

Welcome.

Everyone:

- Pull the updates from the course GitHub repo:
 - `cd <46120-PiWE repo>`
 - `git pull upstream main` ← you might have “upstream2” instead

Physical students:

- Sit with your P0 Team.
- Turn off laptop volume (mute). **←IMPORTANT!**
- Log into the Zoom meeting.
 - Link is on Learn webpage, under “PiWE Links” on main page.
- Double-check your microphone is muted. You can keep your camera off.



46120: Scientific Programming for Wind Energy

Functions and tests

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Agenda for today.

- Pull new course material ✓
- Round robin.
- Functions.
- Tests.
- Begin teamwork on Week 2 homework.



Round robin

Share solutions with your peers and give feedback.



How Round Robins work.

- We will tell you which teams should enter which BORs. Usually 2 to 3 teams per room.
- Physical students:
 - Everyone is on Zoom and in the BOR.
 - Sit with physical team members somewhere you can hear/speak.
- Sometimes will be multiple rounds, so you would switch BORs partway through.
- Teams take turns sharing screen and explaining their work.
 - Other teams provide feedback, take notes.
- Discuss both solutions but also what was challenging/confusing.
- TAs/instructors will drop into/out of BORs just to listen in.
- Afterwards, we will discuss as a class interesting things, remaining questions, etc.



Time to review and collaborate.

- 1 round of 40 minutes.
- 5 minutes: chaos.
- 20 minutes: preclass_assignment/solutions.
 - Team A screenshares & presents their solutions. Teams B & C provides feedback.
 - Switch which group presents/provides feedback.
- 15 minutes: git questions.
 - Go through GitAnswers.md and discuss your answers.
 - Be ready to present a few sentences on (1) what you thought was interesting and (2) any answers you are still unsure about.
- Teams in breakout rooms (BORs):

	Teams
BOR 1	0, 7, 9, 18
BOR 2	1, 10, 19
BOR 3	2, 11, 20
BOR 4	3, 12, 21
BOR 5	4, 13, 22
BOR 6	5, 14, 23
BOR 7	6, 15, 24
BOR 8	8, 16, 17



Notes in plenum.

- (add notes)



LIVE

Python functions

Why copy-paste code when you could reuse it?



A function is a black box.



- Anything defined inside the box cannot be accessed outside the box, even if we can visually see it in the code. Only outputs are accessible.

```
def heyo(s):  
    print('Heyoooooooo', s)  
    return
```

Variable `s` is an argument (input) into the function.

No variables are returned. (Equivalent to `return None`.)

```
heyo('friend')  
print(s)
```

'Heyoooooooo friend'

Variable `s` was only defined inside the function, so this raises an error!!!

Drawing your black box.

- An essential tool for discussing code architecture.
 - You are going to do this on your homework and on your programming projects.
- You should include variable types with inputs and outputs! And shapes of arrays/dataframes if relevant.
- An example:



Some exceptions to the black-box rule.

Extra slides on local vs. global variables at end of slide deck

- Variables defined outside of a function (called **global variables**) can be read inside the function.
 - In certain situations, their values can be updated.
- Example of this

```
>> c = 1  
  
>> def myprint():  
>>     print(c)  
  
1
```



- Why might using global variables be a **bad** idea?
 - What should you do instead?

Keyword arguments.

- We often want the option to pass optional parameters into a function with a default value, called a **keyword argument**. Example:

```
>> def writehello(path, s='Hello!'):
>>     with open(path, 'w') as f:
>>         f.write(s + '\n')
>> writehello('test.txt')
>> writehello('text2.txt', s='Goodbye!')
```

Argument `s` is a keyword argument, with a default value of "Hello!".

Writes "Hello!" to the file.

Writes "Goodbye!" to the file.

- Keyword arguments can be passed in as a dictionary – see tutorials below.
- More tutorials:
 - <https://realpython.com/python-kwargs-and-args/>
 - <https://www.educative.io/answers/what-are-keyword-arguments-in-python>



Good function names.

- There are no “rules” on what to call a function.
- There are guidelines, however.
- PEP8: Function name should be lower case, with underscores.
 - E.g., not `plotTimeSeries()` but rather `plot_timeseries()`.
- Start with a verb.
 - Verbs “get” and “set” are used a lot in programming in general.
- Name should be specific enough to convey meaning.
- Example of a good function name: `make_lowercase()`.



Importing functions.

- Clean up and reuse code by placing reusable functions in a different file.
- E.g., function `double` in file `myfuncs.py`* can be imported/used:

```
from myfuncs import double
```

```
y = double(2)  
print(y)
```

Don't include ".py"!

