiguous Class Attribute Names



Instance attribute

SavingsAccount method

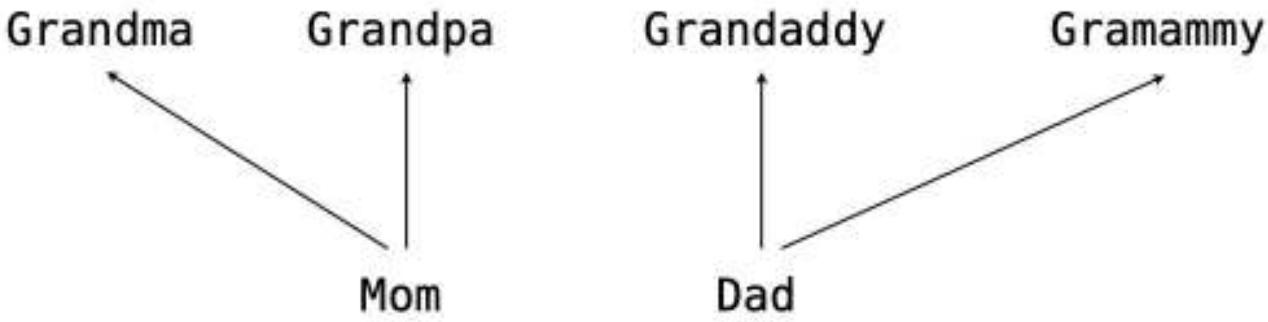
CheckingAccount method

```
>>> such_a_deal = AsSeenOnTVAccount('John’)
>>> such_a_deal.balance
1
>>> such_a_deal.deposit(20)
19
>>> such_a_deal.withdraw(5)
13
```

