



# Hypothesis

Tests that write themselves

David Kua

PyOhio 2017

@davidkua



UNIVERSITY OF  
**TORONTO**

**pagerduty**

We're hiring!

pagerduty

[www.pagerduty.com/careers](http://www.pagerduty.com/careers)

# Agenda

① <sup>High level</sup> Overview of property-based testing

② Hypothesis \*

[www.github.com/dkua/pyohio17-talk](https://www.github.com/dkua/pyohio17-talk)

---

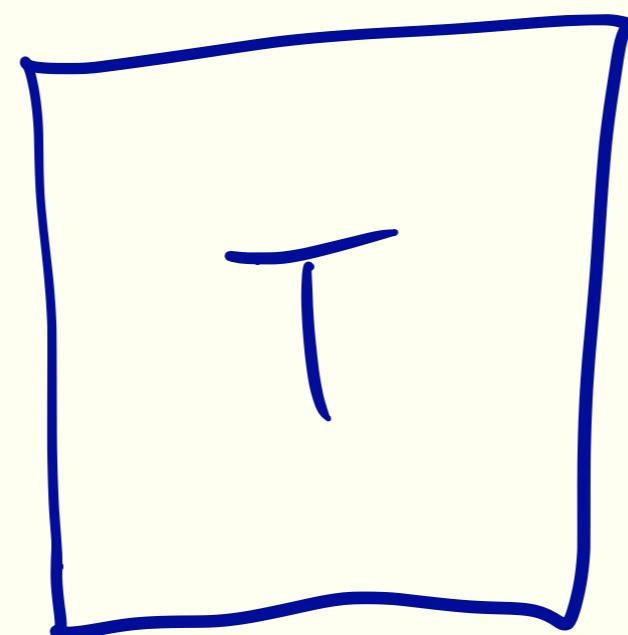
# Hypothesis

~~Tests that write themselves~~

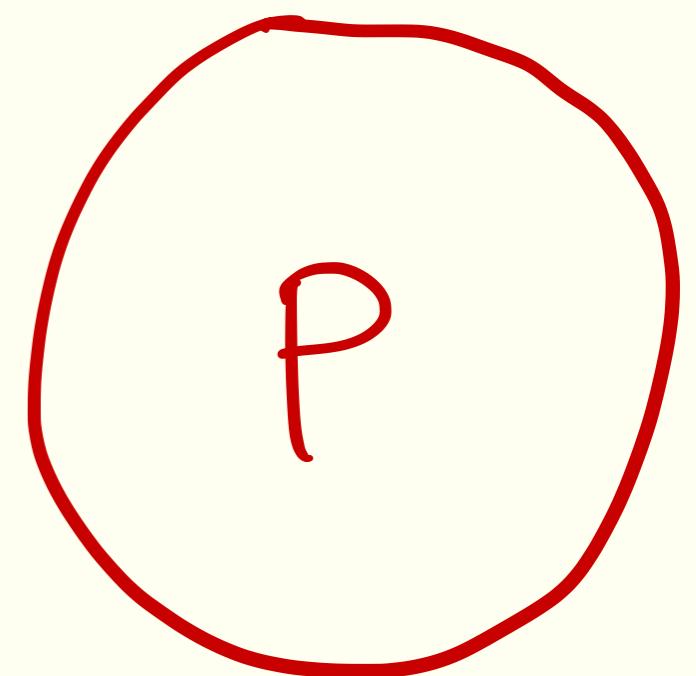
Generating tests from properties  
of your code