- *Note that this required `myfuncs.py` to be in the same directory as the main script.
 - Later we will learn about packaging, which removes this requirement.
- **Important!** Only place functions/classes in the module you are importing from.
 - If you really want code, use a special if statement to protect it:
<https://realpython.com/if-name-main-python/>



In summary.

- View your function as a black box, where you only know the inputs and outputs.
 - Should be able to diagram it with types!
- Don't use global variables!
 - More detailed explanation (and links to online tutorial) at the end of this slide deck.
- Keyword arguments are useful when you only want to update a variable sometimes.
- Organize your code by placing reused functions in a module and importing them.



Questions?



Let's take a break.



Agenda for today.

- Pull new course material ✓
- Round robin. ✓
- Functions. ✓
- Tests.
- Begin teamwork on Week 2 homework.



LIVE

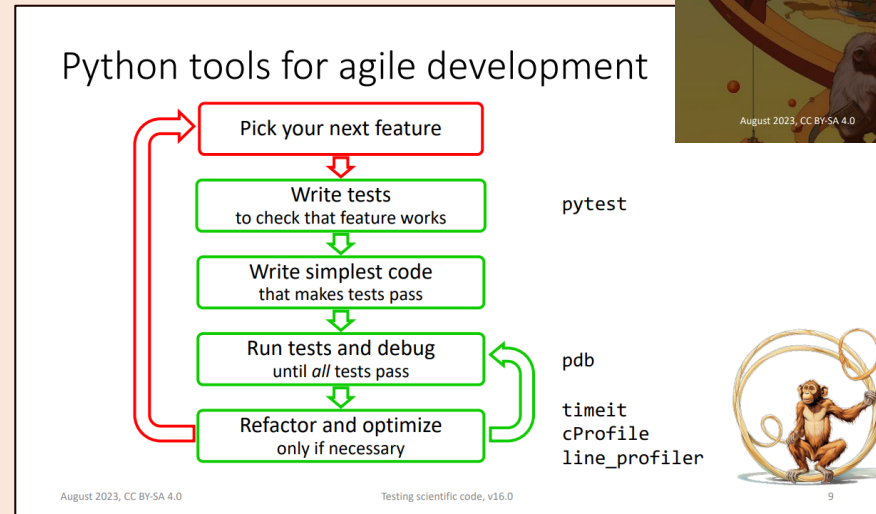
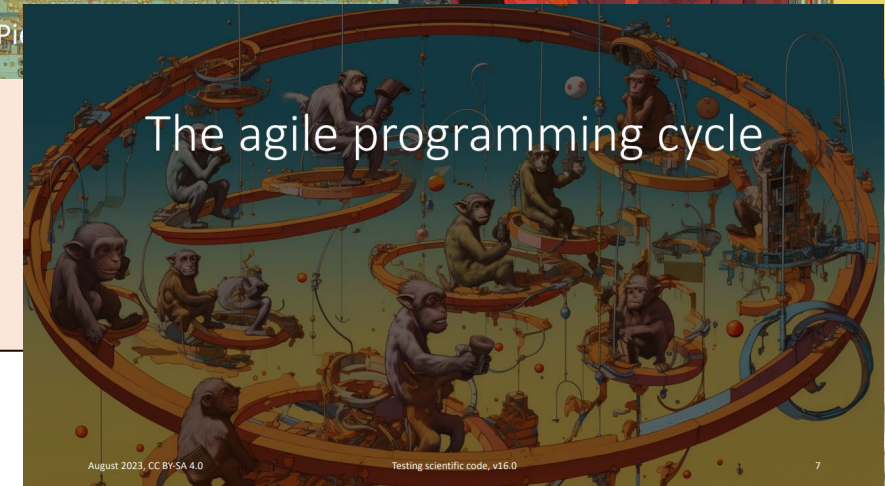
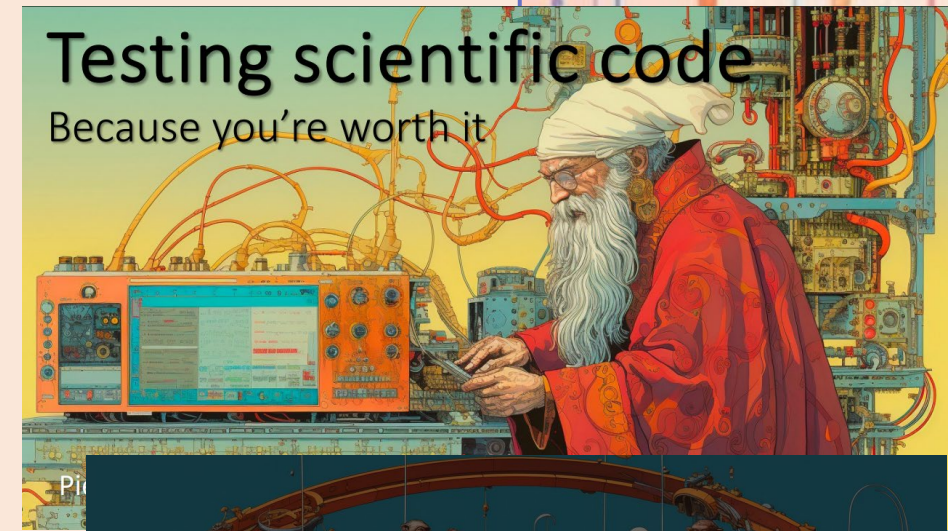
Tests