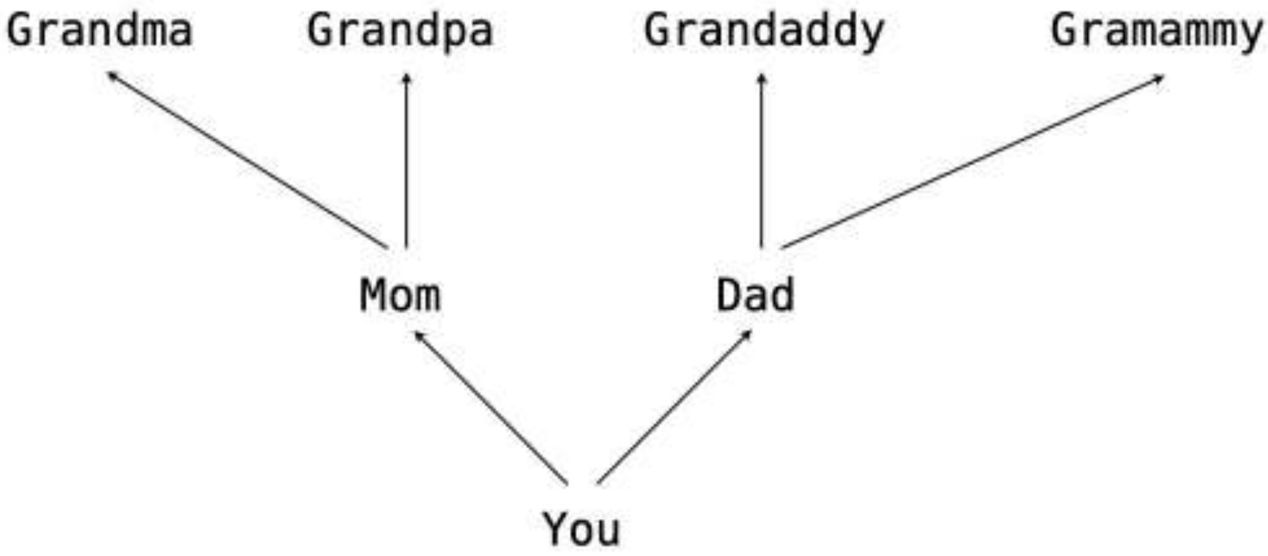
Biological Inheritance

Grandma Grandpa Grandaddy Gramammy

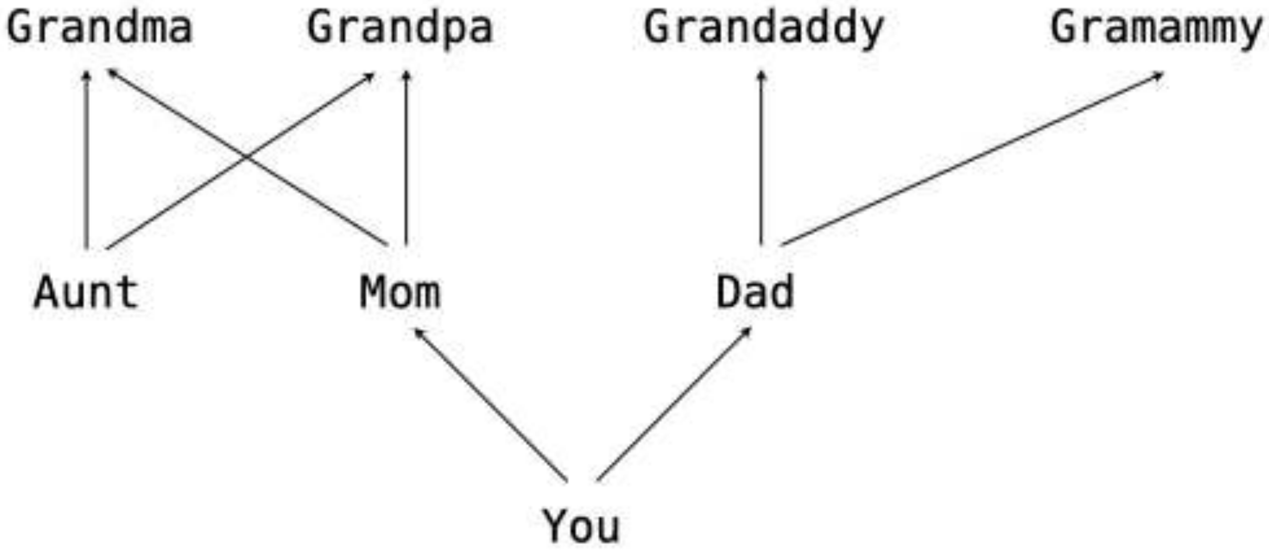
Biological Inheritance



Biological Inheritance



Biological Inheritance

