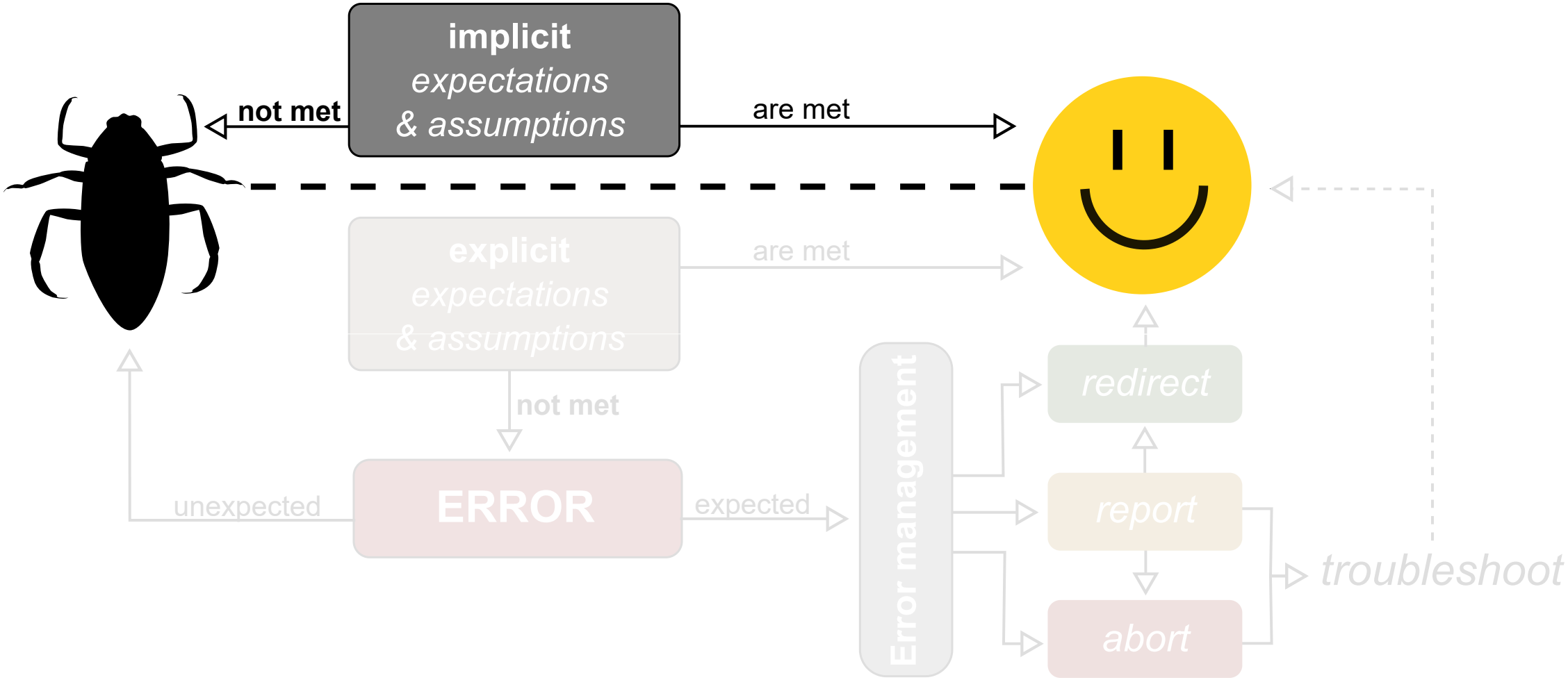
III. Code robustness

In computer science, **robustness** is the ability of a computer system to cope with errors during execution and cope with erroneous input.