Python by smell

Advanced Python constructs for scientists

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What’s this smell?

- You’re here because you started feeling the “code smell”

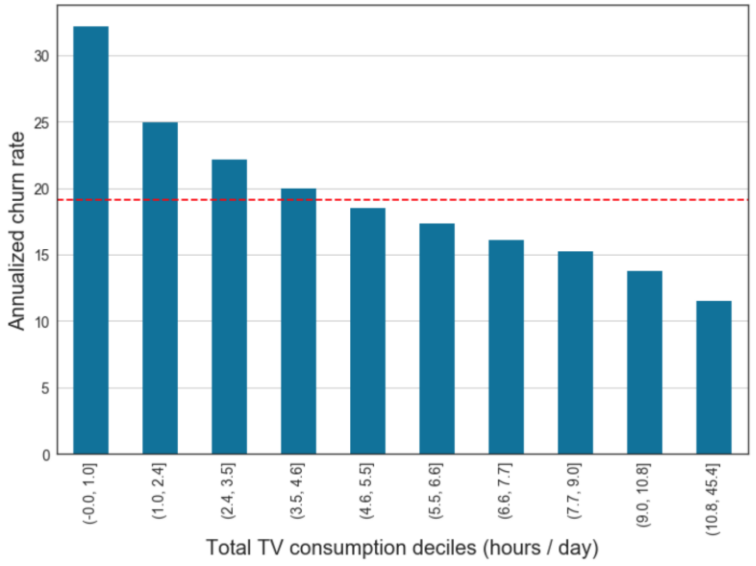
- Scientists in the wild tend to write this…
- What is the smell of the code in the notebooks?

What about this smell?

7.1 Total TV

In [118]:
```
ttv_h_deciles = pd.qcut(ttv_h, 10)
ttv_deciles_churn = tv_merged.groupby(ttv_h_deciles).churned_all.mean() * 12 / 10 * 100
```

In [119]:
```
with plt.rc_context(rc=get_style(figsize=(12 ,8))):
    ax = ttv_deciles_churn.plot.bar(color=blue)
    plt.grid(axis='y')
    plt.xlabel('Total TV consumption deciles (hours / day)')
    plt.ylabel('Annualized churn rate')
    plt.axhline(annual_tv_churn * 100, c='r', ls='--')

    t = ['({:.1f}, {:.1f}]'.format(x.left, x.right) for x in ttv_deciles_churn.index]
    plt.xticks(range(len(t)), t)
```

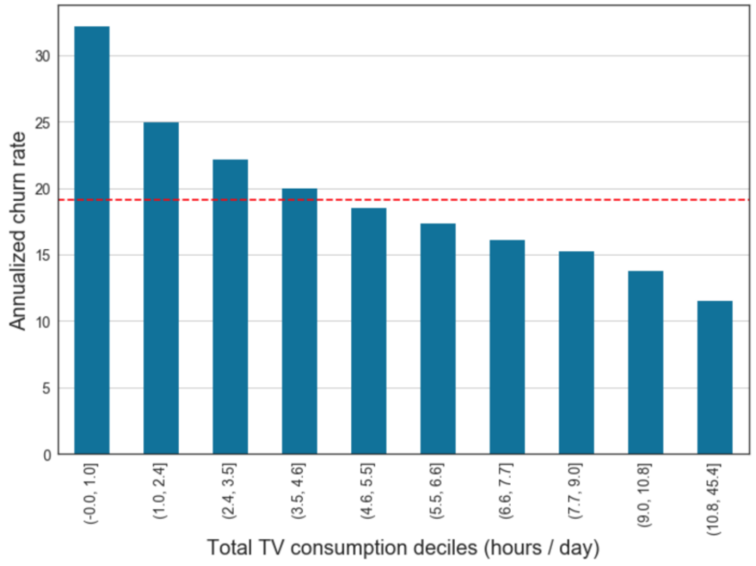


What about this smell?

