Designing Types

From first day of class!

- **Type**: set of values and the operations on them
  - int: (**set**: integers; **ops**: +, –, *, /, …)
  - Time (**set**: times of day; **ops**: time span, before/after, …)
  - Worker (**set**: all possible workers; **ops**: hire,pay,promote,…)
  - Rectangle (**set**: all axis-aligned rectangles in 2D; **ops**: contains, intersect, …)
- To define a class, think of a *real type* you want to make
  - Python gives you the tools, but does not do it for you
  - Physically, any object can take on any value
  - Discipline is required to get what you want

Making a Class into a Type

1. Think about what values you want in the set
   - What are the attributes? What values can they have?
2. Think about what operations you want
   - This often influences the previous question
- To make (1) precise: write a *class invariant*
  - Statement we promise to keep true **after every method call**
- To make (2) precise: write *method specifications*
  - Statement of what method does/what it expects (preconditions)
- Write your code to make these statements true!

Planning out a Class

```
class Time(object):
    """Instances represent times of day.
    Instance Attributes:
        hour: hour of day [int in 0..23]
        min:  minute of hour [int in 0..59]"""

    def __init__(self, hour, min):
        """The time hour:min.
        Pre: hour in 0..23; min in 0..59"""

    def increment(self, hours, mins):
        """Move this time <hours> hours
        and <mins> minutes into the future.
        Pre: hours is int >= 0; mins in 0..59"""

    def isPM(self):
        """Returns: this time is noon or later."""
```

Class Invariant
States what attributes are present and what values they can have.
A statement that will always be true of any Time instance.

Method Specification
States what the method does.
Gives preconditions stating what is assumed true of the arguments.

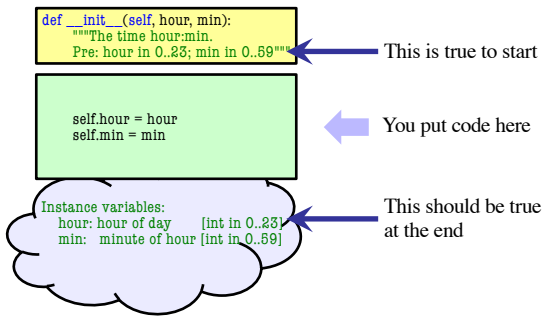
Planning out a Class

```
class Rectangle(object):
    """Instances represent rectangular
    regions of the plane.
    Instance Attributes:
        t: y coordinate of top edge [float]
        l: x coordinate of left edge [float]
        b: y coordinate of bottom edge [float]
        r: x coordinate of right edge [float]
    For all Rectangles, l <= r and b <= t."""

    def __init__(self, t, l, b, r):
        """The rectangle [l, r] x [t, b]
        Pre: args are floats; l <= r; b <= t"""

    def area(self):
        """Return: area of the rectangle."""

    def intersection(self, other):
        """Return: new Rectangle describing
           intersection of self with other."""
```

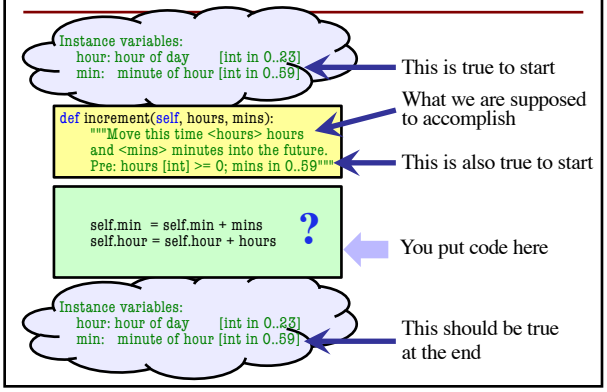
Class Invariant
States what attributes are present and what values they can have.
A statement that will always be true of any Rectangle instance.

Method Specification
States what the method does.
Gives preconditions stating what is assumed true of the arguments.

Implementing an Initializer



Implementing a Method



Enforce Method Preconditions with assert

```
class Time(object):
    """Instances represent times of day."""

    def __init__(self, hour, min):
        """The time hour:min.
        Pre: hour in 0..23; min in 0..59"""
        assert type(hour) == int
        assert 0 <= hour and hour < 24
        assert type(min) == int
        assert 0 <= min and min < 60

    def increment(self, hours, mins):
        """Move this time <hours> hours
        and <mins> minutes into the future.
        Pre: hours is int >= 0; mins in 0..59"""
        assert type(hour) == int
        assert type (min) == int
        assert hour >= 0 and
        assert 0 <= min and min < 60
```

Instance Attributes:
hour: hour of day [int in 0..23]
min: minute of hour [int in 0..59]

Initializer creates/initializes all of the instance attributes.
Asserts in initializer guarantee the initial values satisfy the invariant.

Asserts in other methods enforce the method preconditions.

Hiding Methods From Access

- Put underscore in front of a method will make it **hidden**
  - Will not show up in help()
  - But it is still there…
- Hidden methods
  - Can be used as **helpers** inside of the same class
  - But it is bad style to use them outside of this class
- Can do same for attributes
  - Underscore makes it hidden
  - Do not use outside of class

```
class Fraction(object):
    """Instance attributes:
        numerator:   top      [int]
        denominator: bottom [int > 0]"""
    def _is_denominator(self,d):
        """Return: True if d valid denom"""
        return type(d) == int and d > 0

    def __init__(self,n=0,d=1):
        assert self._is_denominator(d)
        self.numerator = n
        self.denominator = d
```

HIDDEN

Helper method

Enforcing Invariants

```
class Fraction(object):
    """Instance attributes:
        numerator:   top      [int]
        denominator: bottom [int > 0]
    """
```

Invariants: Properties that are always true.

- These are just comments!

```
>>> p = Fraction(1,2)
>>> p.numerator = 'Hello'
```

- How do we prevent this?
- **Idea**: Restrict direct access
  - Only access via methods
  - Use asserts to enforce them
- Examples:

```
def getNumerator(self):
    """Returns: numerator"""
    return self.numerator

def setNumerator(self,value):
    """Sets numerator to value"""
    assert type(value) == int
    self.numerator = value
```

Data Encapsulation

- **Idea**: Force the user to only use methods
- Do not allow direct access of attributes

Setter Method

- Used to change an attribute
- Replaces all assignment statements to the attribute
- **Bad**:

```
>>> f.numerator = 5
```

- **Good**:

```
>>> f.setNumerator(5)
```

Getter Method

- Used to access an attribute
- Replaces all usage of attribute in an expression
- **Bad**:

```
>>> x = 3*f.numerator
```

- **Good**:

```
>>> x = 3*f.getNumerator()
```

Data Encapsulation

```
class Fraction(object):
    """Instance attributes:
        _numerator:   top      [int]
        _denominator: bottom [int > 0]"""

    def getDenomenator(self):
        """Returns: numerator attribute"""
        return self._denomenator

    def setDenomenator(self, d):
        """Alters denomenator to be d
        Pre: d is an int > 0"""
        assert type(d) == int
        assert 0 < d
        self._denominator = d
```

Do this for all of your attributes

Getter

Setter

Naming Convention
The underscore means "should not access the attribute directly."

Precondition is same as attribute invariant.

Mutable vs. Immutable Attributes

Mutable

- Can change value directly
  - If class invariant met
  - **Example**: t.color
- Has both getters and setters
  - Setters allow you to change
  - Enforce invariants w/ asserts

Immutable

- Can't change value directly
  - May change "behind scenes"
  - **Example**: t.x
- Has only a getter
  - No setter means no change
  - Getter allows limited access

May ask you to differetiate on the exam