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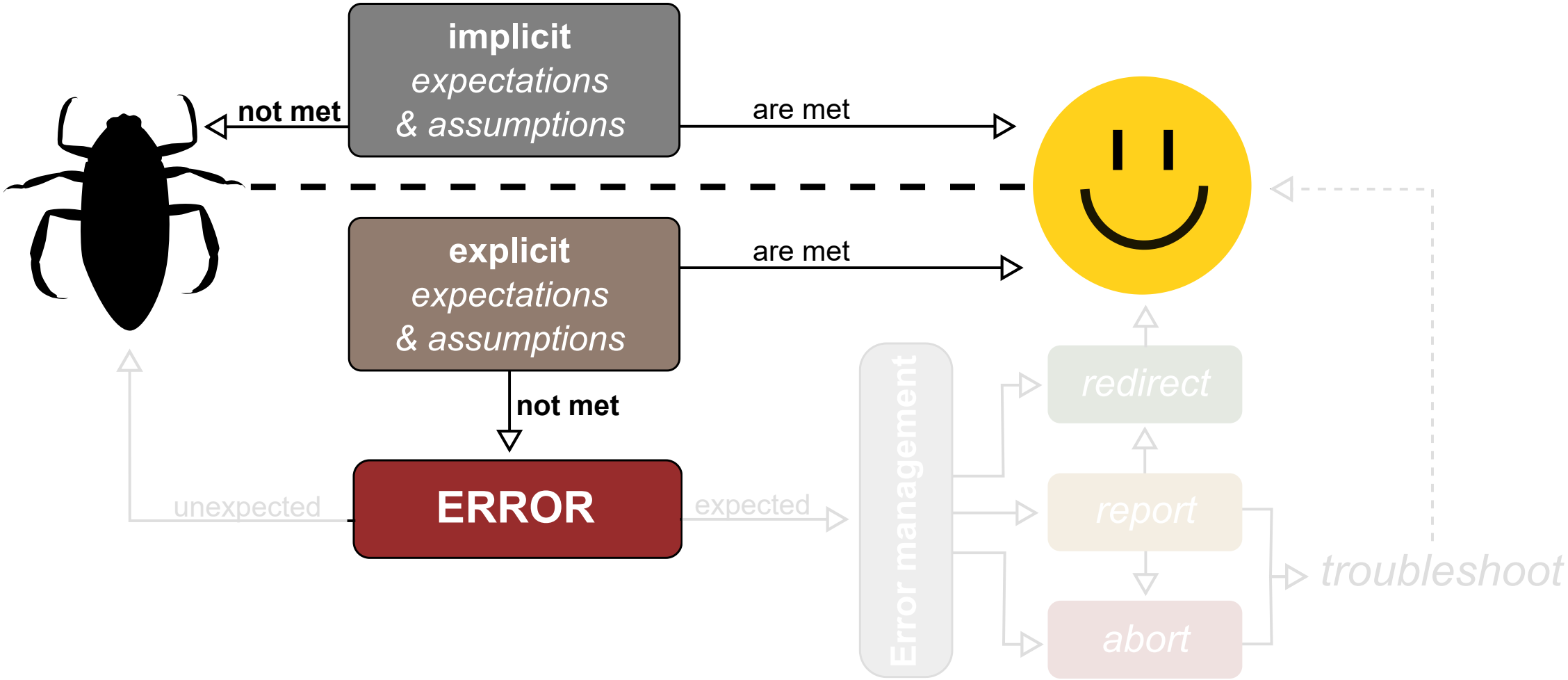
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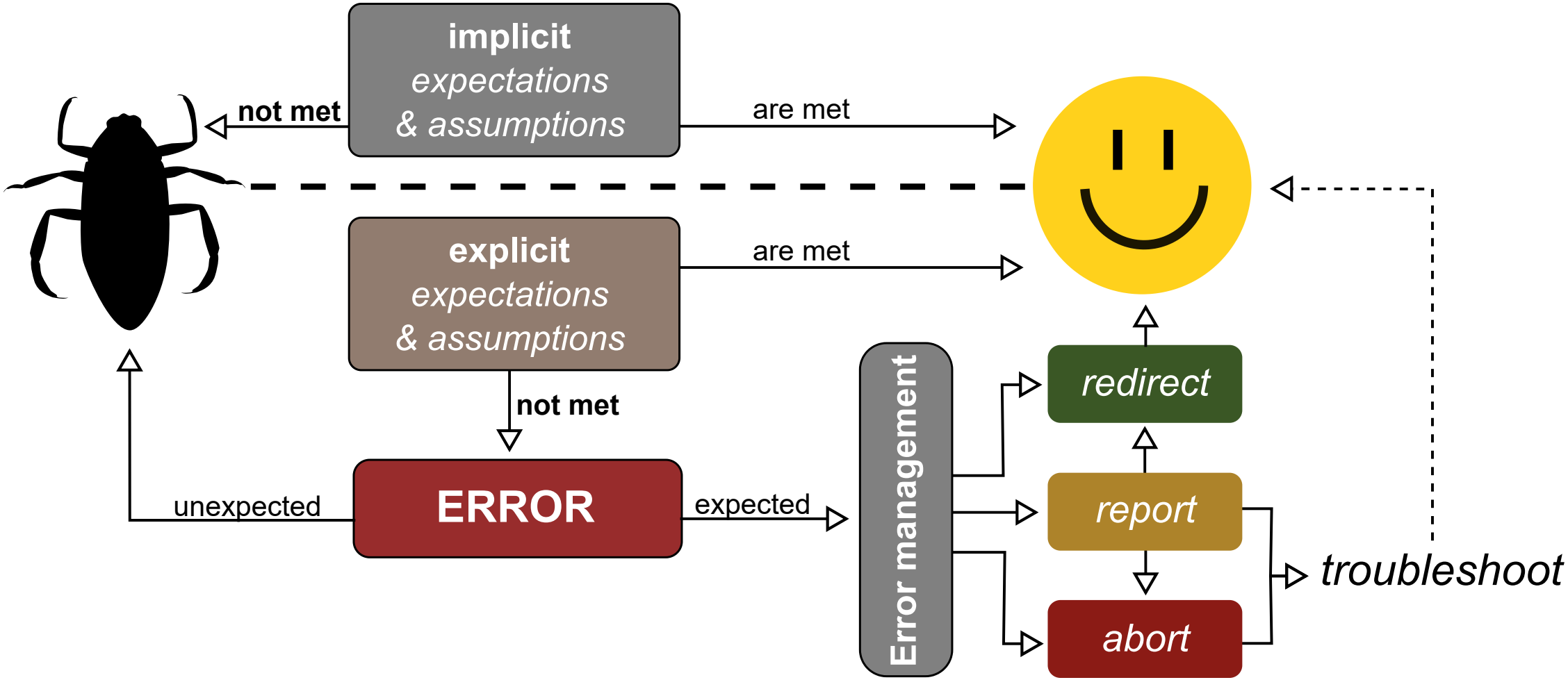
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Error management