7.1 Total TV

```
In [118]: ttv_h_deciles = pd.qcut(ttv_h, 10)
          ttv_deciles_churn = tv_merged.groupby(ttv_h_deciles).churned_all.mean() * 12 / 10 * 100
```

```
In [119]: with plt.rc_context(rc=get_style(figsize=(12 ,8))):
              ax = ttv_deciles_churn.plot.bar(color=blue)
              plt.grid(axis='y')
              plt.xlabel('Total TV consumption deciles (hours / day)')
              plt.ylabel('Annualized churn rate')
              plt.axhline(annual_tv_churn * 100, c='r', ls='--')

              t = ['({:.1f}, {:.1f}]'.format(x.left, x.right) for x in ttv_deciles_churn.index]
              plt.xticks(range(len(t)), t)
```



7.2 Playback

```
In [120]: replay_deciles = pd.qcut(tv_merged.PLAYBACK / ttv_sec_to_hpd, 10)
          replay_deciles_churn = tv_merged.groupby(replay_deciles).churned_all.mean() * 12 / 10 * 100
```

```
In [121]: with plt.rc_context(rc=get_style(figsize=(12 ,8))):
              ax = replay_deciles_churn.plot.bar(color=blue)
              plt.grid(axis='y')
              plt.xlabel('Replay TV consumption deciles (hours / day)')
              plt.ylabel('Annualized churn rate')
              plt.axhline(annual_tv_churn * 100, c='r', ls='--')

              t = ['({:.1f}, {:.1f}]'.format(x.left, x.right) for x in replay_deciles_churn.index]
              plt.xticks(range(len(t)), t)
```

```
In [122]: replay_h = pd.cut(tv_merged.PLAYBACK / ttv_sec_to_hpd, np.arange(0, 8), include_lowest=True)
          replay_churn = tv_merged.groupby(replay_h).churned_all.mean() * 12 / 10 * 100
```

```
In [123]: with plt.rc_context(rc=get_style(figsize=(12 ,8))):
              ax = replay_churn.plot.bar(color=blue)
              plt.grid(axis='y')
              plt.xlabel('Replay TV consumption (hours / day)')
              plt.ylabel('Annualized churn rate')
              plt.axhline(annual_tv_churn * 100, c='r', ls='--')
```

7.3 Trends

```
In [137]: tv_delta = pd.cut(tv_merged.TTV_201703_delta, np.arange(-5.5, 5.6, 1.0))
          tv_delta_churn = tv_merged.groupby(tv_delta).churned_all.mean() * 12 / 10 * 100
```

```
In [138]: with plt.rc_context(rc=get_style(figsize=(12 ,8))):
              ax = tv_delta_churn.plot.bar(color=blue)
              plt.grid(axis='y')
              plt.xlabel('TV consumption trend')
              plt.ylabel('Annualized churn rate')
              plt.axhline(annual_tv_churn * 100, c='r', ls='--')
```

```
In [1651]: tv_delta = pd.cut(tv_merged.TTV_201703_delta, np.arange(-5.5, 5.6, 1.0))
           tv_delta_churn_some = tv_merged[at_least_some_ttv_mask].groupby(tv_delta[at_least_some_ttv_mas
```

```
In [1652]: with plt.rc_context(rc=get_style(figsize=(12 ,8))):
               ax = tv_delta_churn_some.plot.bar(color=blue)
               plt.grid(axis='y')
               plt.xlabel('TV consumption trend')
               plt.ylabel('Annualized TV+Vodafone churn rate')
               plt.axhline(annual_tv_churn * 100, c='r', ls='--')
```

What is wrong with smelly code?

- **Redundant, not flexible**: an update in one place would need to be duplicated everywhere
- **Hard to test**: the code that performs the interesting computation is mixed with the code that does the repetitive boilerplate

Objective

- This is a code smell detection crash course for scientific programming
- **Advanced Python constructs are the way to get rid of the smell!**

All the “advanced Python constructs” smells

The smell of **generators**

```
for ... :
    # Transform / filter
    for ... :
        # Transform / filter
        # The interesting part of the code
```

The smell of **classes**

```
def first_function(x, y, z):
    # Something

def second_function(x, y, z):
    # Something else

def third_function(x, y, z):
    # Something more
```

The smell of **context managers**

```
# Prepare
try:
    # The code you care about
finally:
    # Clean up
```