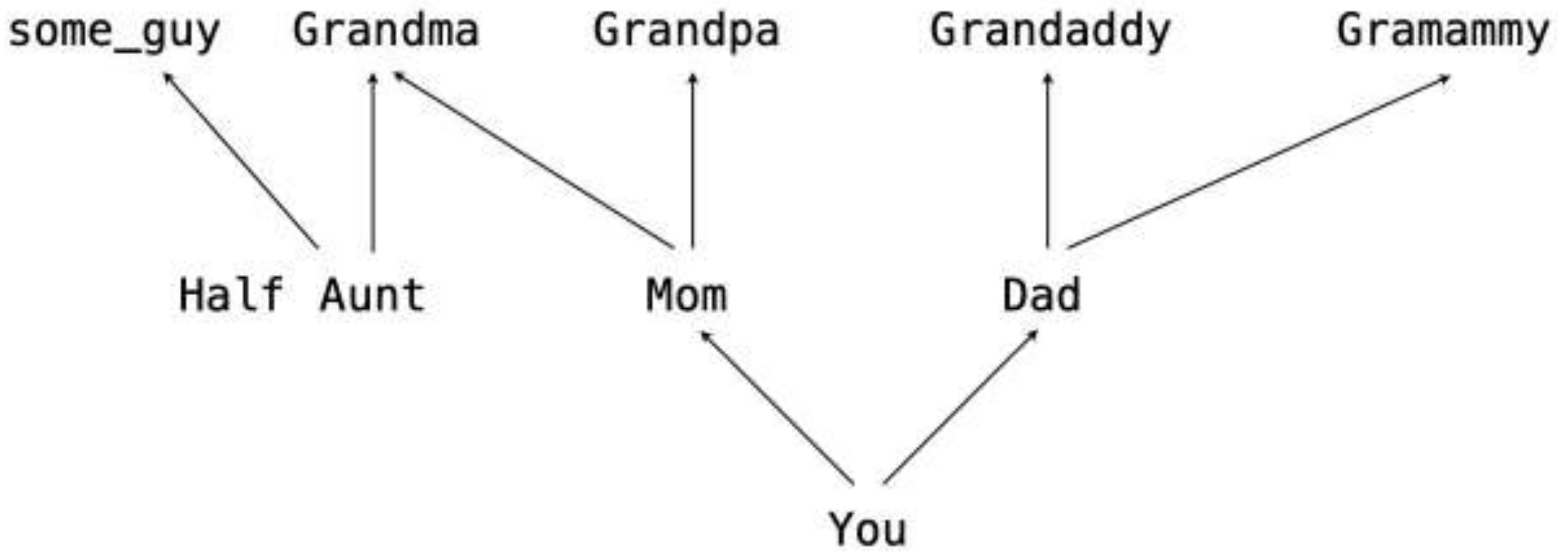


Grandma Grandpa Grandaddy Gramammy

Aunt Mom Dad

You

Biological Inheritance



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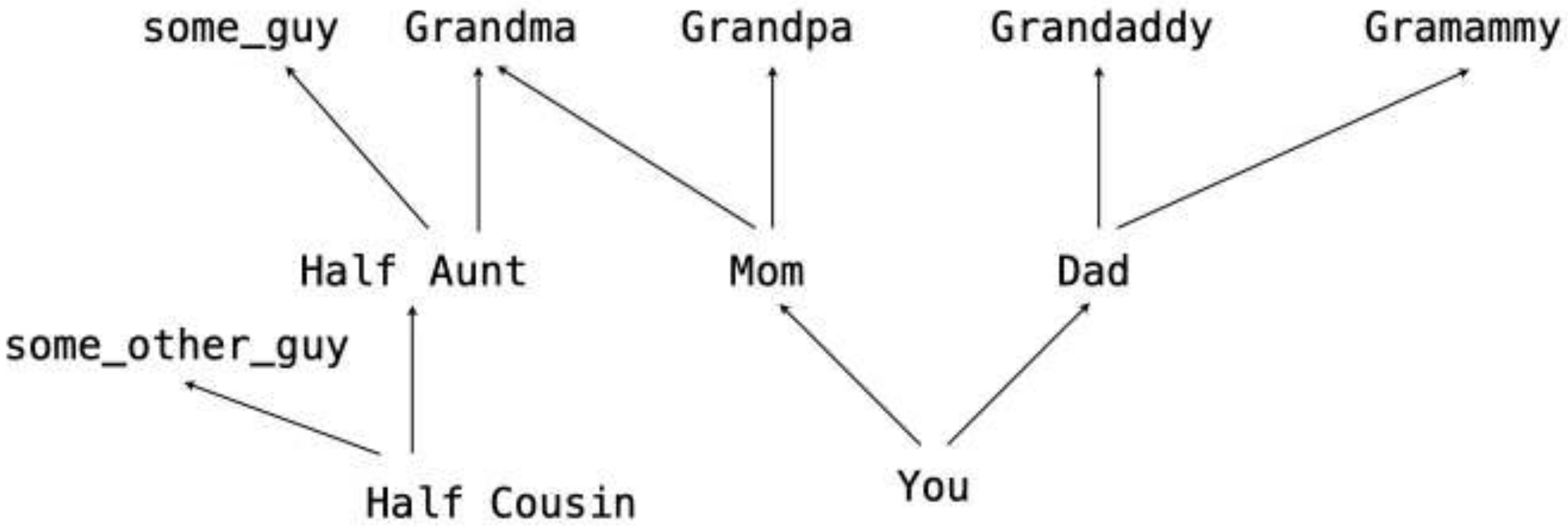

