Recreation

Given that

$$\log(1 + x) = x - \frac{1}{2}x^2 + \frac{1}{3}x^3 - \ldots$$

why is it not the case that

$$\log 2 = 1 - \frac{1}{2} + \frac{1}{3} - \frac{1}{4} + \frac{1}{5} - \frac{1}{6} + \frac{1}{7} - \frac{1}{8} + \frac{1}{9} - \ldots$$

$$= (1 + \frac{1}{3} + \frac{1}{5} + \frac{1}{7} + \frac{1}{9} + \ldots) - (\frac{1}{2} + \frac{1}{4} + \frac{1}{6} + \frac{1}{8} + \ldots)$$

$$= (1 + \frac{1}{3} + \frac{1}{5} + \frac{1}{7} + \frac{1}{9} + \ldots) + (\frac{1}{2} + \frac{1}{4} + \frac{1}{6} + \frac{1}{8} + \ldots)$$

$$- 2(\frac{1}{2} + \frac{1}{4} + \frac{1}{6} + \frac{1}{8} + \ldots)$$

$$= (1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \ldots) - (1 + \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \ldots)$$

$$= 0?$$
Basic Idea.

- **Function-based programs** are organized primarily around the functions (methods, etc.) that do things. Data structures (objects) are considered separate.

- **Object-based programs** are organized around the types of objects that are used to represent data; methods are grouped by type of object.

- Simple banking-system example:

```
Function-based

account
  deposit
  withdraw
  account

Object-based

Account
  deposit
  withdraw
  balance: 1420

Exported methods

Exported field
```
Philosophy

• Idea (from 1970s and before): An abstract data type is
  - a set of possible values (a domain), plus
  - a set of operations on those values (or their containers).

• In IntList, for example, the domain was a set of pairs: (head, tail), where head is an int and tail is a pointer to an IntList.

• The IntList operations consisted only of assigning to and accessing the two fields (head and tail).

• In general, we prefer a purely procedural interface, where the functions (methods) do everything—no outside access to the internal representation (i.e., instance variables).

• That way, implementor of a class and its methods has complete control over behavior of instances.

• In Java, the preferred way to write the “operations of a type” is as instance methods.
## You Saw It All (Maybe) in CS61A: The Account Class

```
class Account:
    balance = 0
    def __init__(self, balance0):
        self.balance = balance0

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

    def withdraw(self, amount):
        if self.balance < amount:
            raise ValueError("Insufficient funds")
        else:
            self.balance -= amount
            return self.balance

myAccount = Account(1000)
print(myAccount.balance)
myAccount.deposit(100)
myAccount.withdraw(500)
```

```
public class Account {
    public int balance;
    public Account(int balance0) {
        this.balance = balance0;
    }
    public int deposit(int amount) {
        balance += amount; return balance;
    }
    public int withdraw(int amount) {
        if (balance < amount)
            throw new IllegalStateException("Insufficient funds");
        else balance -= amount;
        return balance;
    }
}
```

```
Account myAccount = new Account(1000);
print(myAccount.balance)
myAccount.deposit(100);
myAccount.withdraw(500);
```
You Also Saw It All in CS61AS

(define-class (account balance0)
  (instance-vars (balance 0))
  (initialize
   (set! balance balance0)))

(method (deposit amount)
  (set! balance (+ balance amount))
  balance)

(method (withdraw amount)
  (if (< balance amount)
    (error "Insufficient funds")
    (begin
      (set! balance (- balance amount))
      balance)) )

(define my-account
  (instantiate account 1000))
(ask my-account 'balance)
(ask my-account 'deposit 100)
(ask my-account 'withdraw 500)

public class Account {
  public int balance;
  public Account(int balance0) {
    balance = balance0;
  }
  public int deposit(int amount) {
    balance += amount; return balance;
  }
  public int withdraw(int amount) {
    if (balance < amount)
      throw new IllegalStateException("Insufficient funds");
    else balance -= amount;
    return balance;
  }
}

Account myAccount = new Account(1000);
myAccount.balance
myAccount.deposit(100);
myAccount.withdraw(500);
The Pieces

- **Class declaration** defines a new type of object, i.e., new type of structured container.

- **Instance variables** such as `balance` are the simple containers within these objects (*fields* or *components*).

- **Instance methods**, such as `deposit` and `withdraw` are like ordinary (static) methods that take an invisible extra parameter (called `this`).

- The **`new` operator** creates (*instantiates*) new objects, and initializes them using constructors.

- **Constructors** such as the method-like declaration of `Account` are special methods that are used only to initialize new instances. They take their arguments from the `new` expression.

- **Method selection** picks methods to call. For example,

  ```java
  myAccount.deposit(100)
  ```
  tells us to call the method named `deposit` that is defined for the object pointed to by `myAccount`.
  
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Getter Methods

• Slight problem with Java version of Account: anyone can assign to the balance field

• This reduces the control that the implementor of Account has over possible values of the balance.

• Solution: allow public access only through methods:

```java
public class Account {
    private int _balance;
    ...
    public int balance() { return _balance; }
    ...
}
```

• Now Account._balance = 1000000 is an error outside Account.