The smell of **decorators**

```
def my_function(x, y, z):
    # Common boilerplate at beginning
    # Function-specific part
    # Common boilerplate at end
```

*Of all of the most commonly used Python constructs, **context managers** are neck-and-neck with **decorators** in a "Things I use but don't really understand how they work" contest.*

https://jeffknupp.com/blog/2016/03/07/python-with-context-managers/

The smell of generators

One or more nested loops, variables over which one iterates requires some extra transformation or filtering

```
for ... :
    # Transform / filter
    for ... :
        # Transform / filter
        # The interesting part of the code
```

This is the part that actually does some interesting computation. At the moment, it's hard to test it!

… becomes …

```
for ... in my_generator():
    # The interesting part of the code
```

The smell of classes

The same set of parameters is needed for a set of functions. In code calling this function, one needs extra code to keep these parameters in sync.

```
def first_function(x, y, z):
    # Something

def second_function(x, y, z):
    # Something else

def third_function(x, y, z):
    # Something more
```

… becomes …

```
class Xyz:
    def __init__(self, x, y, z):
        ...
```

```
def first_function(xyz):
    # Something

def second_function(xyz):
    # Something else

def third_function(xyz):
    # Something more
```

The smell of context managers

Before executing the code, something needs to happen: open a file, connect to a DB, initialize some hardware

Once the code has executed, we need to clean up, **even if an error occurred**: close the file, commit / revert SQL transactions, disconnect from hardware

```
# Initialize context
try:
    # The code you care about
finally:
    # Clean up context
```

... becomes ...

```
with my_context_manager():
    # The code you care about
```

The smell of decorators

Boilerplate code at the start and/or end of functions. Typical cases: logging, deprecation, conditions checks, caching

```
def my_function(x, y, z):
    # Boilerplate at start
    # Function-specific part
    # Boilerplate at end
```

This is the part that is specific to what the function actually does

… becomes …

```
@my_decorator
def my_function(x, y, z):
    # Function-specific part
```

Decorators are are functions which modify the functionality of other functions.

One smell at the time: generators first

A simple example: when are generators cleaner?

```
# Print square numbers up to 100,000 that are odd and do something with them

for i in range(100000):
    if (i*i) % 2:
        do_something(i*i)

my_numbers = [i*i for i in range(100000) if (i*i) % 2]
my_numbers[:10]
[1, 9, 25, 49, 81, 121, 169, 225, 289, 361]
do_something(my_numbers)
```

Smelly!

Memory!

A simple example: when are generators cleaner?

```
# Print square numbers up to 100,000 that are odd and do something with them

for i in range(100000):
    if (i*i) % 2:                                          Smelly!
        do_something(i*i)

my_numbers = [i*i for i in range(100000) if (i*i) % 2]     Memory!
my_numbers[:10]
[1, 9, 25, 49, 81, 121, 169, 225, 289, 361]
do_something(my_numbers)
```

```
def square_numbers(n):
    i = 1
    while i <= n:
        if (i*i) % 2:
            yield i*i
        i += 1                        Yield instead of return!

for squared in square_numbers(100000):
    do_something(squared)
```

The smell of generators

One or more nested loops, variables over which one iterates requires some extra transformation or filtering

```
for ... :
    # Transform / filter
    for ... :
        # Transform / filter
        # The interesting part of the code
```

This is the part that actually does some interesting computation. At the moment, it's hard to test it!

... becomes ...

```
for ... in my_generator():
    # The interesting part of the code
```

Example

Iterate

Clean

Aggregate

Concat

```
year = 2017
months = [10, 11, 12]
template = 'consumption_{year}{month}.csv'
chunksize = 10

chunks = []
for month in months:
    filename = template.format(year=year, month=month)
    print(filename)

    chunk_iterator = pd.read_csv(filename, sep=',', chunksize=chunksize)
    for chunk in chunk_iterator:
        chunk.columns = chunk.columns.str.replace('{year}{month}_'.format(year=year, month=month), '')

        chunk_sum = pd.DataFrame(
            data={
                'MORNING': chunk['TV_M'] + chunk['VOD_M'],
                'AFTERNOON': chunk['TV_A'] + chunk['VOD_A'],
                'NIGHT': chunk['TV_N'] + chunk['VOD_N'],
                'USER_ID': chunk['USER_ID'],
                'YEAR_MONTH': month,
            }
        )
        chunks.append(chunk_sum)

df = pd.concat(chunks)
```

Ideally…

```
df = pf.concat(aggregate(clean(iterate(months, year, chunksize))))
```

This is actually what we'd like to write:

1. Extract each for-loop step in a reusable element and give it a nice name
2. Do all of this without actually loading all the data in memory for the intermediate steps!