David Kua

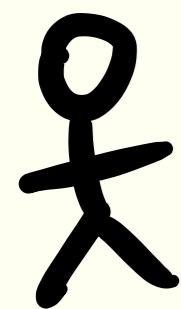
@davidkua

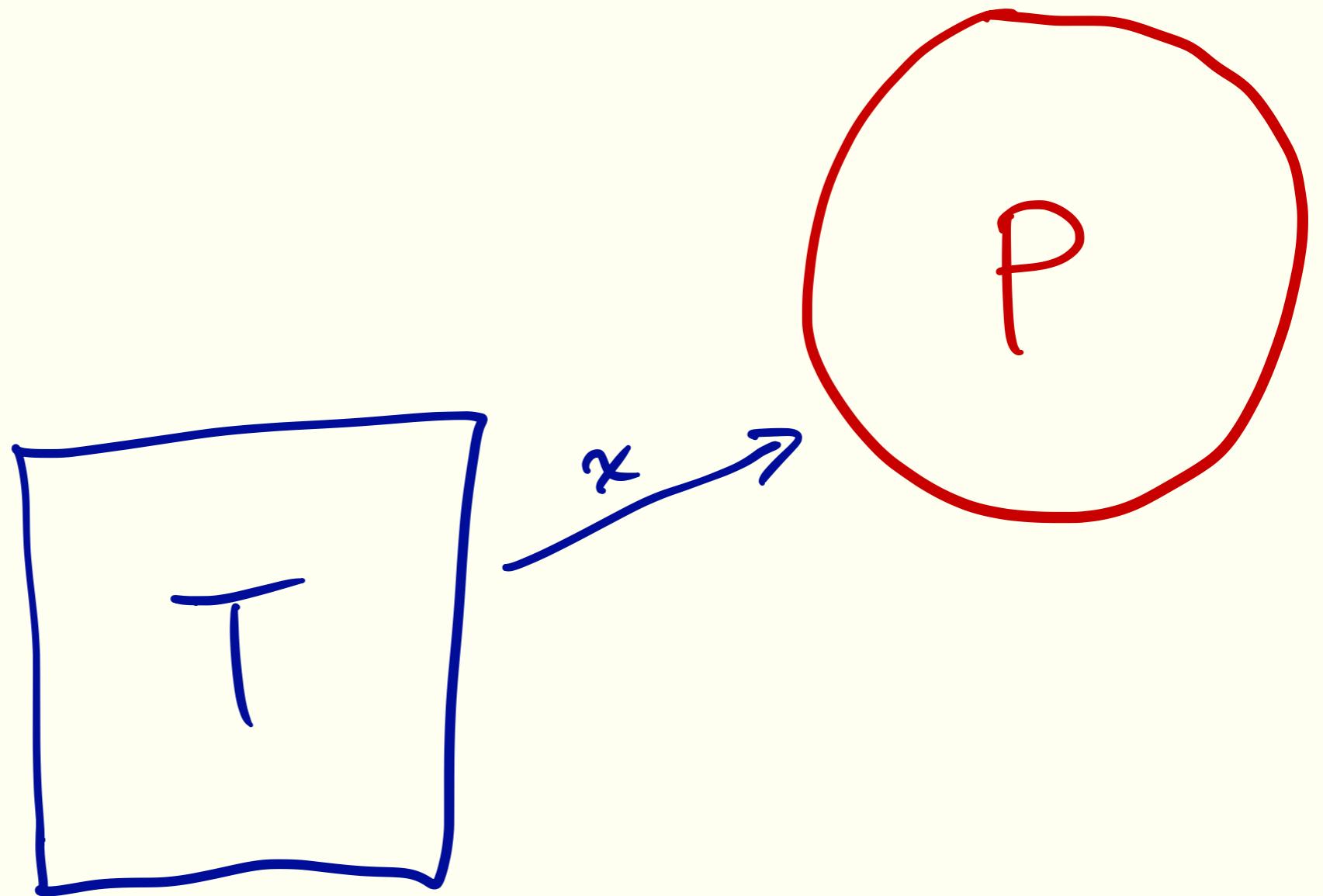


T



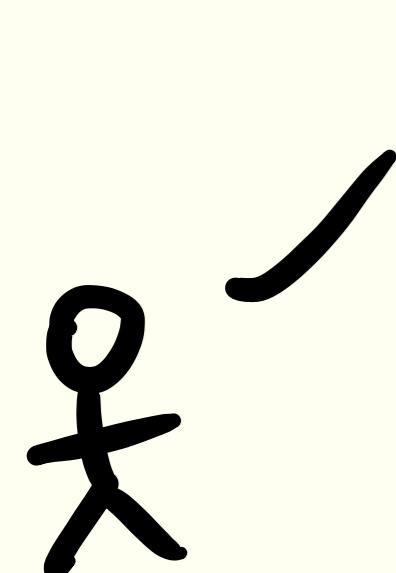
P



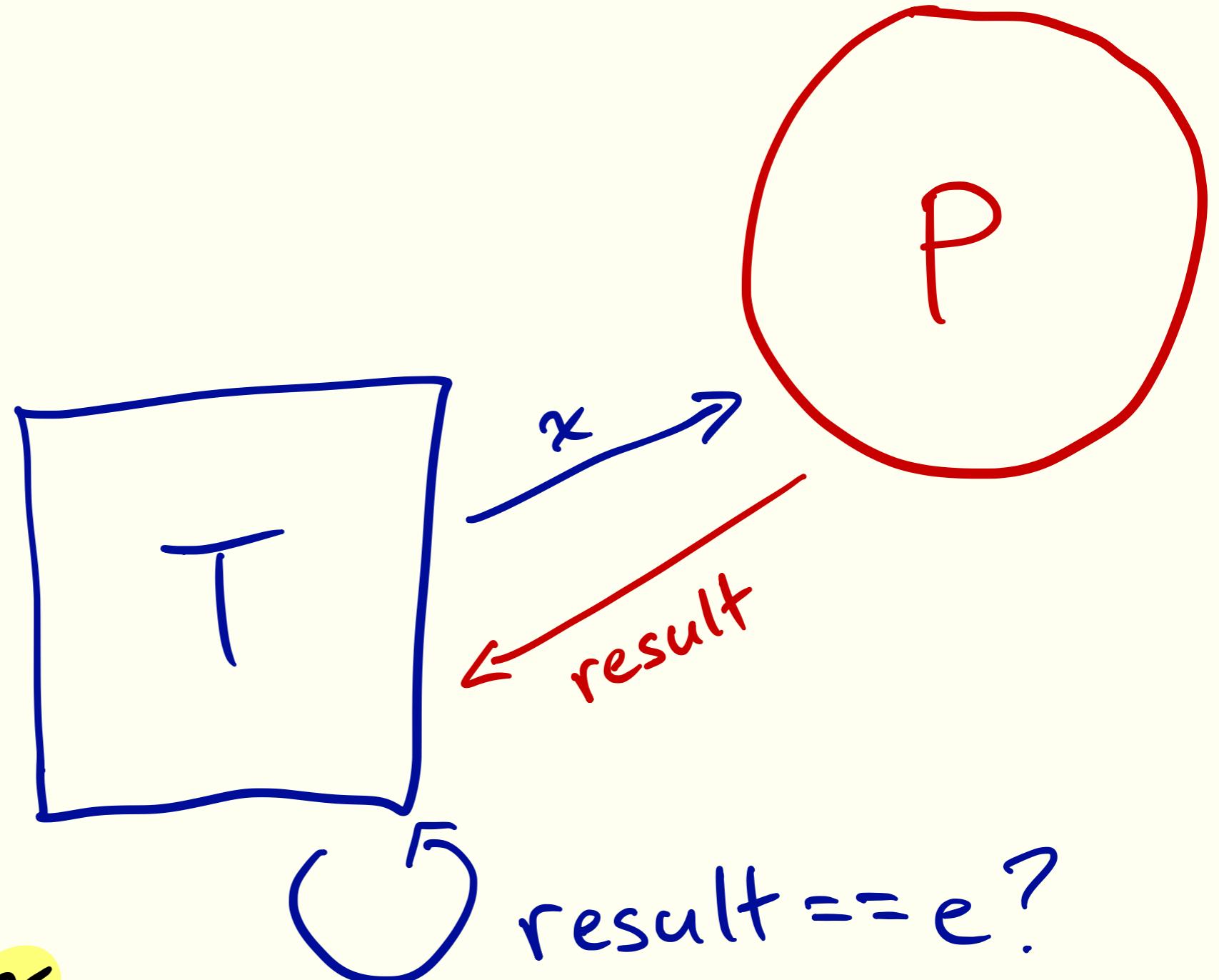


Here's  $x$   
I want  $e$

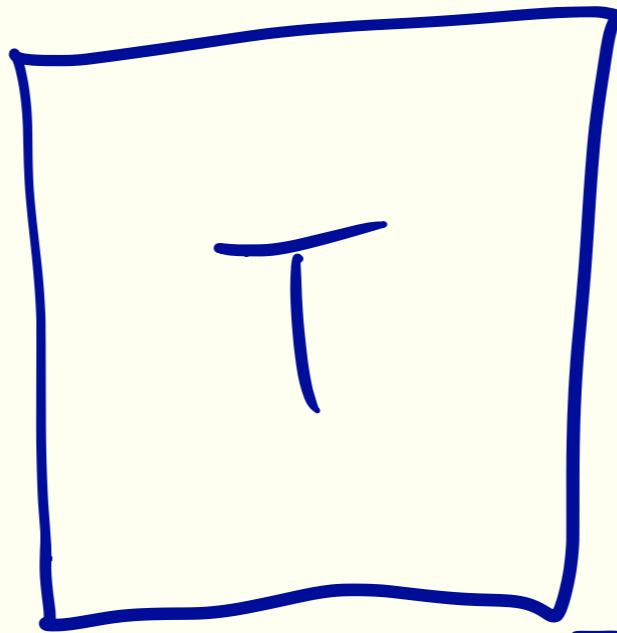
↙



Here's  $x$   
I want  $e$



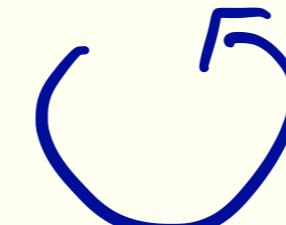
Pass or Fail



$x$

result

P

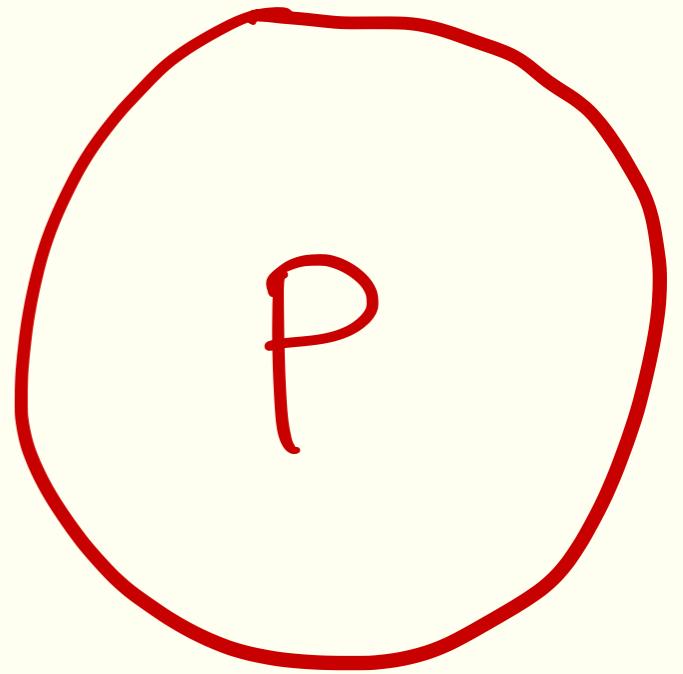
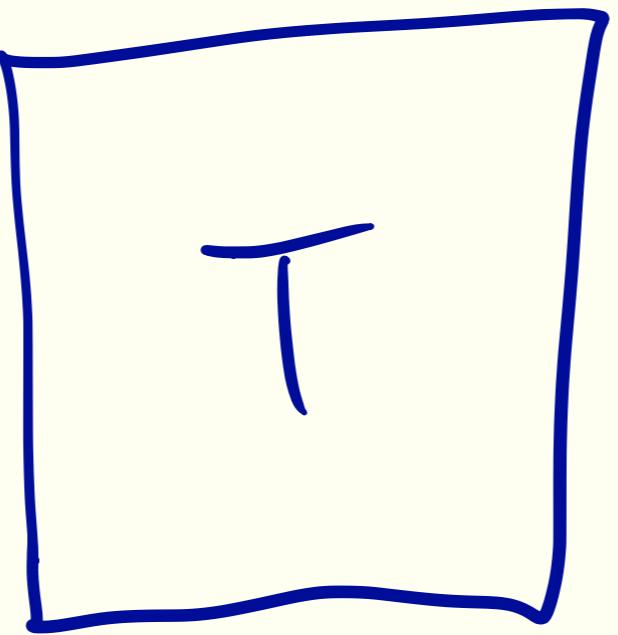