• (I use the convention of putting '_' at the start of private instance variables to distinguish them from local variables and non-private variables. Could actually use balance for both the method and the variable, but please don’t.)
Class Variables and Methods

- Suppose we want to keep track of the bank’s total funds.
- This number is not associated with any particular Account, but is common to all—it is class-wide. In Java, “class-wide” ≡ static.

```java
public class Account {
    ...
    private static int _funds = 0;
    public int deposit(int amount) {
        _balance += amount;
        _funds += amount;  // or this._funds or Account._funds
        return _balance;
    }
    public static int funds() {
        return _funds;  // or Account._funds
    }
    ...
    // Also change withdraw.
}
```

- From outside, can refer to either Account.funds() or to myAccount.funds() (same thing).
Instance Methods

• Instance method such as

```java
int deposit(int amount) {
    _balance += amount;
    _funds += amount;
    return balance;
}
```

behaves sort of like a static method with hidden argument:

```java
static int deposit(final Account this, int amount) {
    this._balance += amount;
    _funds += amount;
    return this._balance;
}
```

• NOTE: Just explanatory: Not real Java (not allowed to declare 'this'). (final is real Java; means “can’t change once initialized.”)
/** (Fictional) equivalent of deposit instance method. */
static int deposit(final Account this, int amount) {
    this._balance += amount;
    _funds += amount;
    return this._balance;
}

• Likewise, the instance-method call myAccount.deposit(100) is like a call on this fictional static method:

    Account.deposit(myAccount, 100);

• Inside a real instance method, as a convenient abbreviation, one can leave off the leading 'this.' on field access or method call if not ambiguous. (Unlike Python)
'Instance' and 'Static' Don't Mix

- Since real static methods don't have the invisible `$this` parameter, makes no sense to refer directly to instance variables in them:

```java
public static int badBalance(Account A) {
    int x = A._balance;  // This is OK
    // (A tells us whose balance)
    return _balance;     // WRONG! NONSENSE!
}
```

- Reference to `_balance` here equivalent to `$this->_balance`,
- But this is meaningless (`whose` balance?)
- However, it makes perfect sense to access a static (class-wide) field or method in an instance method or constructor, as happened with `_funds` in the `deposit` method.
- There's only one of each static field, so don't need to have a 'this' to get it. Can just name the class (or use no qualification inside the class, as we've been doing).
Constructors

- To completely control objects of some class, you must be able to set their initial contents.

- A constructor is a kind of special instance method that is called by the `new` operator right after it creates a new object, as if

\[
L = \text{new IntList}(1, \text{null}) \implies \begin{cases} 
\text{tmp = pointer to } 0 \N \\
\text{tmp.IntList}(1, \text{null}); \\
L = \text{tmp};
\end{cases}
\]
Multiple Constructors and Default Constructors

- All classes have constructors. In the absence of any explicit constructor, get default constructor, as if you had written:

  ```java
  public class Foo {
      public Foo() {} } 
  ```

- Multiple overloaded constructors possible, and they can use each other (although the syntax is odd):

  ```java
  public class IntList {
      public IntList(int head, IntList tail) {
          this.head = head; this.tail = tail;
      }

      public IntList(int head) {
          this(head, null); // Calls first constructor.
      }

      ... 
  }
  ```
Constructors and Instance Variables

- Instance variables initializations are moved inside constructors that don't start with `this(...)`.  

```java
class Foo {
    int x = 5;
    Foo(int y) {
        DoStuff(y);
    }
    Foo() {
        this(42);
    }
}

class Foo {
    int x;
    Foo(int y) {
        x = 5;
        DoStuff(y);
    }
    Foo() {
        this(42); // Assigns to x
    }
}
```
## Summary: Java vs. Python

<table>
<thead>
<tr>
<th>Java</th>
<th>Python</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{class Foo} { \texttt{int x = ...;}};\texttt{Foo(...)} { ... } \texttt{int f(...)} { ... } \texttt{static int y = 21;} \texttt{static void g(...)} { ... } }</td>
<td>\texttt{class Foo: \ldots} \texttt{x = ...} \texttt{def __init__(self, \ldots): \ldots} \texttt{def f(self, \ldots): \ldots} \texttt{y = 21 # Referred to as Foo.y}  \texttt{@staticmethod} \texttt{def g(...): \ldots}</td>
</tr>
<tr>
<td>aFoo.f(...)</td>
<td>aFoo.f(...)</td>
</tr>
<tr>
<td>aFoo.x</td>
<td>aFoo.x</td>
</tr>
<tr>
<td>new Foo(...)</td>
<td>new Foo(...)</td>
</tr>
<tr>
<td>this</td>
<td>this</td>
</tr>
</tbody>
</table>

- `aFoo.f(...)`: Call a method `f` on an instance of `Foo`.
- `aFoo.x`: Access the instance variable `x`.
- `new Foo(...)`: Create a new instance of `Foo`.
- `this`: A keyword used to refer to the current object in Java.

Self: # (typically)