Let's get there step by step…

Go to “generators” notebooks

Recap: Generators

- Generators are used to get rid of repetitive loops, often nested ”for” loops followed by filtering of the data
- Generators return one item at the time, the list of items does not need to be in memory
- A generator is defined as a function containing the keyword ”yield”:

```
def odd_numbers(n):
    """ Generator for the first `n` odd numbers. """
    for i in range(n):
        # Use `yield` instead of `return`: execution will start again from here
        yield i * 2 + 1

for i in odd_numbers(5):
    print(i)
```

One smell at the time: classes (an introduction)

The smell of classes

The same set of parameters is needed for a set of functions. In code calling this function, one needs extra code to keep these parameters in sync.

```
def first_function(x, y, z):
    # Something

def second_function(x, y, z):
    # Something else

def third_function(x, y, z):
    # Something more
```

… becomes …

```
class Xyz:
    def __init__(self, x, y, z):
        ...
```

```
def first_function(xyz):
    # Something

def second_function(xyz):
    # Something else

def third_function(xyz):
    # Something more
```

Go to “classes” notebooks

Recap: Classes

- Classes are used to get rid of set of parameters that belong together and are passed over and over to a set of functions
- Classes are templates for bundles of data and “methods”, i.e. functions that have access to the data stored in an instance
- A ”class method” is used to build an instance in some alternative way, e.g. using data from a file

Recap: Class structure

```python
class MyClass:
    def __init__(self, param1, param2):
        self.param1 = param1
        if param2 is None:
            param2 = 12.3
        self.param2 = param2

    def my_method(self, foo, bar):
        result = self.param2 * foo + self.param2 * bar
        return result

    def to_json(self):
        params = {
            'param1': self.param1,
            'param2': self.param2,
        }
        return json.dumps(params)

    @classmethod
    def from_json(cls, json_str):
        json_dict = json.loads(json_str)
        instance = cls(json_dict['params1'], json_dict['params2'])
        return instance
```

The constructor is used to first populate an instance, called by convention “self”

Classes can define “methods”, i.e. functions that have access to the data stored in an instance

A ”class method” is used to build an instance in some alternative way, e.g. using data from a file

```python
instance = MyClass(5, 18)
instance = MyClass.from_json(json_str)
```

Here is how you create instances from the constructor or a class method

What belongs to a class?

- YES
  - + Data that always belongs together: better create several simple classes than one class that contains everything
  - + Methods to load/save data, create data bundle in different ways (factory methods)
  - + Methods to update parameters
- NO
  - - Methods to visualize data: follow the Model-View pattern.
    You will want to visualize the data in many different ways, better have separate utility visualization functions that take one of the instances as input and visualize them.
  - - Similarly, anything for which you can imagine to write 5 different variants depending on your mood

Another smell of classes

Several "specializations" of conceptually similar functions

```
for data in list_of_data:
    if data['type'] == 'TYPE1':
        type1_foo(data)
        type1_bar(data)
    elif data['type'] == 'TYPE2':
        type2_foo(data)
        type2_bar(data)
```

... becomes ...

Classes may have methods with the same interface, the class type determines the "specialization".