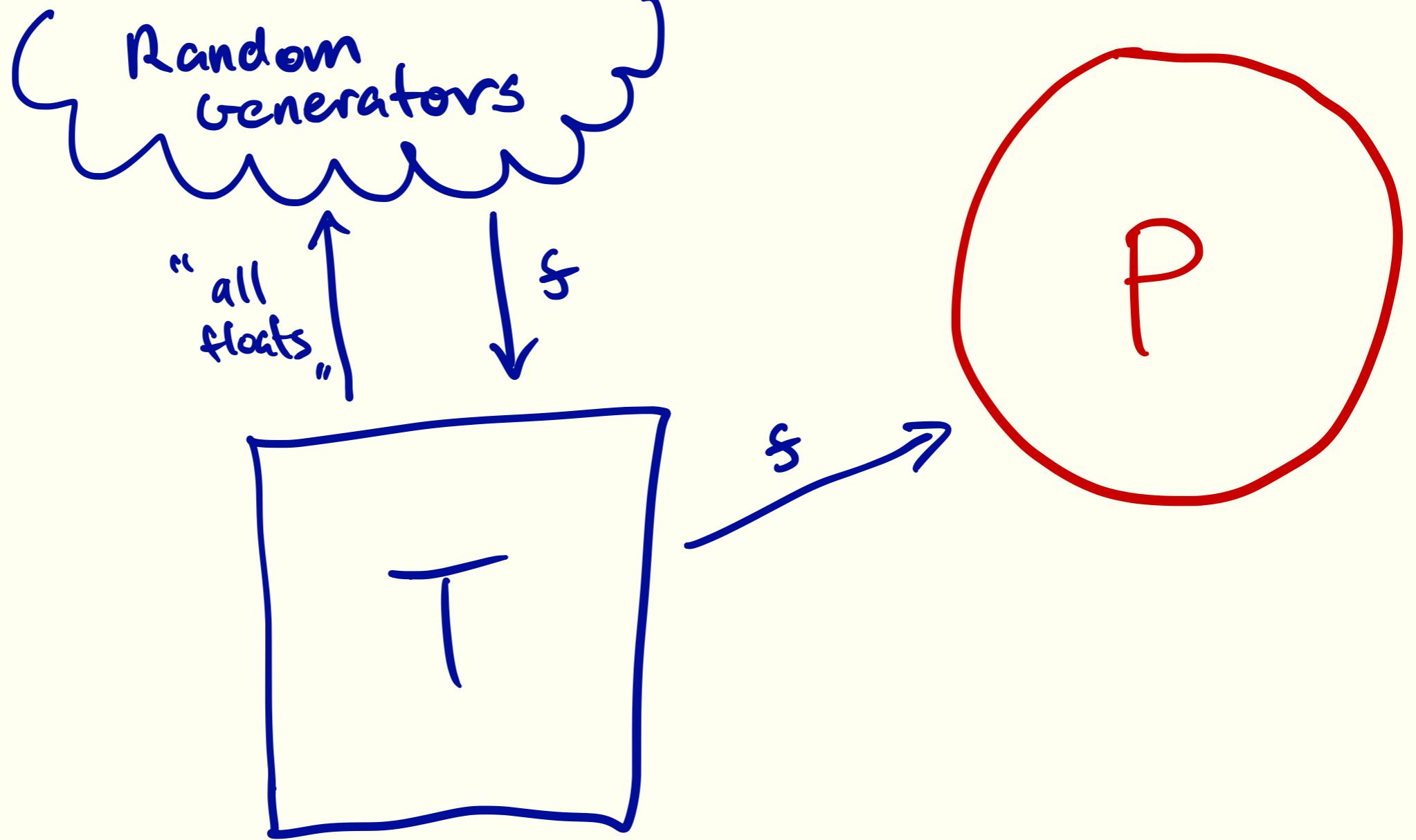
result == e?

