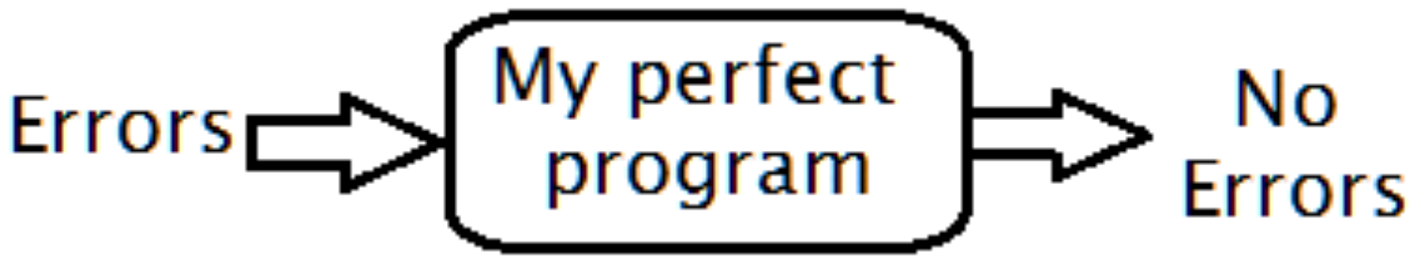
Errors

And How to Handle Them

GIGO

- There is a saying in computer science: “Garbage in, garbage out.”
  - Is this true, or is it just an excuse for bad programming?
  - Answer: Both.

- Here’s what you want:



- Can you do it?

Errors and exceptions

- Your program isn't alone in the universe—it has to interact with things outside itself
  - Users typing things in
  - Data read from files
  - Calls to your functions from "the outside world"
  - Your calls to "someone else's" functions
- It helps to think in terms of "my code" and "not my code"
  - An ***error*** is a mistake in your code, and it's your fault
  - An ***exception*** is a mistake that isn't in your code, and isn't your fault, but that doesn't mean you can ignore it
- This isn't entirely accurate, and the distinction isn't really all that clear, but it's a reasonable simplification

Sanity checking

- While Python has some built-in features for dealing with various kinds of mistakes, there are some simple things you can do without them
- ***Sanity checking*** is simply testing whether values are reasonable

```
age = int(input("What is your age? "))
if age < 3 or age > 120:
    print("No you're not!")
```

Errors

- An ***error*** is a bug in your code—fix it!

- There is no substitute for careful testing, but when errors do occur—
  - Putting in **`print`** statements (and later removing them, when the code works) is generally the most helpful
  - Using the debugger to step through your code is sometimes helpful
  - **`assert`** statements (covered next) can, on rare occasions, be helpful
- Other suggestions—
  - Take a break—do something else for a while
  - Explain your code to a friend
    - They don't have to understand you, but they should pretend to listen
    - If you have no friends, explain your code to your dog, or to your teddy bear
      - Not to your cat—they really don't listen

Executable documentation

- ***Comments*** are useful to the human reader, but ignored by the computer
- ***Assertions*** are useful to the human reader, *and* their validity can be checked by the computer
  - Unfortunately, assertions are limited to statements that can be expressed by a boolean expression
  - **Syntax:**
    `assert` *boolean_expression*
    or
    `assert` *boolean_expression*`,` *message*
  - If the boolean expression is `False`, an AssertionError occurs
- The primary purpose of the `assert` statement is to inform the human reader that the following code can assume the assertion is true
  - The *message* is hardly every required, but if used, should provide additional information
- Another purpose of the assert statement is to tell you when you are mistaken, and contrary to your expectations, the boolean expression is `False`

`assert` and require

- Some languages have both "assert" and "require"
  - **`assert`** *boolean_expression* says that, at this point in the code, I believe the *boolean_expression* to be **`True`**
  - **`require`** *boolean_expression* says that, in order for the following code to work correctly, the *boolean_expression* must be **`True`**
- Python has only **`assert`**, but since "assert" and "require" do essentially the same thing (signal that an error has occurred), we can implement "require" using **`assert`**
- ```
  def require(b):
      assert b, "Requirement not met."
  ```
- Or we can simply use **`assert`** to mean **`require`**
  ```

Example