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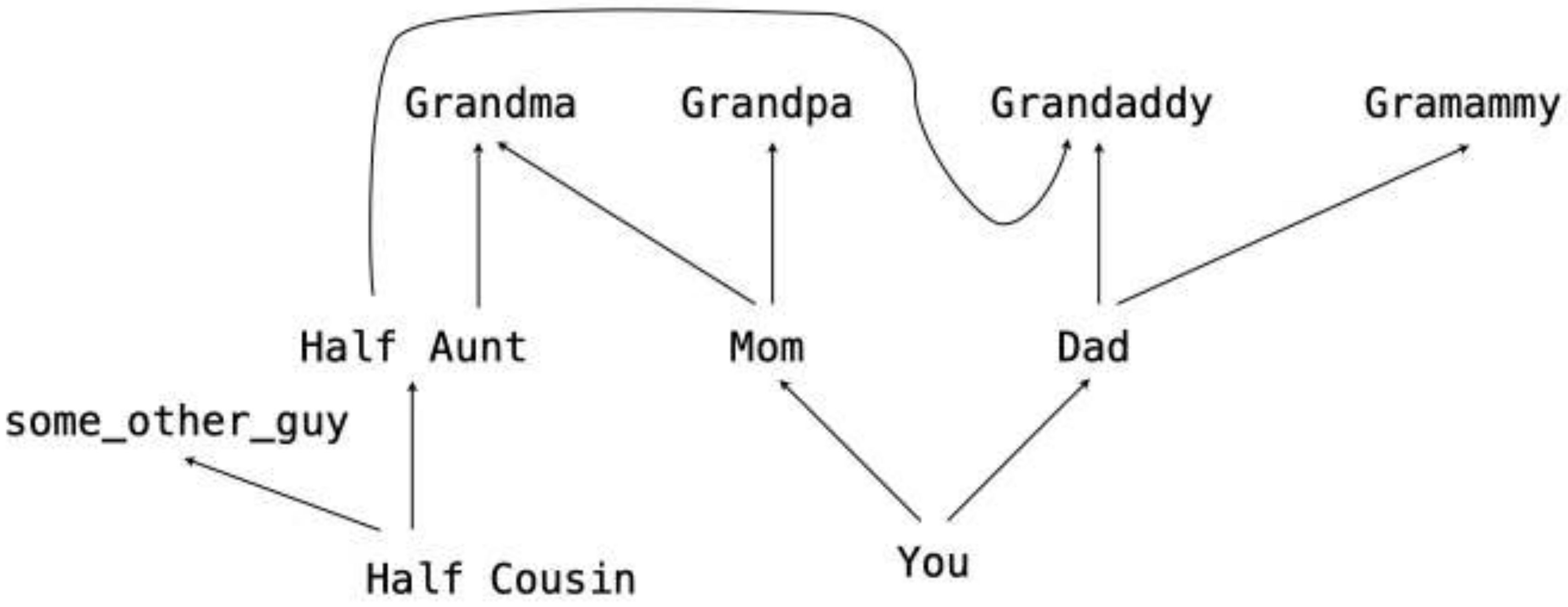