One can even define a hierarchy of classes where some methods are re-used!

```
for instance in instances:
    instance.foo(data)
    instance.bar(data)
```

Another smell of classes – simple example

Several “specializations” of conceptually similar functions →

```
for data in geometric_objects:
    if data['type'] == ‘SQUARE':
        area = area_square(data)
    elif data['type'] == ‘CIRCLE':
        area = area_circle(data)
```

… becomes …

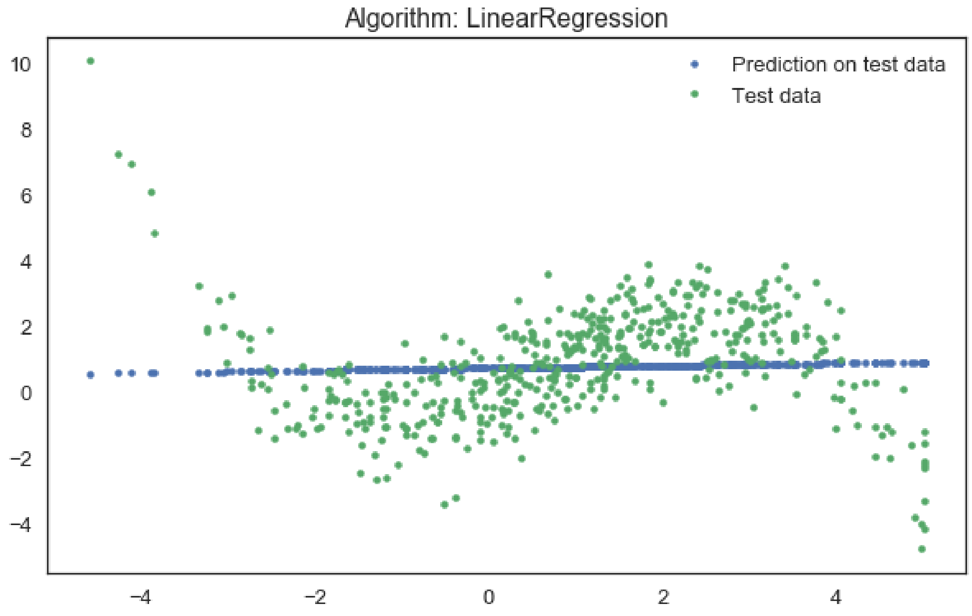
Classes may have methods with the same interface, the class type determines the “specialization”. →

```
for instance in geometric_objects:
    area = instance.area()
```

One can even define a hierarchy of classes where some methods are re-used!

Real example: sklearn

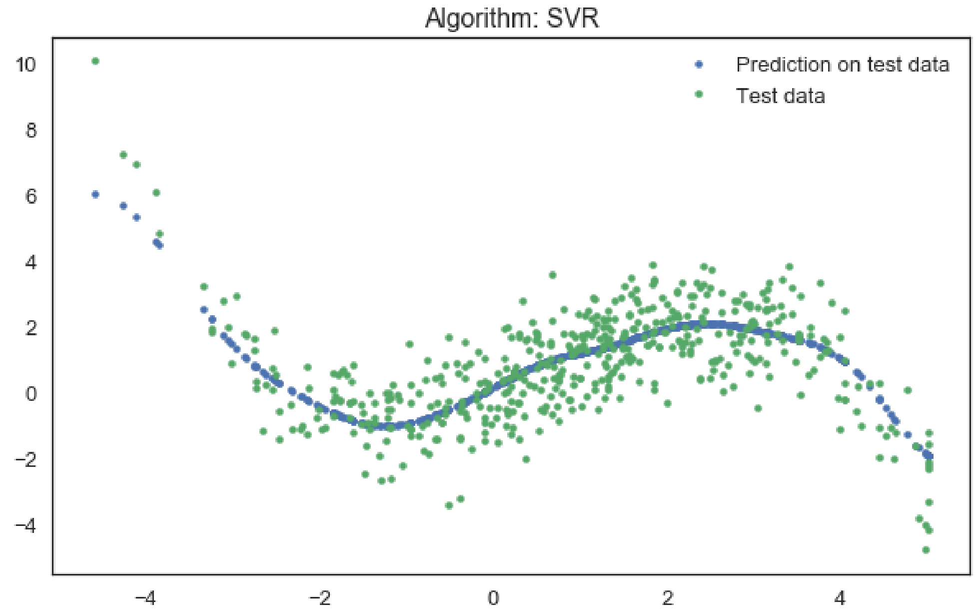
```
from sklearn.linear_model import LinearRegression

model = LinearRegression()
model.fit(X_train, y_train)

score = model.score(X_test, y_test)
print('Model score:', round(score, 4))

y_pred = model.predict(X_test)
with plt.rc_context(rc={'figure.figsize': (10, 6)}):
    plt.plot(X_test, y_pred, '.', label='Prediction on test data')
    plt.plot(X_test, y_test, '.', label='Test data')
    plt.legend()
    plt.title('Algorithm: ' + model.__class__.__name__)
```




```
Model score: 0.0066
```