Here's  $x$   
I want  $e$

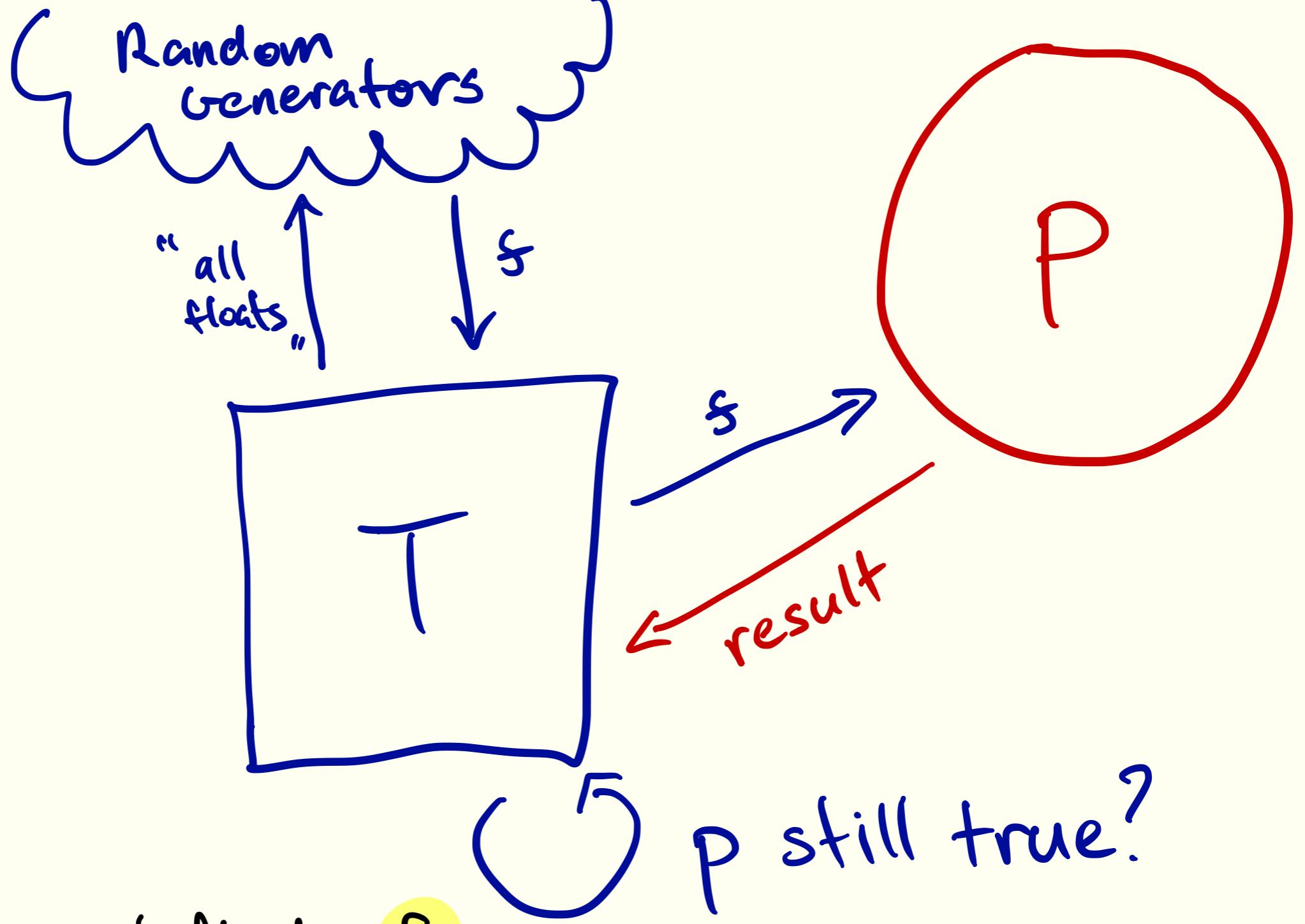


Random  
generators

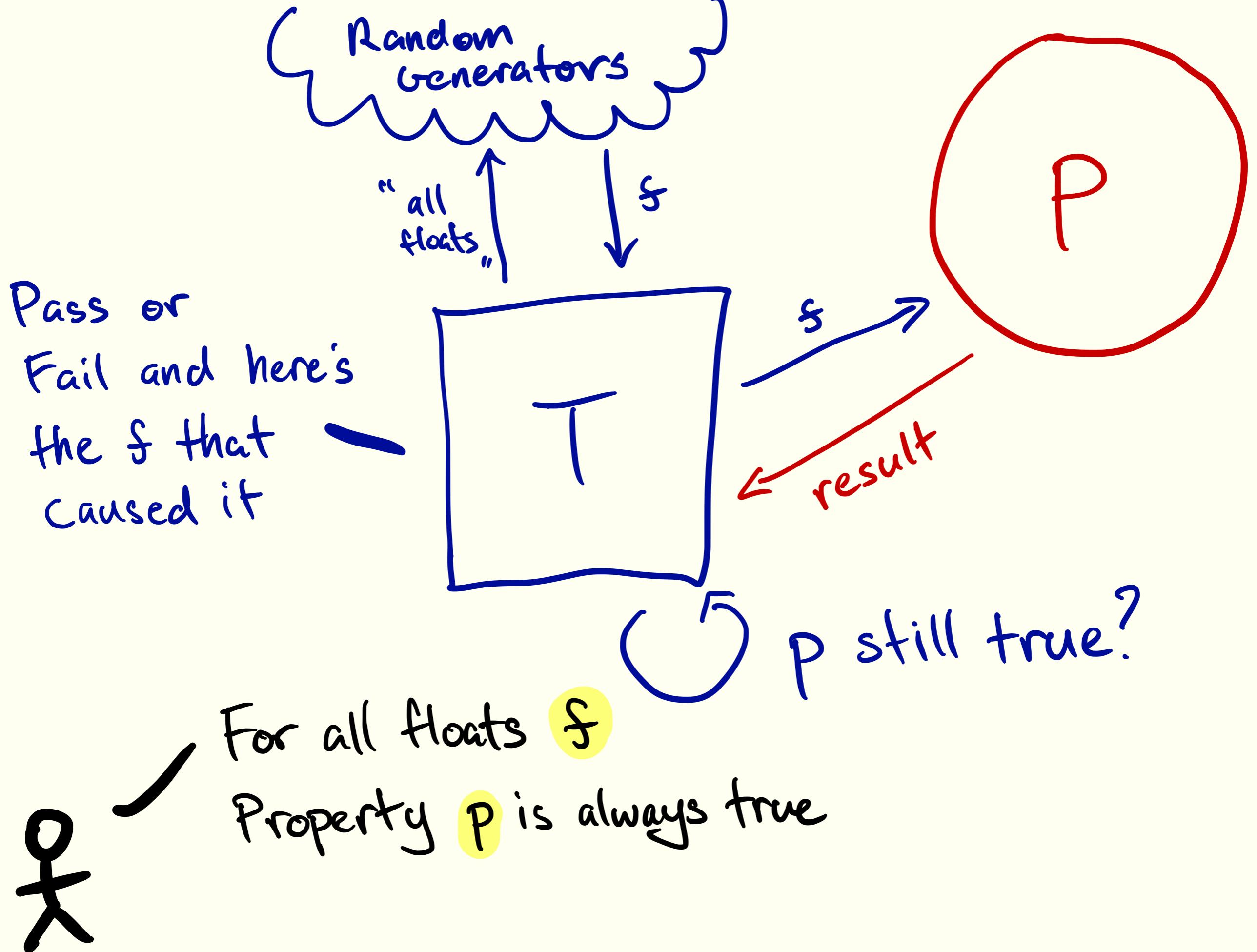




For all floats  $f$   
Property  $P$  is always true



For all floats  $f$   
Property  $P$  is always true



# Unit Testing

Give an input.

2, 4, 57, 100, 999...

Give a result.

true, true, false, true, false...

# Property-based Testing

Describe the inputs. "All ints"

Describe condition(s)  
that must hold.

"Remainder is 0"

or

"Result is an int"

# Pros

- # of tests only limited by power & time
- code overhead is minimized
- random generation more likely to find edge case

# Cons

- harder & longer to write
- finding properties can be difficult
- random generation might miss an edge case

An extra tool in your toolkit

What about  
Behaviour Driven  
Development (BDD)  
and Fuzz Testing?

# Frameworks

Haskell - QuickCheck

Erlang - Erlang QuickCheck, PropEr

Clojure - test.check

Scala - ScalaCheck

F# - FsCheck

PHP - Eris

C - QuickCheck for C

... and more

# Hypothesis

- Python 2.7, 3.3+
- Py.test, unittest, Nose (maybe)
- extra packages for: Django,  
  datetime,  
  NumPy
- super dope

[github.com/HypothesisWorks/hypothesis-python](https://github.com/HypothesisWorks/hypothesis-python)

# Finding properties

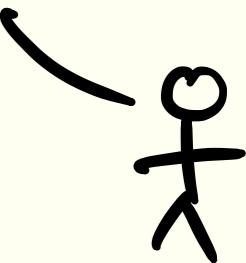
“copy + paste”

“given”

“who cares”

“reversible”

The names  
are terrible  
I know.  
Sorry.



0

Addition

$$x + y = y + x$$

# w/ Unit Tests

```
def test_add_zero():
    assert 0 + 1 == 1 + 0

def test_add_single_digits():
    assert 1 + 2 == 2 + 1

def test_add_double_digits():
    assert 10 + 12 == 12 + 10
```

“copy  
+  
paste”

# w/ Hypothesis

```
from hypothesis import given
import hypothesis.strategies as st

→ @given(st.integers(), st.integers())
def test_add(x, y):
    assert x + y == y + x
```

# Running Hypothesis

```
(pycon) ~/pyconca16-talk [master] » pytest --hypothesis-show-statistics add_example.py
=====
platform darwin -- Python 2.7.12, pytest-3.0.4, py-1.4.31, pluggy-0.4.0
rootdir: /Users/dkua/pyconca16-talk, ini file:
plugins: hypothesis-3.6.0
collected 4 items

add_example.py ....
===== Hypothesis Statistics =====

add_example.py::test_add:


- 200 passing examples, 0 failing examples, 0 invalid examples
- Typical runtimes: < 1ms
- Stopped because settings.max_examples=200


===== 4 passed in 0.11 seconds =====
(pycon) ~/pyconca16-talk [master] » █
```