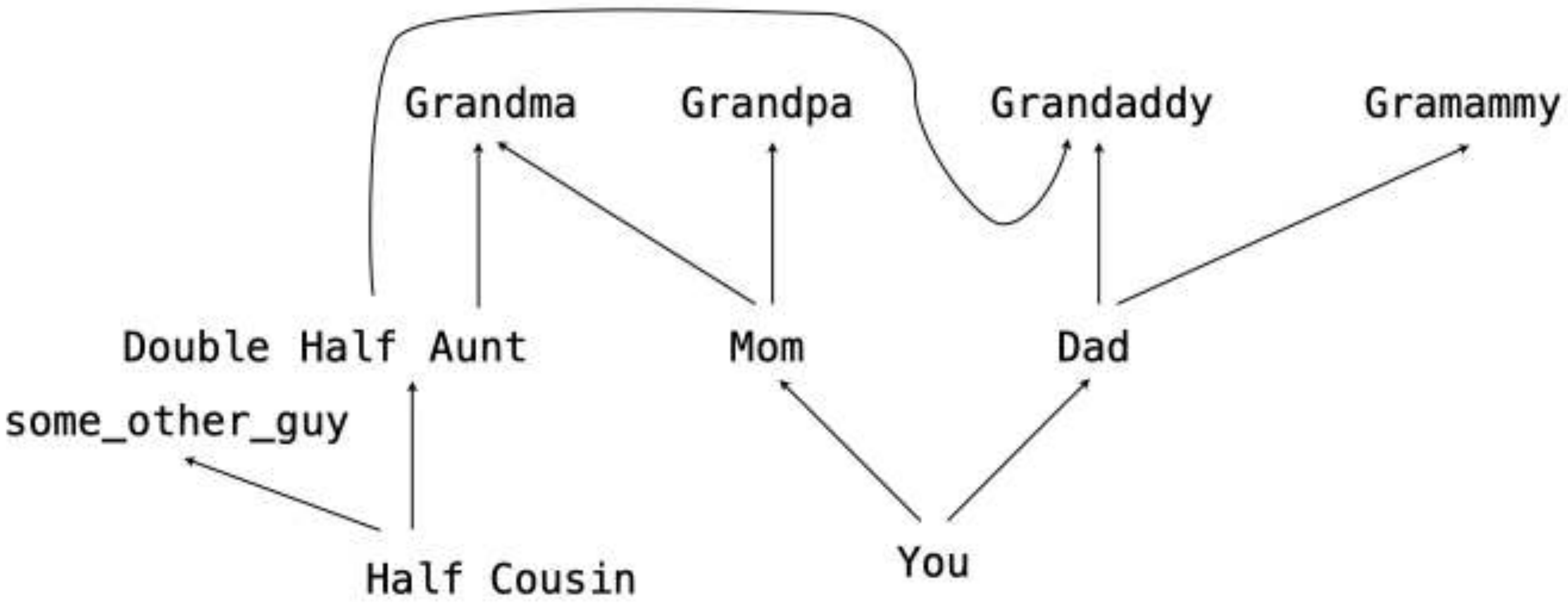
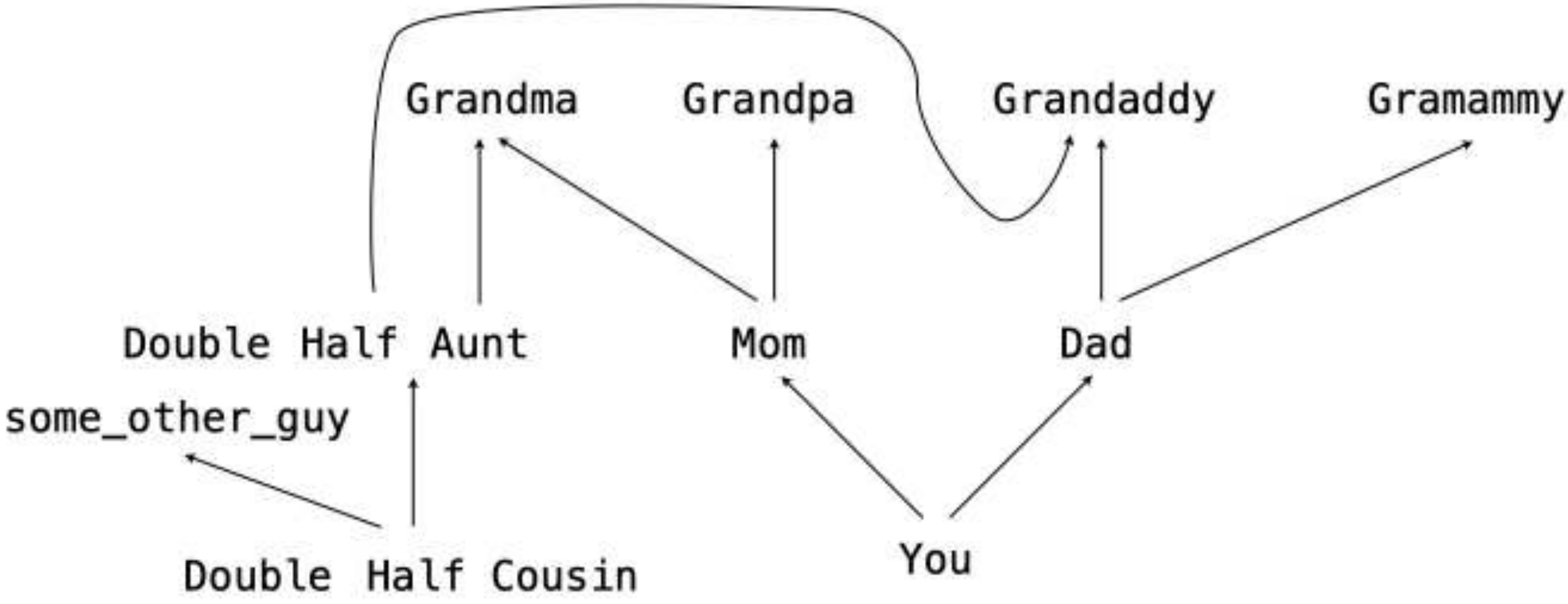