Protect the user:

- Make assumptions and expectations explicit.
  - check values before processing them
  - identify and manage exceptions
- Produce errors when expectations are not met.
- Consider error options, and perform error management:
  - redirect the program
  - log or report the error, to allow the user (or developer) to troubleshoot
  - if necessary: abort the run

Advanced robustness: testing

Protect the developer (including you!)

- Test the expected behavior of your functions:
  - Confirm a known output given a known input
  - Do errors get produced as expected when the input calls for it?
- Capture unexpected errors to identify further options for error management
- You can automate running tests when pushing to Github using Continuous Integration
- Tests are **definitely** worth learning when your project increases in size!

Who is already applying tests in their project?

Throwing an error

```
def read_vector_value(index=0, my_vector=[10,5,4,12,25]):
    if index > len(my_vector) - 1:
        raise IndexError('Index higher than vector length.')
    return my_vector[index]

read_vector_value(index=6)
```

Why not simply adjust the function output?

```
def read_vector_value(index=0, my_vector=[10,5,4,12,25]):
    if index > len(my_vector) - 1:
        return None
    return my_vector[index]

print(read_vector_value(index=6))
```

- *Because it is unclear if `None` is expected behavior or indicative of a problem.*
- *Because you now need to handle `None` downstream*

Redirecting with exceptions

If you do not want to interrupt your script when an error is raised: use try/catch ('except' in Python).

Note that Python and MATLAB allow you to distinguish by error type!

Python

```
def read_vector_value(index=0, my_vector=[10,5,4,12,25]):
    if index > len(my_vector) - 1:
        raise IndexError('Index higher than vector length')
    return my_vector[index]
```

This will catch the exception

```
try:
  read_vector_value(6)
except IndexError: ## raised
  print("This is an exception")
except ValueError: # not raised
  print("This is an exception")
```

MATLAB

```
function value = read_vector_value(index, my_vector)
    if index > length(my_vector)
        ME = MException('MyComponent:indexError', ...
            'Index higher than vector length');
        throw(ME)
    end
    value = my_vector(index);
end
```

This will catch the exception

```
try
  value = read_vector_value(6, [10,5,4,12,25]);
catch ME
  if (strcmp(ME.identifier, 'MyComponent:indexError'))
    disp("This is an exception")
  end
end
```

Validating input

Consider early statements in the script to validate (data) input as a gatekeeper.