# hypothesis. strategies

none

booleans

floats

integers

complex numbers

tuples

lists

binary

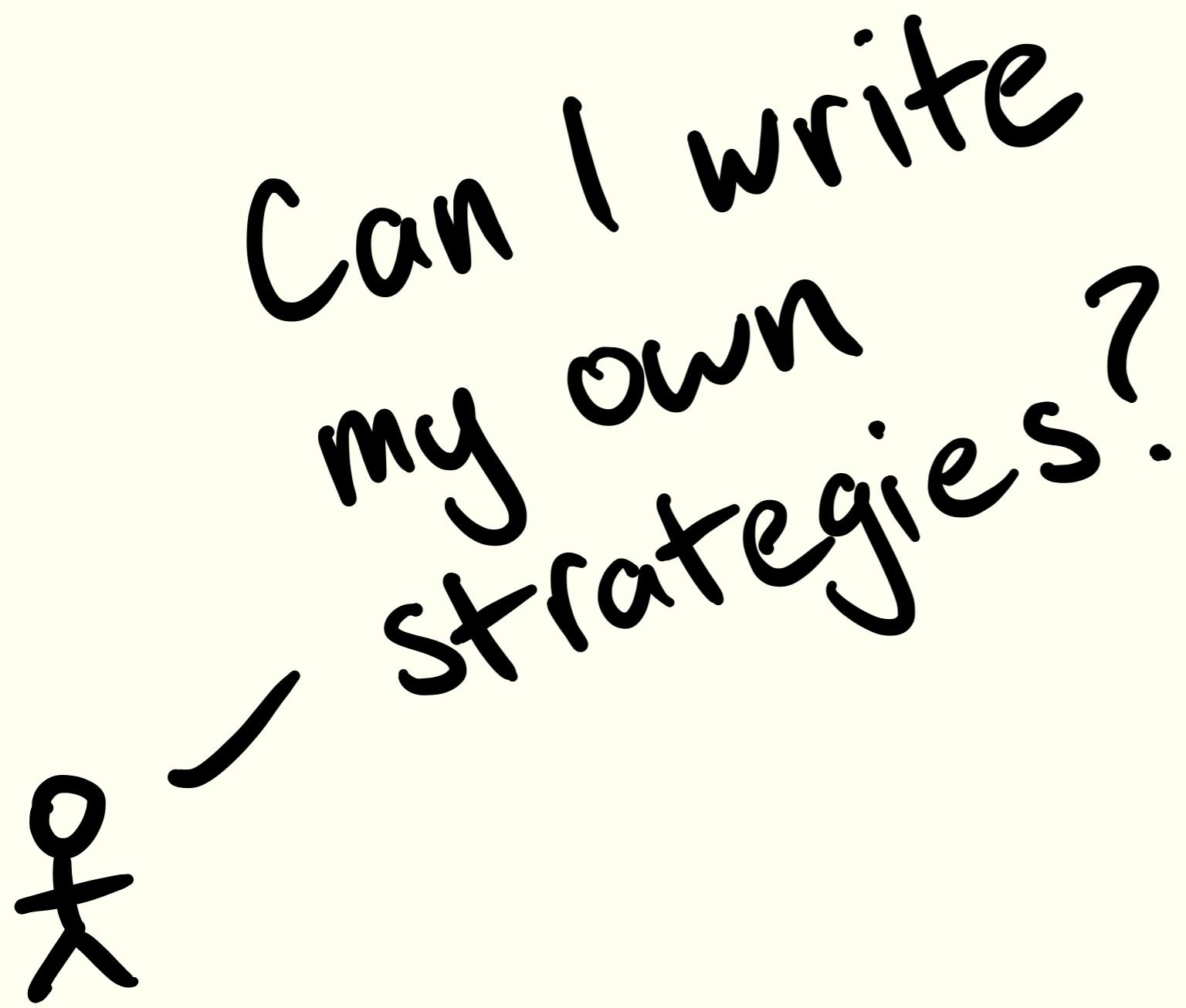
sets

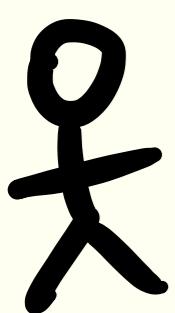
dictionaries

frozen sets

... and more!

②





Make sure that  
all books support Unicode  
and never cost less than  
nothing!



“given”



```
class Book(object):
    def __init__(self, title, author, price):
        self.title = title
        self.author = author
        self.price = price
    def __unicode__(self):
        return u"%s by %s ($%s)" % (self.title, self.author, self.price)
    def __repr__(self):
        return self.__unicode__().encode("utf-8")
```

the  
input

↖ a property

↖ and another

# Use builds()

```
from hypothesis import given
import hypothesis.strategies as st
```

```
books = st.builds(  
    Book,  
    title=st.text(),  
    author=st.text(),  
    price=st.floats(),  
)
```

```
@given(books)  
def test_unicode(book):  
    print(book)
```

```
@given(books)  
def test_never_negative(book):  
    assert book.price >= 0.00
```

the object  
the input

# A Hypothesis failure!

```
===== FAILURES =====
test_never_negative
```

---

```
@given(books)
> def test_never_negative(book):

book_example.py:36:
../.virtualenvs/pycon/lib/python2.7/site-packages/hypothesis/core.py:524: in wrapped_test
    print_example=True, is_final=True
../.virtualenvs/pycon/lib/python2.7/site-packages/hypothesis/executors.py:58: in default_new_style_executor
    return function(data)
../.virtualenvs/pycon/lib/python2.7/site-packages/hypothesis/core.py:111: in run
    return test(*args, **kwargs)
```

---

```
-----
```

```
book = by ($nan)

@given(books)
def test_never_negative(book):
    assert book.price >= 0.00
E    assert nan >= 0.0
E    + where nan = by ($nan).price
```

the failed line

why it failed

```
----- Hypothesis -----
Falsifying example: test_never_negative(book= by ($nan))
===== 1 failed, 1 passed in 1.16 seconds =====
```

the example  
that failed

# The fix

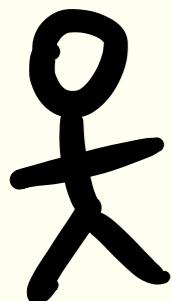
```
class Book(object):
    def __init__(self, title, author, price):
        self.title = title
        self.author = author
        if not price >= 0.00:
            price = 0.00
        self.price = price

    def __unicode__(self):
        return u"%s by %s ($%s)" % (self.title, self.author, self.price)

    def __repr__(self):
        return self.__unicode__().encode("utf-8")
```

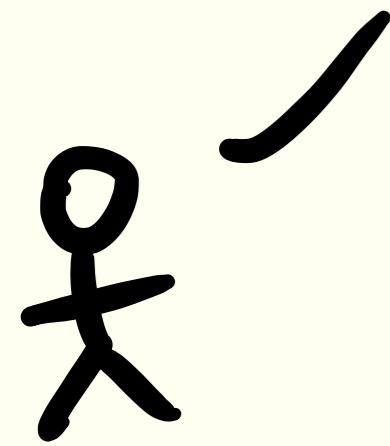
③

The future  
is in online  
shopping! We need  
a shopping cart.



My boss wants a  
shopping cart. What  
makes a bad shopping  
cart for my boss?





My boss wants a  
shopping cart. What  
makes a bad shopping  
cart for my boss?

total < 0

“Who  
cares,”

“reversible”

```
class ShoppingCart(object):
    def __init__(self):
        self.cart = {}
        self.total = 0.00 initial state
    def add(self, item):
        if item in self.cart:
            self.cart[item] += 1
        else:
            self.cart[item] = 1
        self.total += item.price -
    def remove(self, item):
        if item in self.cart:
            self.cart[item] -= 1
            if self.cart[item] == 0:
                del self.cart[item]
            self.total -= item.price -
```

*composable!*

```
@given(st.lists(books))
def test_add(list_of_books):
    cart = ShoppingCart()
    for book in list_of_books:
        cart.add(book)
    assert cart.total == sum(book.price for book in list_of_books)

@given(st.lists(books))
def test_remove(list_of_books):
    cart = ShoppingCart()
    for book in list_of_books:
        cart.remove(book)
    assert cart.total == 0.00

@given(st.lists(books))
def test_add_remove(list_of_books):
    cart = ShoppingCart()
    for book in list_of_books:
        cart.add(book) ←
        cart.remove(book) ←
    assert cart.total == 0.00 ← initial state
```

```
===== FAILURES =====
test_add_remove
```

---

```
@given(st.lists(books))
> def test_add_remove(list_of_books):

cart_example1.py:72:
--虚机环境/PyCharm/lib/python2.7/site-packages/hypothesis/core.py:524: in wrapped_test
    print_example=True, is_final=True
--虚机环境/PyCharm/lib/python2.7/site-packages/hypothesis/executors.py:58: in default_new_style_executor
    return function(data)
--虚机环境/PyCharm/lib/python2.7/site-packages/hypothesis/core.py:111: in run
    return test(*args, **kwargs)
```