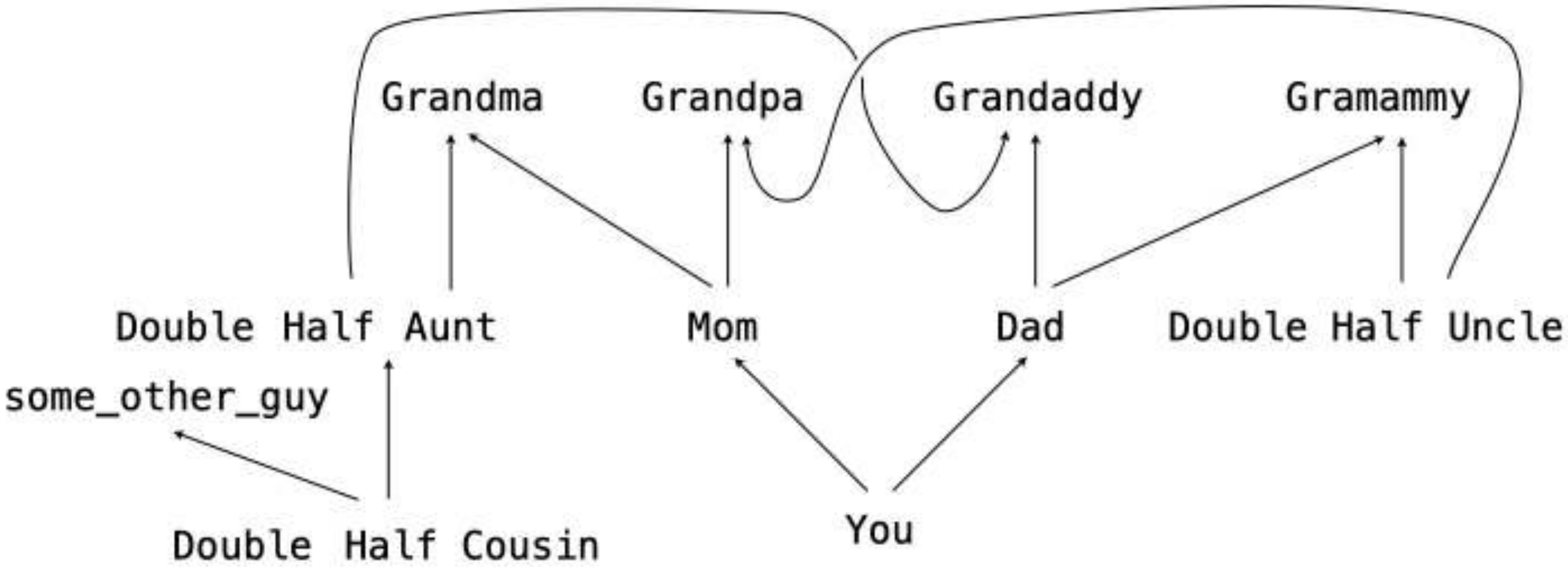
Biological Inheritance



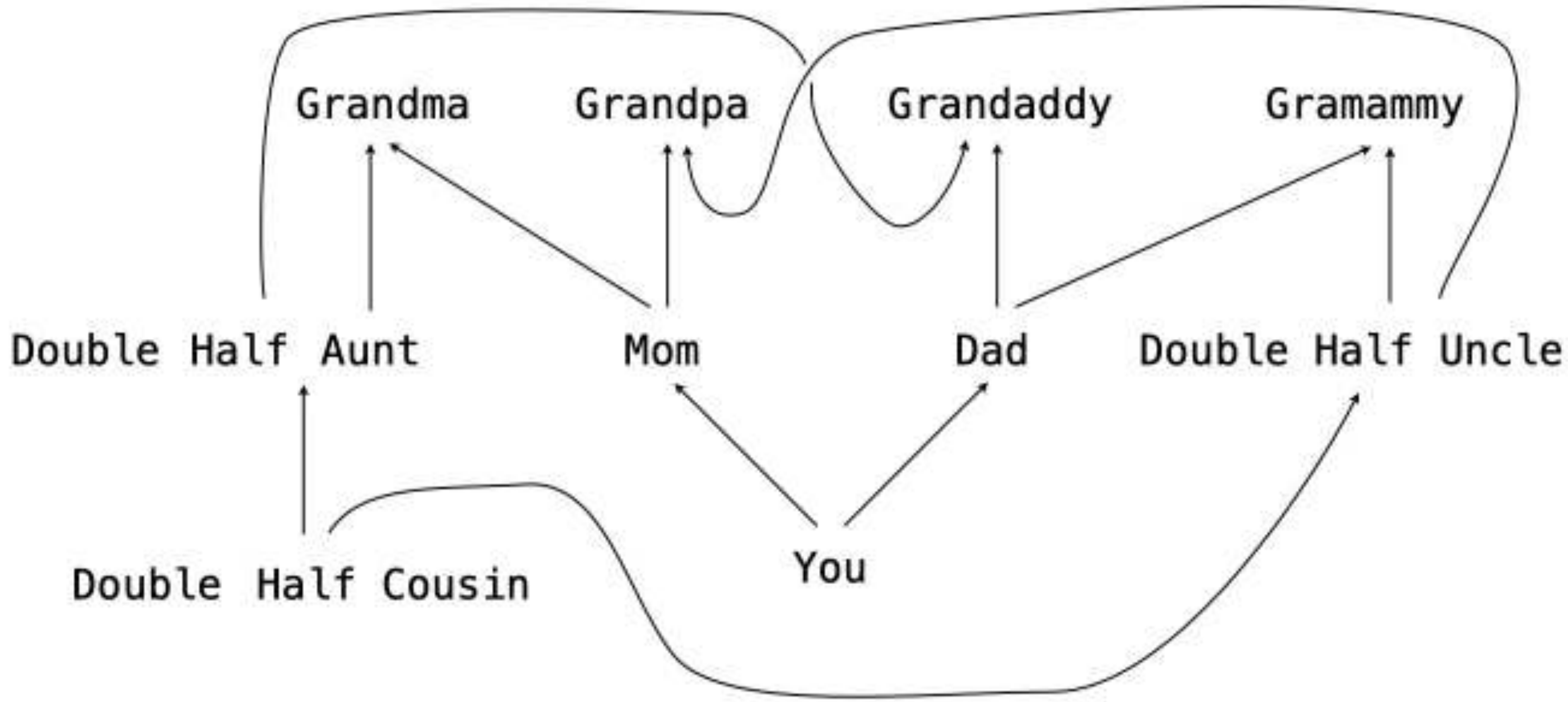
Biological Inheritance