With if/else:

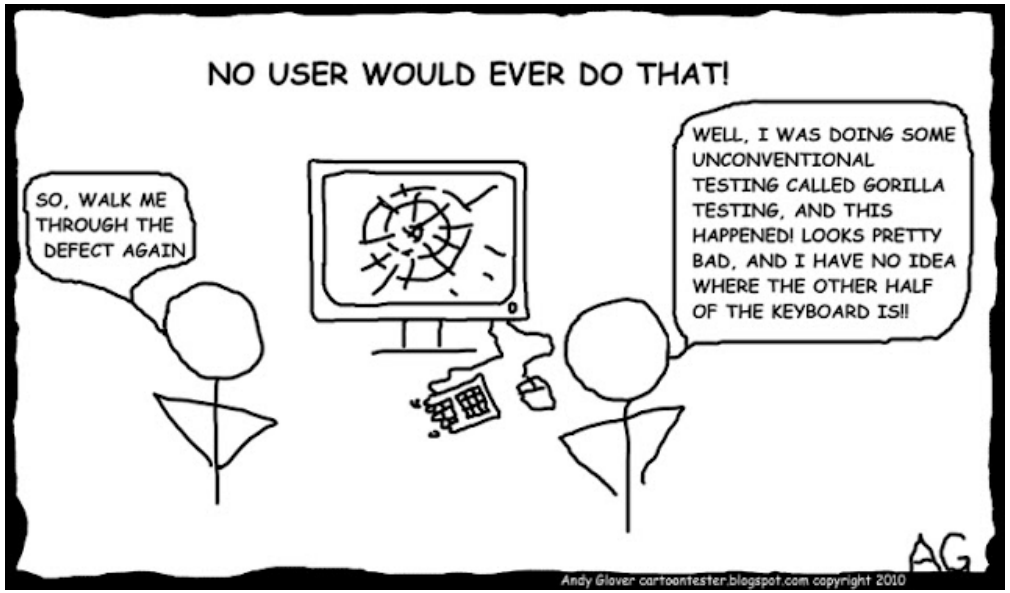
```
if isempty(protein_data)
  ME = MException('MyComponent:valueError', ...
              'Data set cannot be empty');
        throw(ME)
end
```

Tip: create a function to check inputs or use an argument parser

Expectations and assumptions

Expect the worst

- use of wrong input values for functions
- malformed text input
- wrong data types



Your turn: explicit expectations

Identify assumptions in your code

- What assumptions/expectations exist on your data or (user) input?
- What assumptions/expectations exist on the input of (a) function(s)?

Make the input/data assumptions explicit

- Write a piece of code that tests the validity of data/input, and reports an error if the expectations are not met.

Test the input for a function

- Modify the code inside your function to check the value of the arguments using if/else statements and raise an error in case an argument is out of the range.

Defensive programming

- Assume that mistakes will happen and introduce guards against them.
- Use assertions for things you believe will/should never happen.
- Use exceptions for anomalous or exceptional conditions requiring special processing.

```
def kelvin_to_celsius(temp_k):
    """
    Converts temperature in Kelvin
    to Celsius.
    """
    assert temp_k >= 0.0, "ERROR: negative T_K"
    temp_c = temp_k - 273.15
    return temp_c
```

Testing your code

Untested software can be compared to uncalibrated detectors

> *Before relying on a new experimental device, an experimental scientist always establishes its accuracy. A new detector is calibrated when the scientist observes its responses to known input signals. The results of this calibration are compared against the expected response.*

How do you now check the validity of your analysis?

Unit testing

Unit testing is a generic testing approach.

Your software is tested by focusing on smaller units, for instance a function or class.

- in python with pytest or unittest
  (Extra packages\imports are needed)
- in Matlab with Testing frameworks

When to write tests

It is always a balance: there is no "always/never"

Questions to ask yourself

- Can I easily verify the outcome of my code visually (plot)?
- Do I want to reuse parts of my code?
- Do others rely on the code?
- Do I need to verify contributions from other developers?
- How do I ensure bugs don't return?

Python: Testing our read_vector function

With pytest

```
# test_read_vector_value.py
import read_vector_value
import pytest
def test_retrieval():
    assert read_vector_value(0) == 10

def test_error():
    with pytest.assertRaises(IndexError):
        read_vector_value(6)
```

In the terminal, call

```
pytest test_read_vector_value.py
```

MATLAB: Testing our read_vector function

Using script-based testing

```
% test parameters
my_vector = [10,5,4,12,25];

%% Test 1: index
value = read_vector_value(3, my_vector);
assert(value == 4)

%% Test 2: index out of range
try
    value = read_vector_value(6, my_vector);
catch ME
    assert(strcmp(ME.identifier,'MyComponent:indexError'))
end
```

```
results = runtests('test_read_vector_value')
```

Your turn

Defensive programming

Check your code for conditions you believe will/should never happen and apply assert statements to prevent this.

Optional: Write a unit test

Write a unit test for a function

For python:

```
pip install pytest
```

Recommendations for writing robust software

- Error management
- Try-except statements
- Defensive programming
- Unit tests
- Automate with GitHub Actions / Gitlab runners

Example: PVMD Toolbox Continuous Integration pipeline