Real example: sklearn

```
from sklearn.svm import SVR

model = SVR(kernel='rbf')
model.fit(X_train, y_train)

score = model.score(X_test, y_test)
print('Model score:', round(score, 4))

y_pred = model.predict(X_test)
with plt.rc_context(rc={'figure.figsize': (10, 6)}):
    plt.plot(X_test, y_pred, '.', label='Prediction on test data')
    plt.plot(X_test, y_test, '.', label='Test data')
    plt.legend()
    plt.title('Algorithm: ' + model.__class__.__name__)
```




```
Model score: 0.6144
```

One smell at the time: Context managers

The smell of context managers

Before executing the code, something needs to happen: open a file, connect to a DB, initialize some hardware

Once the code has executed, we need to clean up, **even if an error occurred**: close the file, commit / revert SQL transactions, disconnect from hardware

```
# Initialize context
try:
    # The code you care about
finally:
    # Clean up context
```

… becomes …

```
with my_context_manager():
    # The code you care about
```

The classic example

```
with open('MyFile.txt', 'w') as outfile:
    outfile.write('Writing this.')
```

```
file = open('MyFile.txt ', 'w')
try:
    file.write('Writing this.')
finally:
    file.close()
```

```
with my_context_manager():
    # The code you care about
```

```
try:
    # The code you care about
except:
    # When things go wrong
finally:
    # Clean up context
```

Context managers can be implemented as classes or using decorators/generators

```
from contextlib import contextmanager

@contextmanager
def open_file(name):
    f = (name, 'w')
    yield f
    f.close()
```

```
class File(object):
    def __init__(self, file_name, method):
        self.file_obj = open(file_name, method)
    def __enter__(self):
        return self.file_obj
    def __exit__(self, type, value, traceback):
        self.file_obj.close()
```

```
with open_file('MyFile.txt') as f:
    f.write('Writing this.')
```

```
with File('MyFile.txt', 'w') as f:
    f.write('Writing this.')
```

Go to “context managers” notebooks

Recap: Context managers

- Context managers eliminate the smell of repeatedly setting up and cleaning up an environment in which code needs to run

```python
from contextlib import contextmanager

@contextmanager
def my_context(params):
    print('Set up environment')
    try:
        yield  # Here the block of code is executed
    finally:
        print('Clean up environment')

with my_context(params):
    print('Do something interesting here')
```

FYI: most general way of defining context manger

- `@contextmanager` is a shortcut for writing a class with magic methods `__enter__` and `__exit__`:

```
class MyContext():

    def __init__(self, params):
        self.params = params

    def __enter__(self):
        print('Set up environment')

    def __exit__(self, *args):
        # This is called even if there is an exception!
        print('Clean up environment')


with MyContext(params):
    print('Do something interesting here')
```

Keep your nose ready!

The smell of **generators**

```
for ... :
    # Transform / filter
    for ... :
        # Transform / filter
        # The interesting part of the code
```

The smell of **context managers**

```
# Prepare
try:
   # The code you care about
finally:
   # Clean up
```

The smell of **classes**

```
def first_function(x, y, z):
    # Something

def second_function(x, y, z):
    # Something else

def third_function(x, y, z):
    # Something more
```

The smell of **decorators**

```
def my_function(x, y, z):
    # Common boilerplate at beginning
    # Function-specific part
    # Common boilerplate at end
```

Decorators

- Decorators are functions which modify the functionality of other functions
- Everything in Python is an object

```
def hi(name):
    return ″hi ″ + name

print(hi(″Jana″))
hi Jana

greet = hi                    #Assign a function to a variable!

print(greet(″Jana″))
hi Jana
```