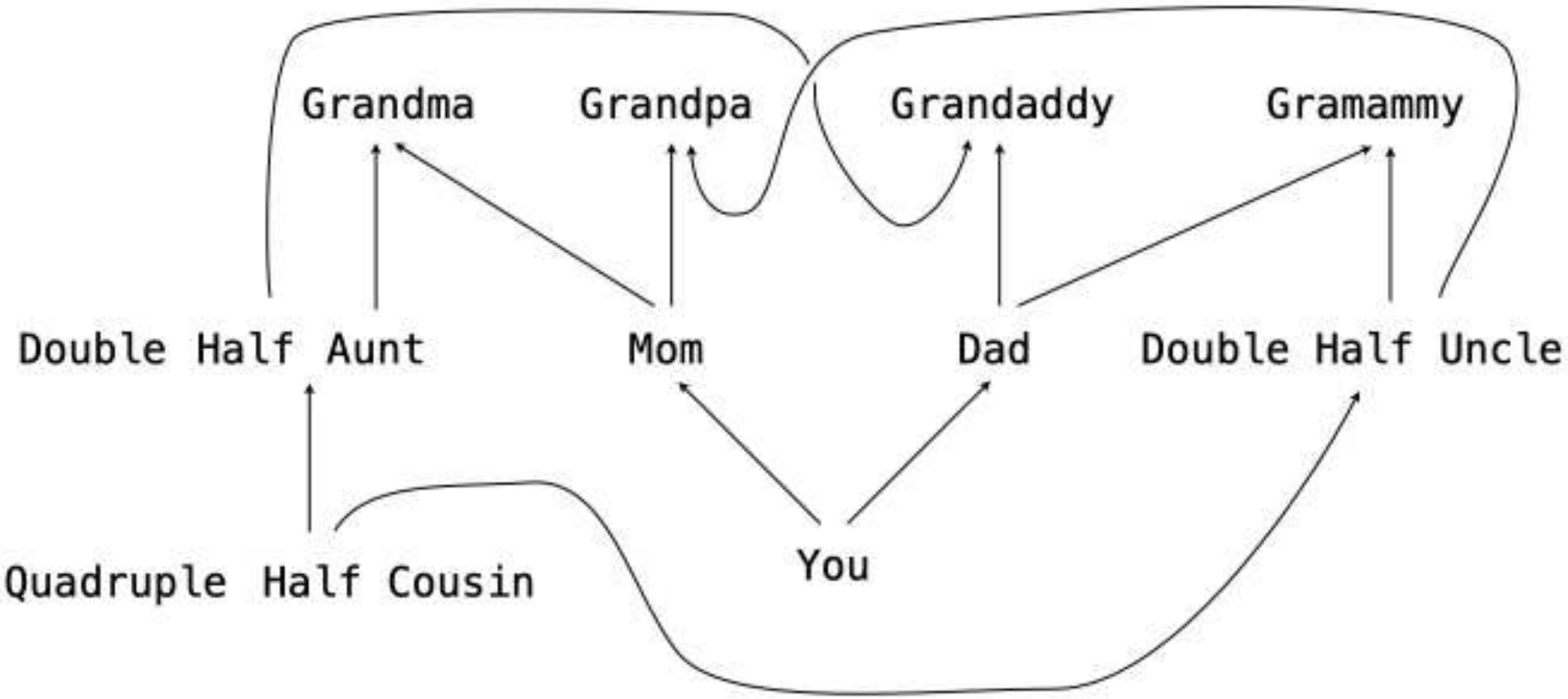
Biological Inheritance



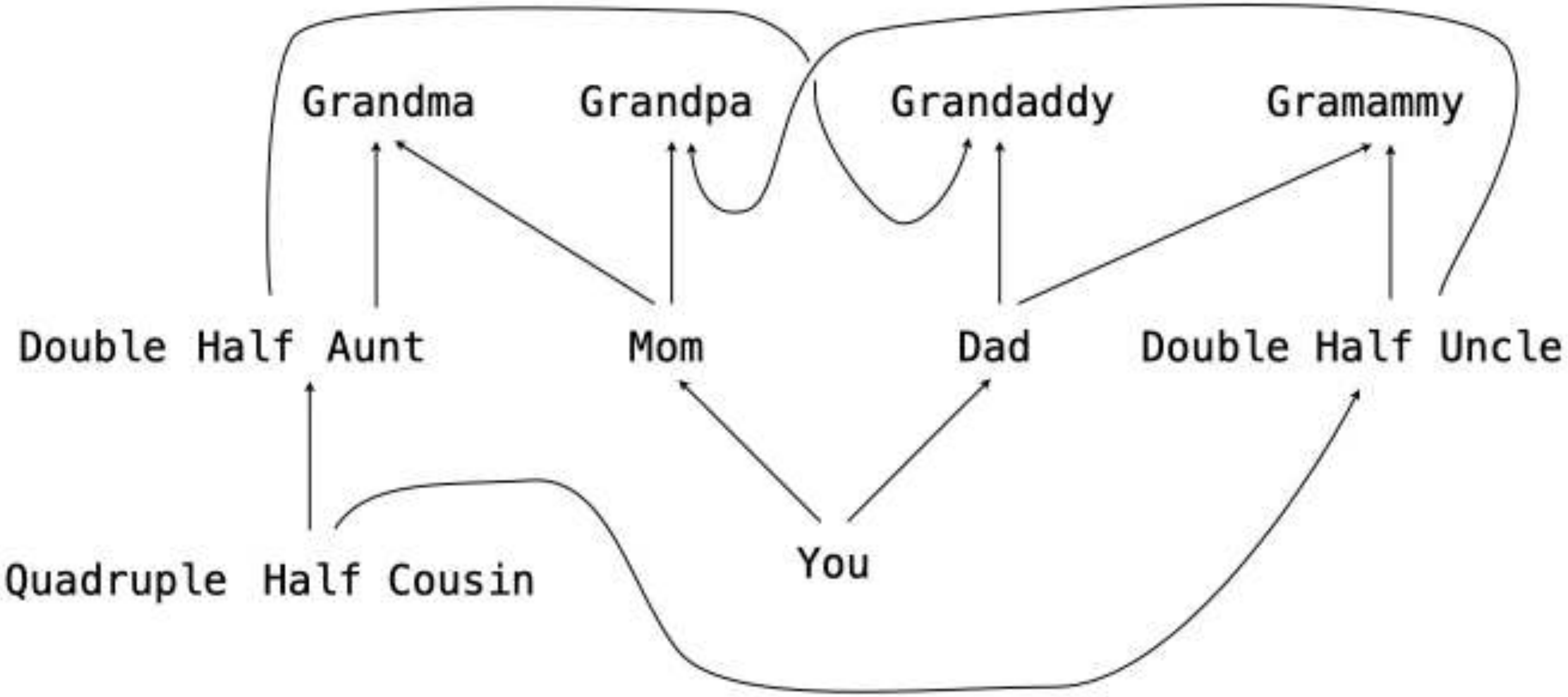
Biological Inheritance



Biological Inheritance



Biological Inheritance



Moral of the story: Inheritance can be complicated, so don't overuse it!