Make sure your code does what it should.

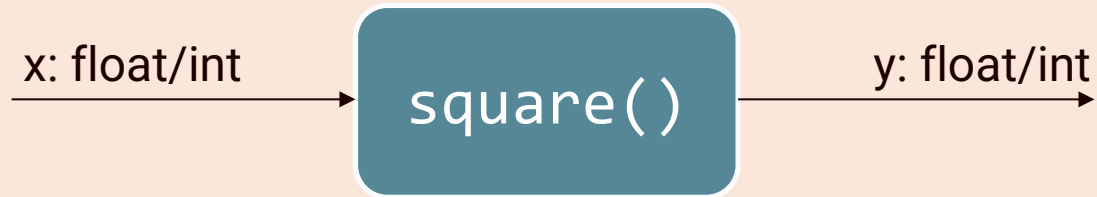


Before I get started.

- I highly, highly recommend reading the slides from the lecture on testing and debugging by Pietro and Lisa [1].
 - Part of a summer school in Advanced Scientific Python Programming [2].
 - This lecture is heavily inspired by how Pietro taught me testing in ASPP 2017.
- Pietro and Lisa's slides have more technical details (and gorgeous images) than I will present here.
 - Worth reading over the summer.



So. We want to make sure a function “works”.

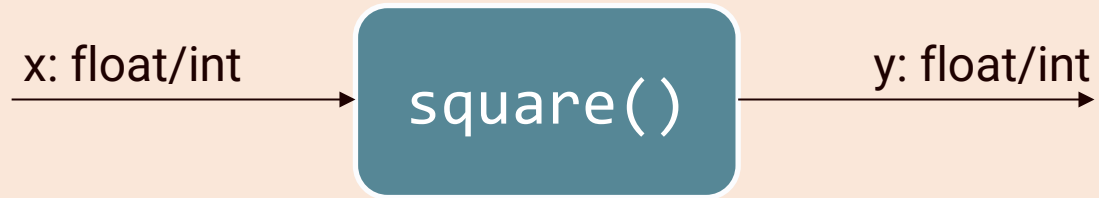


Individually, take 2 minutes and list some behaviors of this function we could/should test.

- Think beyond just calculations – what about object types? What should happen if we get an unexpected input?



Possible things to test.



- Behaviors to test:
 - (add notes)



Anatomy of a test.

- A test is just another function.
- Structure:
 - **Given.** Put your system in the right state for testing.
 - Create data, initialize parameters, define constants, expected output, etc.
 - **When.** Execute the feature that you are testing.
 - Typically, one or two lines of code.
 - **Then.** Compare outcomes with the expected ones.
 - Define the expected result of the test.
 - Use of *assertions* that check that the new state of your system matches your expectations.
- Assert statement raises an error if a provided expression is false.
 - So the test function will check something looks as expected and raise an error if it doesn't.



Let's see this example for square.

Live-coding!

bold/* = follow along with me

1. Open VS Code in the testing folder.*
2. Examine `square()`, which is part of `arithmetic.py`.
3. Look at (and run) `test_arithmetic.py`.*
4. Make the test fail, then fix it.

```
"""Check some of the functions in arithmetic.
"""
from arithmetic import square

def test_square_integer():
    """Test that the square function returns the correct value for an
    integer input."""
    # given
    x = 2
    y_theo = 4
    # when
    y = square(x)
    # then
    assert y == y_theo

# code to execute only if Python is executed directly on this module,
# NOT on import
if __name__ == '__main__':
    test_square_integer()
```


Exercise: write a test for a float input.

Use the integer-test as an example, make a new function to test floats.