```
def first_asterisk(s):
    """Returns the index of the first
       '*' in a string."""
    require('*' in s)
    for index in range(0, len(s)):
        if s[index] == '*':
            break
    assert s[index] == '*'
    assert '*' not in s[:index]
    return index
```

- This is excessive, and I don't recommend it as a general practice, but the occasional use of **`assert`** can be helpful

Someone else's problem

- An ***exception*** is a mistake that you can detect, but not a bug you can fix
  - It is "someone else's problem"
  - Later in the course we will talk about ***classes***, and the phrase "someone else" will mean "some other class"
- When you detect such a mistake, you should ***raise*** (or ***throw***) ***an exception***
  - **Syntax:** `raise` *name_of_exception*`(`*message*`)`
  - The most general type of exception has the name `Exception`, so usually you would just say `raise Exception(`*message*`)`
- Used correctly, raising an exception immediately exits the function that it is in

Square root example

```
def square_root(n):
    """Finds the square root of a
       non-negative number."""
    if n < 0:
        raise Exception("square_root called with "
                        + str(n))
    epsilon = 0.0000001
    guess = n / 2
    quotient = n / guess
    while abs(quotient - guess) > epsilon:
        guess = (guess + quotient) / 2
        quotient = n / guess
    return guess
```

- Raising the exception says to the caller, **"You're doing it wrong!"**

Flow of control

- When an exception is raised, the usual flow of control is disrupted
  - The exception must be ***caught***
    - We will talk about how to do this shortly
- Here's what happens when a function throws an exception:
  - Control immediately returns to the function that called this one
    - If that function catches the exception, it executes whatever code is necessary to deal with the situation
    - If the function does not catch the exception, it returns to the function that called it, and so on up the line
    - If no function ever catches the exception, the program terminates with an error message
  - In other words, the exception "propagates up the call chain" until it is caught, or the system catches it and terminates the program
- Exceptions are for dealing with errors, ***not*** for routine flow of control

Catching exceptions

- **Syntax:**

```
try:
        code that might result in an exception
except  type_of_exception_1:
        code to do something when exception 1 occurs
except  type_of_exception_2:
        code to do something when exception 2 occurs
finally:
        code to be performed whether or not an exception occurred
```

- You may have as many **`except`** clauses as you like
- **`except`** and **`finally`** are both optional, but you must have at least one
- **Semantics:**
  - The code in the **`try`** part is executed
  - If an exception occurs, the first **`except`** clause of the right type is executed
    - If no **`except`** clause is of the right type, control goes to the calling function
    - To catch ***any*** type of exception, say **`except Exception:`**
  - The **`finally`** clause is executed, whether or not an exception occurred

Reading in an integer

```
def get_int(prompt):
    """Gets an integer from the user"""
    try:
        age = int(input(prompt))
        return age
    except ValueError:
        print("That's not an integer!")
        return get_int(prompt)
```

```
>>> get_int("What is your age? ")
What is your age? fh
That's not an integer!
What is your age? dgghdf
That's not an integer!
What is your age? 99
99
```
(result printed by IDLE)

Getting the message

- ```
  try:
      root = square_root(-5)
  except Exception as msg:
      print(msg)
  ```

- `square_root called with -5`

- If the exception occurs and you don't catch it, the program will crash and the system will print out the message

- ```
  >>> square_root(-5)
  Traceback (most recent call last):
    File "<pyshell#42>", line 1, in <module>
      square_root(-5)
    File "/Users/dave/Box Sync/Programming/
  Python3_programs/scratch.py", line 34, in square_root
      raise Exception("square_root called with " +
  str(n))
  Exception: square_root called with -5
  ```

`assert` or `raise`?

- When an `assert` statement fails, it raises an `AssertionError`, which is a kind of `Exception`
- Hence, the following two things are almost exactly equivalent:
  - `assert` *boolean_expression*`,` *message*
  - `if not` *boolean_expression*`:`

```
    raise AssertionError(message)
```

- So when do you use which?
  - You should `assert` things which you really expect to be true; and if they aren't, you should fix your code so that they are
  - When your function gets invalid data (provided by "someone else") you should `raise` an exception, thus making it "their problem"

The End

"Never test for an error condition you don't know how to handle."

- Steinbach's Guideline for Systems Programming