---

```
list_of_books = [ by ($inf)]
```

---

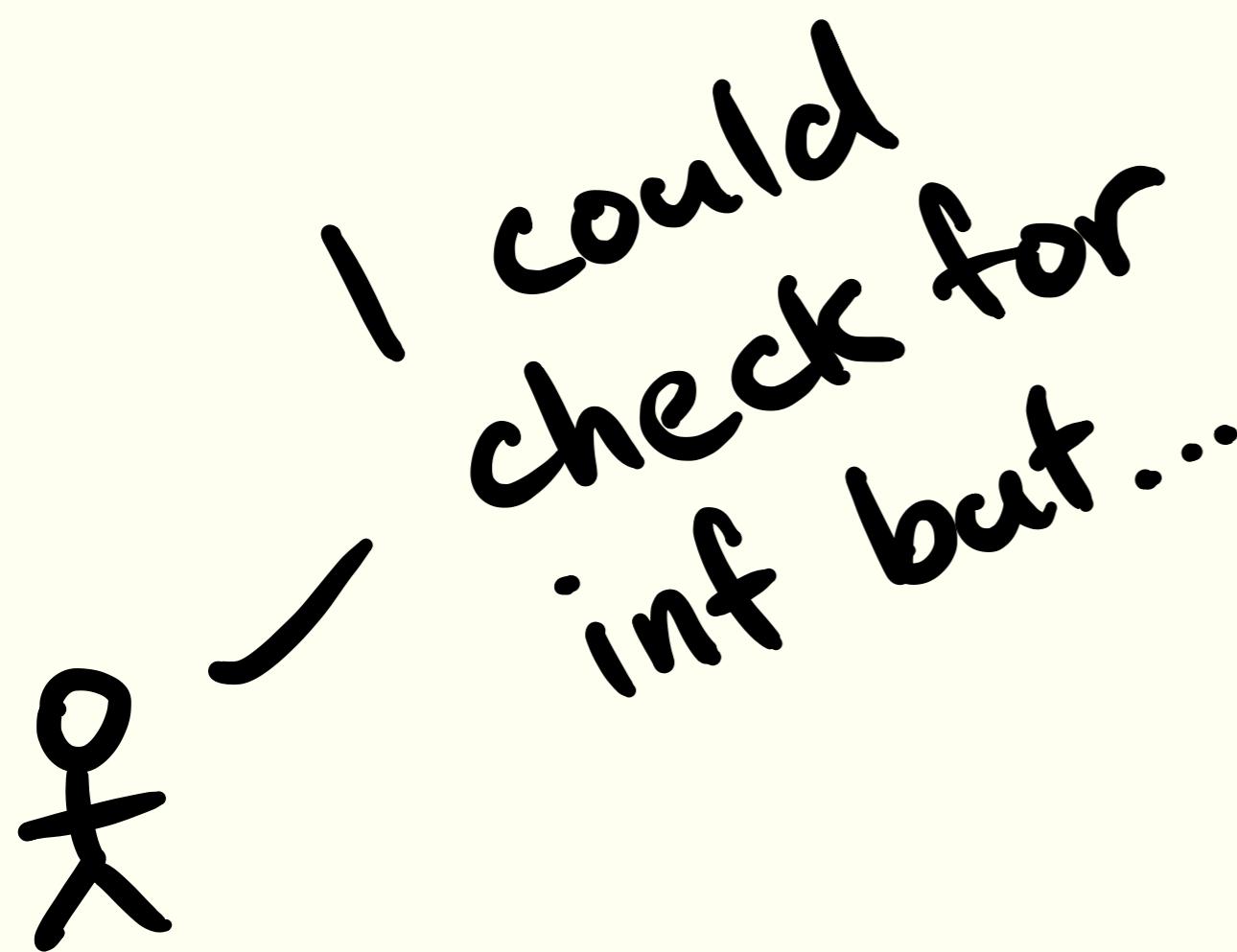
```
@given(st.lists(books))
def test_add_remove(list_of_books):
    cart = ShoppingCart()
    for book in list_of_books:
        cart.add(book)
        cart.remove(book)
>     assert cart.total == 0.00
E     assert nan == 0.0
E       +  where nan = <cart_example1.ShoppingCart object at 0x1033188d0>.total
```

nan? ?  
ohh...  
inf - inf  
= nan

---

```
cart_example1.py:77: AssertionError
----- Hypothesis -----
Falsifying example: test_add_remove(list_of_books=[ by ($inf)])
===== 1 failed, 2 passed in 1.63 seconds =====
```

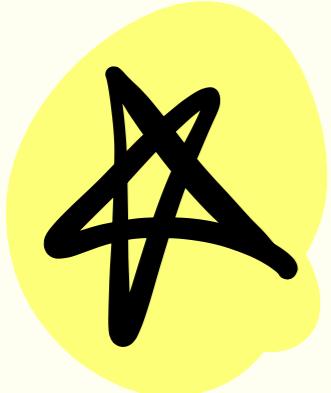
```
books = st.builds(  
    Book,  
    title=st.text(),  
    author=st.text(),  
    price=st.floats(allow_infinity=False),  
)
```



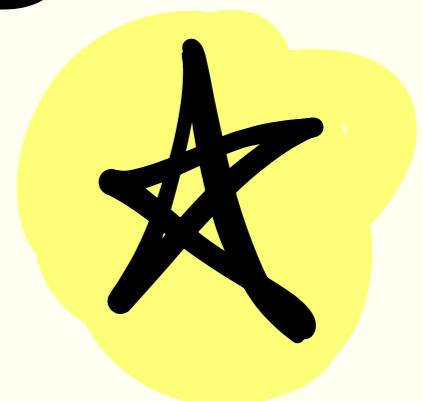
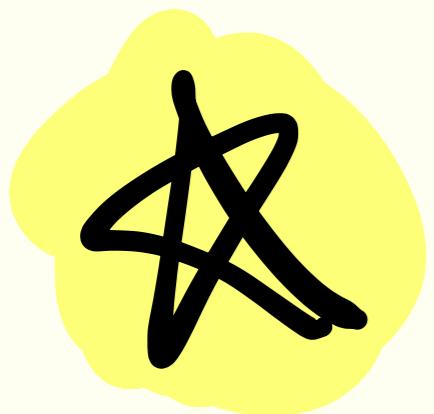
customizable



4



Rule Based  
Stateful Testing



We need  
to add coupons!



o - k...

```
def add_discount(self, coupon):
    if self.total > 0 and coupon not in self.discounts:
        self.discounts[coupon] = coupon.percent
        self.total *= self.discounts[coupon]

def remove_discount(self, coupon):
    if coupon in self.discounts:
        self.total /= self.discounts[coupon]
        del self.discounts[coupon]
```

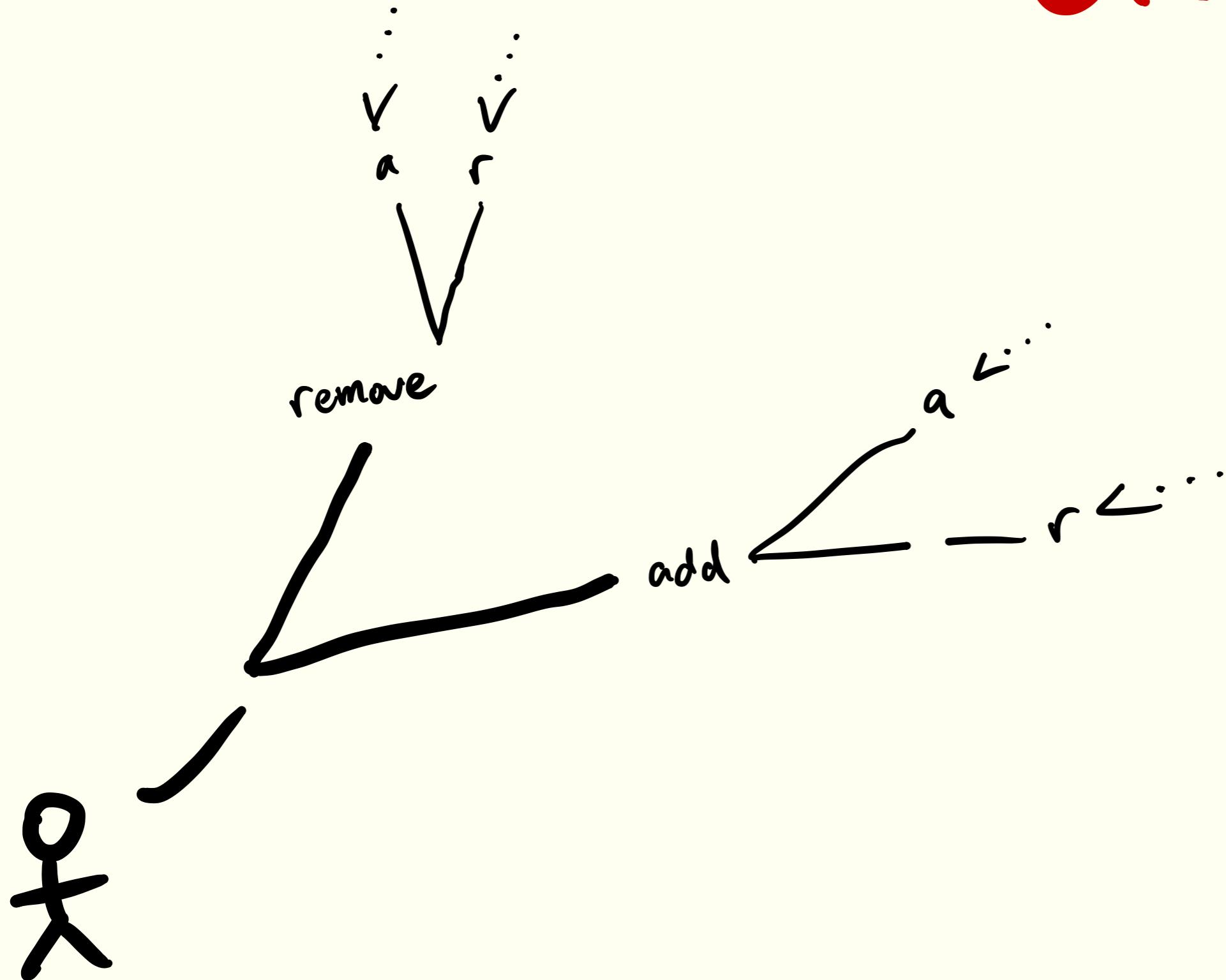
```
[  
    Coupon(name='100FF', percent=0.9),  
    Coupon(name='200FF', percent=0.8),  
    Coupon(name='300FF', percent=0.7),  
    Coupon(name='400FF', percent=0.6),  
    Coupon(name='500FF', percent=0.5),  
    Coupon(name='600FF', percent=0.4),  
    Coupon(name='700FF', percent=0.3),  
    Coupon(name='800FF', percent=0.2),  
    Coupon(name='900FF', percent=0.1)  
]
```