- Individually or in pairs*, write a new function in `test_arithmetic.py` called `test_square_float()` that tests the following values:
 - *Virtual students: find a BOR with another student or 2. Ask for help in Slack if you can't find a BOR.
 - Input is 3.4, expected output is 11.56.
- Remember to add your function to the if block at the end of the module -- otherwise your function will not run!
- Execute `test_arithmetic.py` again. Does your test function pass?
- **To get help:** Post in Slack / #debugging if you want a TA to enter your BOR.

SPOILERS! It's not so easy this time.

- You have “finished” this exercise when you have written a test that you think *should* work. We'll come together and discuss how to make the test *actually* pass.



Let's live-code the “solution” together.

- Tell me, what shall I write?



Common pitfalls of scientific testing.

This slide is mostly for reference. Please see slides 23 and higher in [1] for more details.

- Floating-point numbers.
 - Use `np.isclose` and change the tolerance if needed.
- Numpy arrays.
 - Use `np.testing.assert_equal` or `assert_allclose`.
- NaNs.
 - They aren't equal to themselves. Use `np.isnan`.



Downsides of the current test configuration.

- There are some drawbacks with the current testing module:
 1. If any test fails, none of the subsequent tests are run.
 2. Adding lines at end of file adds extra chances for human error.
 - I.e., someone writes a test but forgets to add the line at the bottom of the file.
 3. Placing all tests in a single module can be cumbersome for big projects.
 4. We can't run a subselection of tests, e.g., only run the smoke tests.
 5. We can't test for more advanced behaviors, e.g., if a particular error is raised.
 6. There is no way to know how much of our code is untested.



A hero to the rescue!



pytest and pytest-cov.

- pytest:
 - “[A] mature full-featured Python testing tool that helps you write better programs” [4].
 - Collects all of your test functions (assuming a certain naming convention), runs them all, then assembles the information into a report.
 - Rich flexibility for parameterization and other test fixtures.
 - Can also run two other common types of test suites (unittest and nose) out of the box.
 - Can be expanded via plugins.
- pytest-cov:
 - A plugin for pytest that lets you calculate percentage of code covered by a test suite.
 - We’ll use this later in the semester. 😊



How to run pytest.

- Let's do it together!

- Run pytest on a file or folder:

`pytest filename.py` ← run pytest on a particular file (executes all functions that start with `test_`)

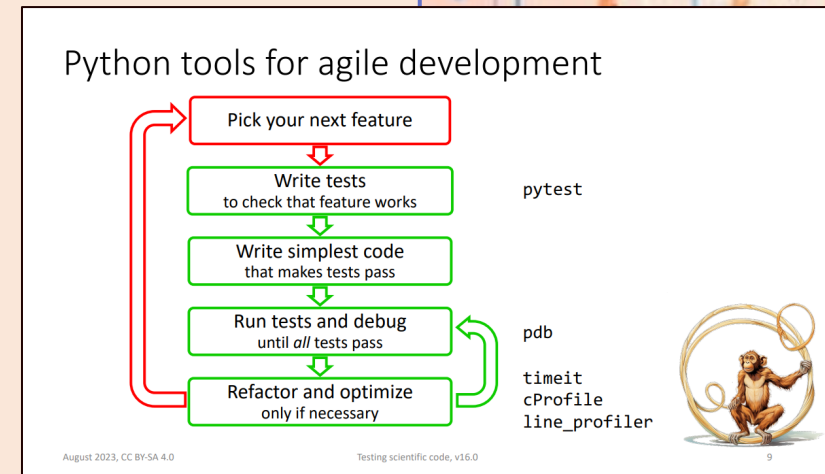
`pytest foldername/` ← collects all files who start with `"test_"`

`pytest .` ← collect files in current folder that start with `"test_"`



Final notes.

- I only scraped the surface in this lecture.
 - Did not discuss unittest or nose tests.
 - Also didn't discuss integrating your test suite with CI/CD pipelines.
 - Nor test-driven (agile) development.
- Pytest has a bunch of really cool utilities that I did not discuss.
 - Labelling tests so you can run a subselection by name.
 - Labelling tests that are expected to fail, e.g., if a feature is not yet implemented.
 - Parameterizing tests so you can check multiple inputs with the same test.
 - Creation of temporary files/directories for testing.
 - So much more!



"test-driven development"

Homework for this week

Time to get your hands dirty!



Overview.

Remember, you're expected to work about 6 hours outside of class. Schedule time for that.



- As always, your homework is detailed on the [course GitHub repo](#).
 - **Short summary:** restructure your `preclass_assignment` into functions and a main script, diagram your functions, and write tests for them.

In a moment, we will open BORs, one for each team.