Example taken from http://book.pythontips.com/en/latest/decorators.html

Decorators

```
def hi():
    return "Hi"

print(hi())
Hi

#Assign a function to a variable!
greet = hi

print(greet())
Hi
```

```
def decorator_func(func):
    def wrapper_func():
        print("Wrapper function started")
        func()
        print("Wrapper function ended")
    return wrapper_func

hi = decorator_func(hi)
hi
<function __main__.decorator_func.<locals>.wrapper_func()>

#Same as saying hi = decorator_func(hi)
@decorator_func
def hi():
    print("Hi")

hi()
Wrapper function started
Hi
Wrapper function ended
```

Decorators are useful for logging, analytics…

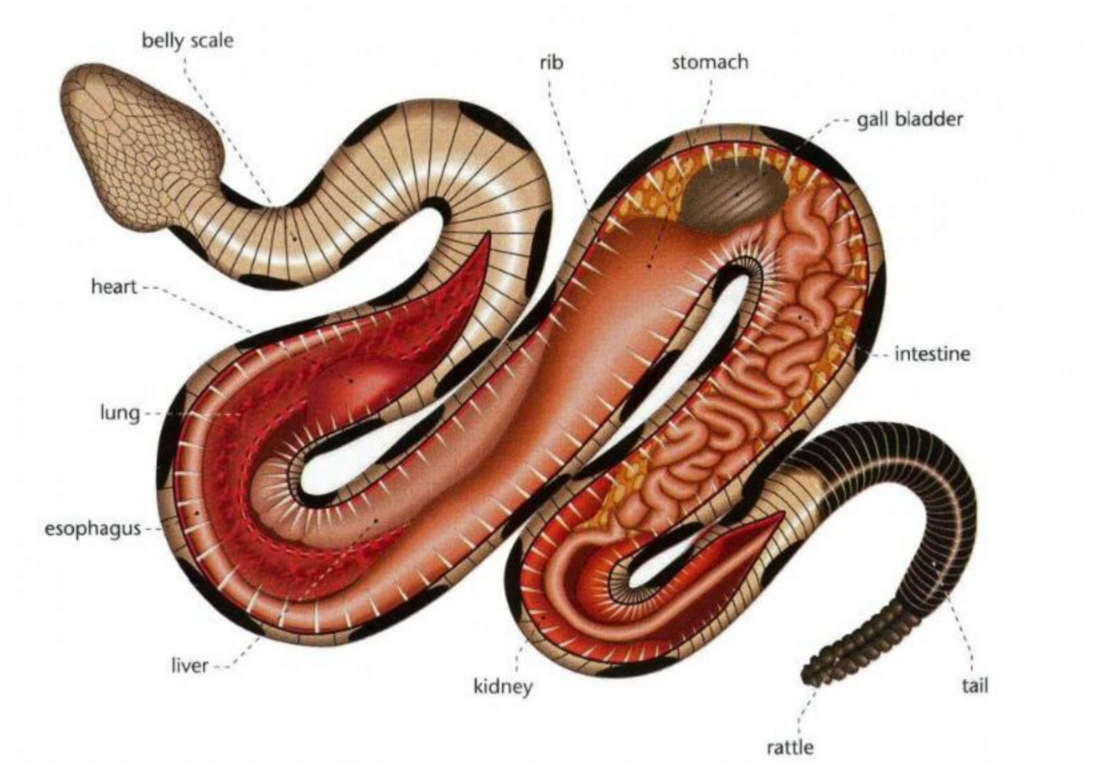
```
from myapp.log import logger

def log_order_event(func):
    def wrapper(*args, **kwargs):
        logger.info("Ordering: %s", func.__name__)
        order = func(*args, **kwargs)
        logger.debug("Order result: %s", order.result)
    return order
return wrapper

@log_order_event
def order_pizza(*toppings):
    # let's get some pizza!
```

Example taken from https://www.oreilly.com/ideas/5-reasons-you-need-to-learn-to-write-python-decorators

Where to go from here…

realpython.com

Thank you!


belly scale
rib
stomach
gall bladder
heart
intestine
lung
esophagus
liver
kidney
tail
rattle