named tuples

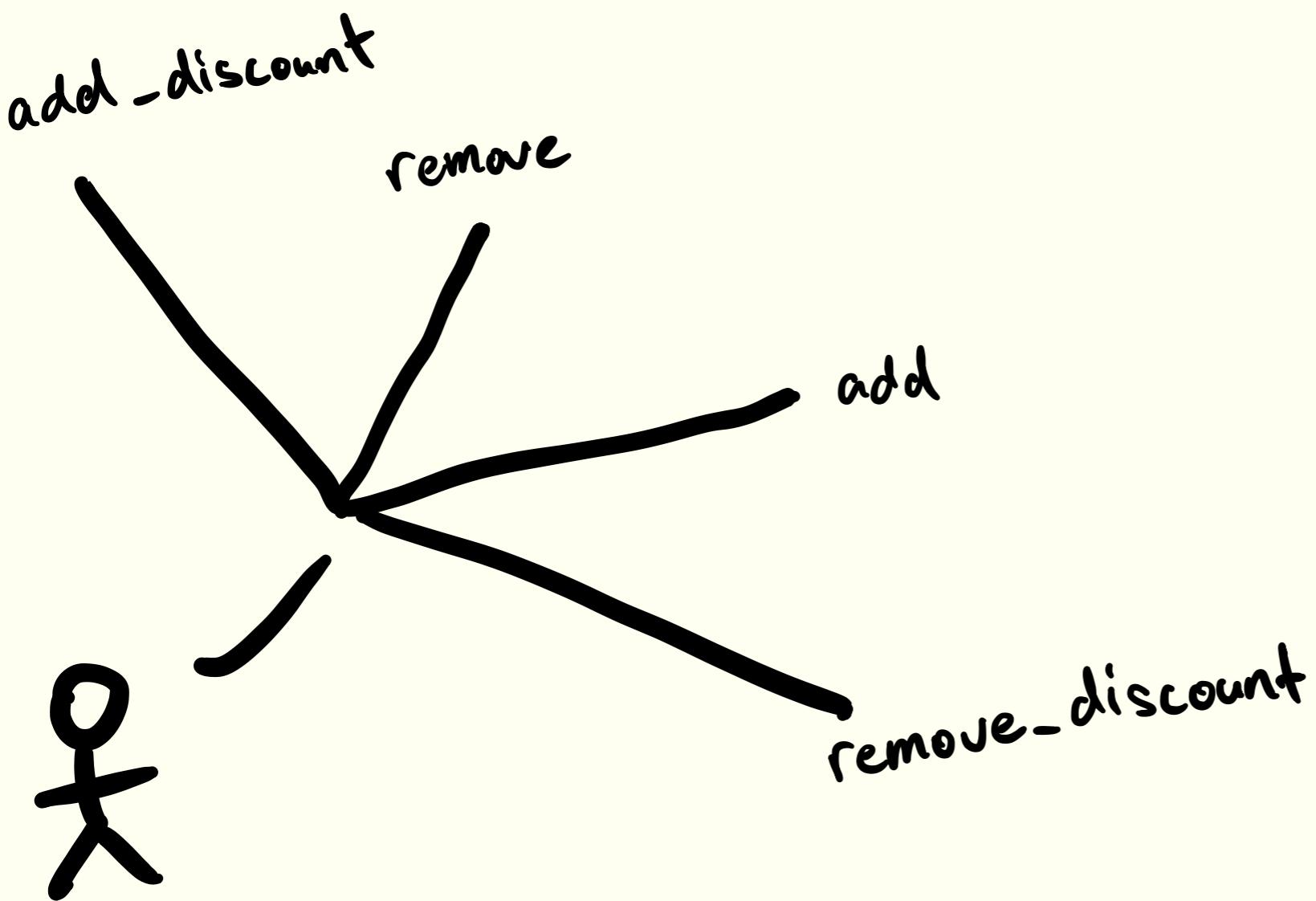


How can I  
verify the  
program as  
a whole?

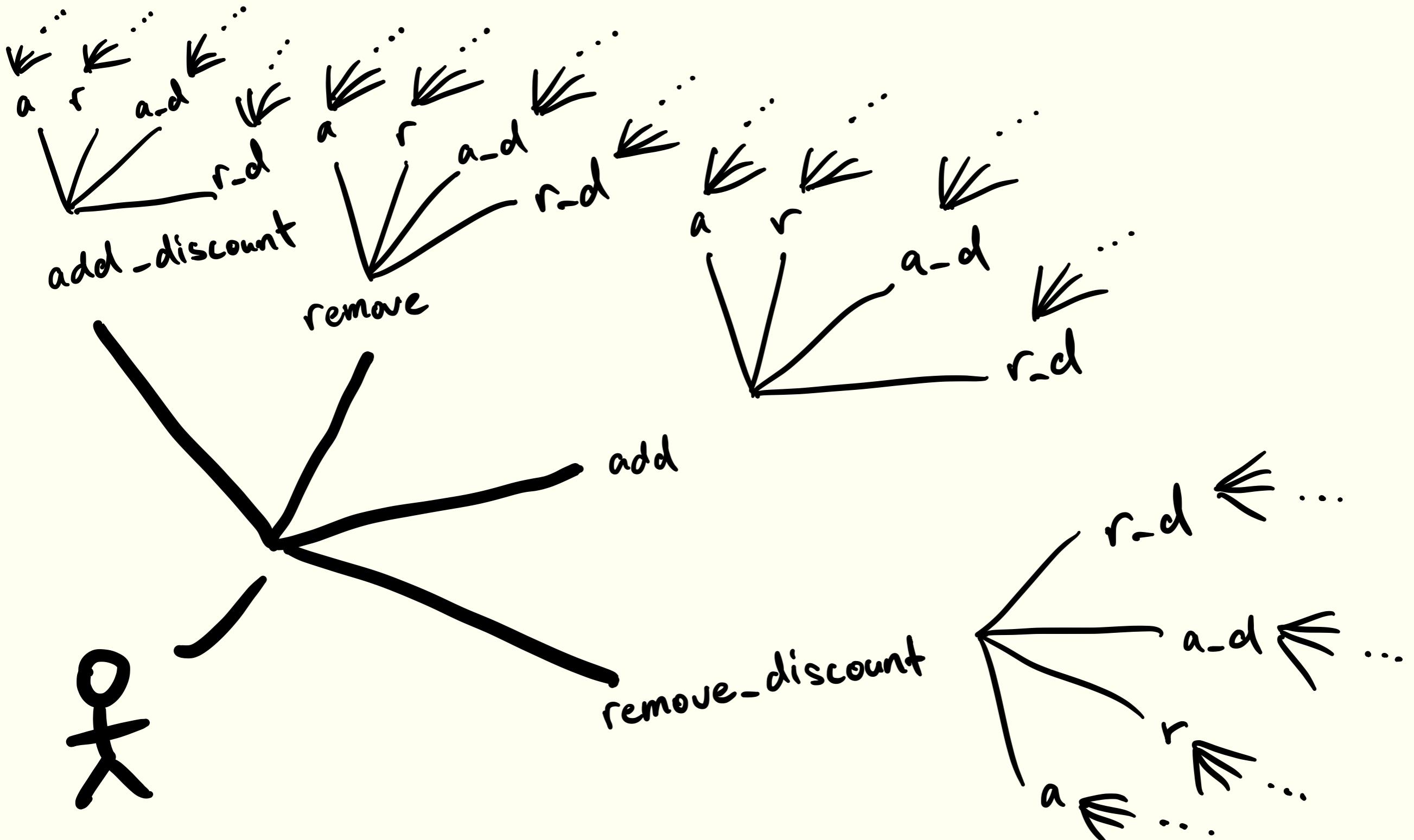
OK...