- Each team enters their BOR (same as your team ID). Perhaps find a physical spot outside the auditorium.
- Complete **Part 1** of the weekly assignment in class, then move on as agreed with your team.
- **To get help during class:** Post in Slack / #debugging if you want a TA to enter your BOR or come find your group.

Any questions?

References.

1. Pietro and Lisa's GitHub on Testing and Debugging from 2023 [GitHub - ASPP/2023-heraklion-testing-debugging](#)
2. Summer School in Advanced Scientific Python Programming [ASPP2024/start](#)
3. Tutorial on effective testing with pytest [Effective Python Testing With Pytest – Real Python](#)
4. Pytest docs <https://docs.pytest.org/>



More on global vs. local variables

For the curious.



Namespaces and scopes.

- Really good article on this: <https://realpython.com/python-namespaces-scope/>
- The distinction between global and local variables is tied up into broader concepts called namespaces and scopes.
- A **namespace** is a place Python stores the symbolic names of the variables you define in a code.
- There are actually four different namespaces (built-in, global, enclosing, local) where Python can look for a variable you have defined.
 - The last line where you assign a value to your variable (e.g., “x = 4”) determines its namespace.
- The order in which Python looks for a defined variable is Local, Enclosed, Global, Built-in.
 - Referred to as **LEGB** rule.



Example of a non-explicit global variable that works.

Using global variables like this is NOT recommended. See last slide for discussion on why.

```
c = 1
```

Here is our assign statement, so Python will look for this variable in the global space.

```
def myfun():
```

```
    print(c)
```

Here we tell Python to acquire the value of c, then print the value.

Python looks first in the local namespace but does not find a “c” there. So then it looks in the enclosed namespace – same story.

```
myfun()
```

Finally it looks in the global namespace and finds that a symbolic “c” has been defined, with value 1. So this code would print “1”.



Example of a non-explicit global variable that DOESN'T work.

```
c = 1
```

```
def myfun():
```

```
    c = c + 2
```

```
    print(c)
```

```
myfun()
```

Here is our last assign statement, so Python classifies this as a local (not global) variable.

Here we tell Python to acquire the value of c, then print the value.

The problem now is that the interpreter believes that c is a local variable, but the *value* of c has never been defined in the local scope!

So if we execute this code, we will get an `UnboundLocalError`.



Example of an explicit global variable that works.

Using global variables like this is NOT recommended. See last slide for discussion on why.

```
c = 1
```

Here is our assign statement, so Python will look for this variable in the global space.

```
def myfun():  
    global c  
    c = c + 2  
    print(c)
```

We can (but shouldn't) use the "global" declaration to declare that a variable is defined in the global scope.

Now the interpreter knows where to access the value of c.
This code would print "3" upon execution.

```
myfun()
```



Why you shouldn't use global keywords.

- An example: I define a function `myfun` in a module that takes a variable `x` and increments its value by 2. But let's say you don't know that. Suddenly, this code would be extremely confusing to you:

```
>> x = 4  
  
>> myfun(x)  
  
>> print(x)  
  
6
```

- Similarly, let's say I share with you a function that looks like this:

```
def myfun2(x):  
    return m*x
```

- Maybe I always define a global variable “`m`” before calling this function, but you don't know that! Suddenly you can't run my code! Oh no!



Why you shouldn't use global keywords.

- The use of global variables likely makes your code less (a) debugable and (b) shareable.
- It is much better practice to pass your variables in as arguments. If we rewrite the `myfun2` function from the last slide, it looks like this:

```
def myfun2(x, m):  
    return m*x
```

- So, now we explicitly passed in the “m” variable, making the code more clear and easier to share. Nice!
- Finally, I highly recommend reading this tutorial. It explains these concepts in even more detail and with several code examples.
 - <https://realpython.com/python-namespaces-scope/>



More examples and tutorials of global and local variables.

- Global examples:
 - [Python Global Keyword \(With Examples\) \(programiz.com\)](https://programiz.com/python/global-keyword/)
 - [Global and Local Variables in Python – GeeksforGeeks](https://www.geeksforgeeks.org/global-local-variables-python/)
- Why you get error:
 - [UnboundLocalError: local variable referenced before assignment in Python. | by VINTA BHARATH SAI REDDY | Medium](https://medium.com/@vinta_bharath_sai_reddy/unboundlocalerror-local-variable-referenced-before-assignment-in-python-1234567890)
- Why you shouldn't do this:
 - [Why Is Using Global Variables Considered a Bad Practice? | Baeldung on Computer Science](https://www.baeldung.com/cs/global-variables-bad-practice)