4...



NO!



hypothesis.stateful

@rule

RuleBasedStateMachine

Bundle

```
class CartMachine(RuleBasedStateMachine):
    Carts = Bundle("carts")
    BOOKS = st.lists(books, min_size=10).example()

    @rule(target=Carts)
    def new_cart(self):
        return ShoppingCart()

    @rule(cart=Carts, item=st.sampled_from(BOOKS))
    def add_item(self, cart, item):
        cart.add(item)
        assert cart.total >= 0.00

    @rule(cart=Carts, item=st.sampled_from(BOOKS))
    def remove_item(self, cart, item):
        cart.remove(item)
        assert cart.total >= 0.00

    @rule(cart=Carts, coupon=st.sampled_from(COUPONS))
    def add_coupon(self, cart, coupon):
        cart.add_discount(coupon)
        assert cart.total >= 0.00

    @rule(cart=Carts, coupon=st.sampled_from(COUPONS))
    def remove_discount(self, cart, coupon):
        cart.remove_discount(coupon)
        assert cart.total >= 0.00

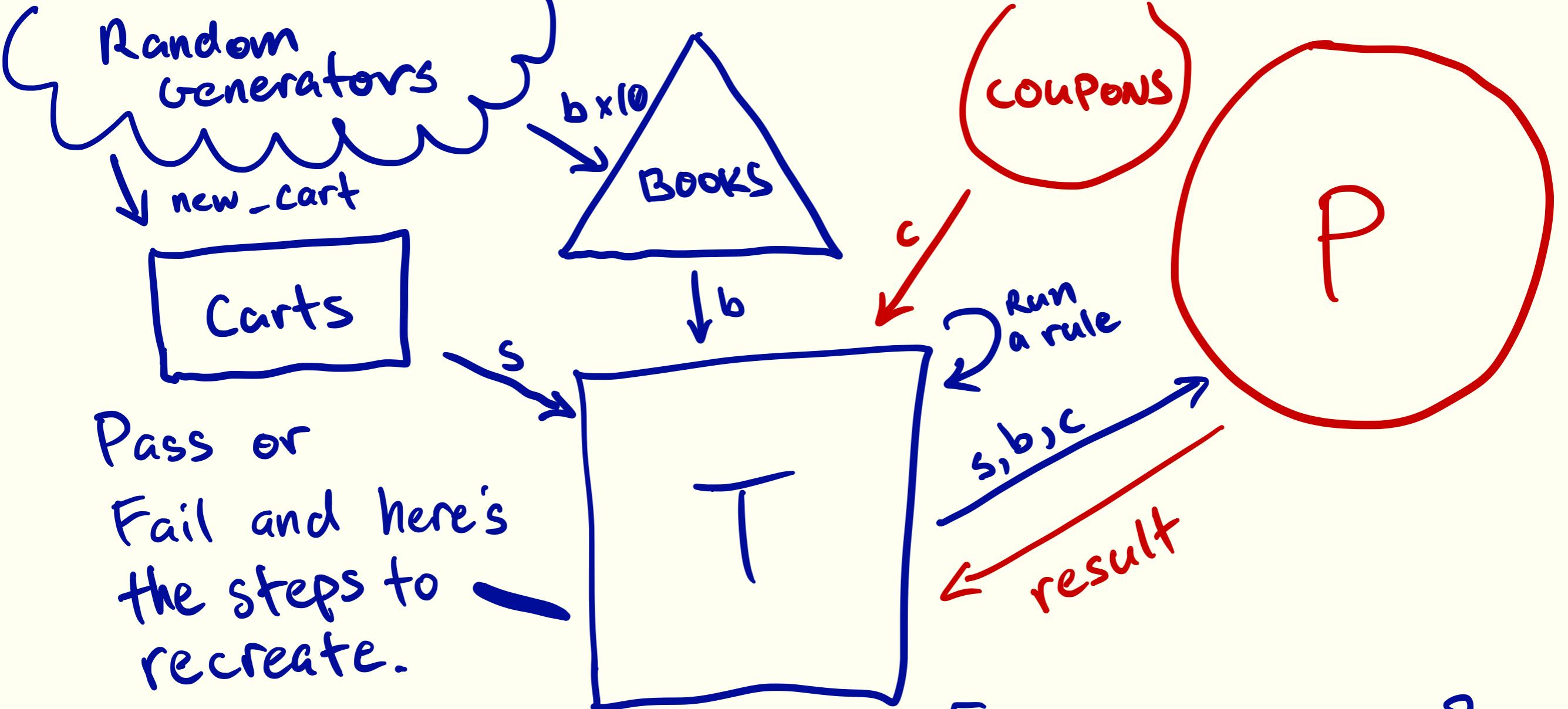
TestCarts = CartMachine.TestCase
```

collection  
of state

Checking  
Property

Similar to @given

so Pytest  
finds it



For all carts  $s$  in Carts.  
 For all books  $b$  in BOOKS.  
 For all coupons  $c$  in COUPONS.

Property  $P = c.\text{total}$  is non-negative.

# Running it...

```
self = CartMachine({'carts': [VarReference(name=u'v1')]})}, cart = <cart_example2.ShoppingCart object at 0x10cffdbd0>
item = 刷0 ²
驥瘤脴 ?by 霽 ($994.245374416)

@rule(cart=Carts, item=st.sampled_from(BOOKS))
def remove_item(self, cart, item):
    cart.remove(item)
    assert cart.total >= 0.00
E     AssertionError: assert -99.42453744155341 >= 0.0
E         + where -99.42453744155341 = <cart_example2.ShoppingCart object at 0x10cffdbd0>.total

cart_example2.py:91: AssertionError
----- Hypothesis -----
Step #1: v1 = new_cart()
Step #2: add_item(item=刷0 ²
驥瘤脴 ?by 霽 ($994.245374416), cart=v1)
Step #3: add_coupon(coupon=Coupon(name='100FF', percent=0.9), cart=v1)
Step #4: remove_item(item=刷0 ²
驥瘤脴 ?by 霽 ($994.245374416), cart=v1)
===== 1 failed in 0.51 seconds =====
```

} Steps ?!

- ① new\_cart
- ② add\_item
- ③ add coupon
- ④ remove\_item

$$t_1 = \emptyset$$

$$t_2 > \emptyset$$

$$t_2 > t_3 > \emptyset$$

$$t_4 < \emptyset \Rightarrow \text{FAIL!}$$

$t_n$  = total at  
step n

# The fix

```
class ShoppingCart(object):
    def __init__(self):
        self.cart = {}
        self.discounts = {}

    @property
    def total(self):
        subtotal = 0.00
        for item, num in self.cart.items():
            subtotal += item.price * num
        for discount in self.discounts.values():
            subtotal *= discount
        return subtotal
```

self.total ??

Resources

[hypothesis.readthedocs.io](https://hypothesis.readthedocs.io)

[github.com/HypothesisWorks](https://github.com/HypothesisWorks)

[hypothesis.works](https://hypothesis.works)

[propertesting.com](https://propertesting.com)

# QuickCheck:

## A Lightweight Tool for

### Random Testing of

#### Haskell Programs

Koen Claessen & John Hughes

Slides + Code

[www.github.com/dkua/pyohio17-talk](https://www.github.com/dkua/pyohio17-talk)

Feedback or Questions

@davidkua ↗

david@kua.io

Thank  
You !!

