Programming Principles in Python (CSCI 503/490)

Syntax & Types

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(some slides adapted from Dr. Reva Freedman)

Administrivia

- Course Web Site
- TAs: Naga Jyothi Kota & Angel Prathyusha Koyi
- Syllabus
  - Plagiarism
  - Accommodations
- Assignments
- Tests: 2 (Feb. 21, Apr. 3) and Final (May 6)
- Course is offered to both undergraduates (CS 490) and graduates (CS 503)
  - Grad students have extra topics, exam questions, assignment tasks

Office Hours & Email

- TA office hours will be held in person in PM 356
  - M 11am-12pm, 3–5pm, Tu 9:30am-12:30pm, W 1-4pm, Th 9:30am-12:30pm
- Prof. Koop's office hours will be held in person in PM 461
  - M: 1:45-3:00pm, W: 10:45am-12:00pm, or by appointment
  - You do not need an appointment to stop by during scheduled office hours,
  - If you wish to meet virtually, please schedule an appointment
  - If you need an appointment, please email me with **details** about what you wish to discuss and times that would work for you
- Many questions can be answered via email. **Please consider writing an email before scheduling a meeting.**

Using Python & JupyterLab on Course Server

- https://tiger.cs.niu.edu/jupyter/
- Login with you Z-ID (lowercase z)
- You should have received an email with your password
- Advanced:
  - Can add your own conda environments in your user directory

Using Python & JupyterLab Locally

- www.anaconda.com/download/
- Consider mamba (faster) and conda-forge
- Anaconda includes JupyterLab
- Use Python 3.12 (may have to install)
- Anaconda Navigator
  - GUI application for managing Python environment
  - Can install packages & start JupyterLab
- Can also use the shell to do this:
  - `$ jupyter lab`
  - `$ conda install <pkg_name>`

Zen of Python

- Written in 1999 by T. Peters in a message to Python mailing list
- Attempt to channel Guido van Rossum's design principles
- 20 aphorisms, 19 written, 1 left for Guido to complete (never done)
- Archived as PEP 20
- Added as an easter egg to python (`import this`)
- Much to be deciphered, in no way a legal document
- Jokes embedded
- Commentary by A.-R. Janhangeer

Explicit Code

- Goes along with complexity
- Bad:

```
def make_complex(*args):
    x, y = args
    return dict(**locals())
```

- Good

```
def make_complex(x, y):
    return {'x': x, 'y': y}
```

[The Hitchhiker's Guide to Python]

Don't Repeat Yourself

- "Two or more, use a for" [Dijkstra]
- Rule of Three: [Roberts]
  - Don't copy-and-paste more than once
  - Refactor into methods
- Repeated code is harder to maintain
- Bad

```
f1 = load_file('f1.dat')
r1 = get_cost(f1)
f2 = load_file('f2.dat')
r2 = get_cost(f2)
f3 = load_file('f3.dat')
r3 = get_cost(f3)
```

- Good

```
for i in range(1,4):
    f = load_file(f'f{i}.dat')
    r = get_cost(f)
```

Assignment 1

- Released today, due next Monday
- Goal: Become acquainted with Python using notebooks
- Make sure to follow instructions
  - Name the submitted file a1.ipynb
  - Put your name and z-id in the first cell
  - Label each part of the assignment using markdown
  - Make sure to produce output according to specifications

Modes of Computation

- Python is **interpreted**: you can run one line at a line without compiling
- Interpreter in the Shell
  - Execute line by line
  - Hard to structure loops
  - Usually execute whole files (called scripts) and edit those files
- Notebook
  - Richer results (e.g. images, tables)
  - Can more easily edit past code
  - Re-execute any cell, whenever

Python Interpreter from the Shell

- On tiger, use `conda init` to make sure you are using the latest version of python (the same version used by the notebook environment)
  - bash
  - conda init
  - conda activate py3.12
- We will discuss this more later, but want to show how this works

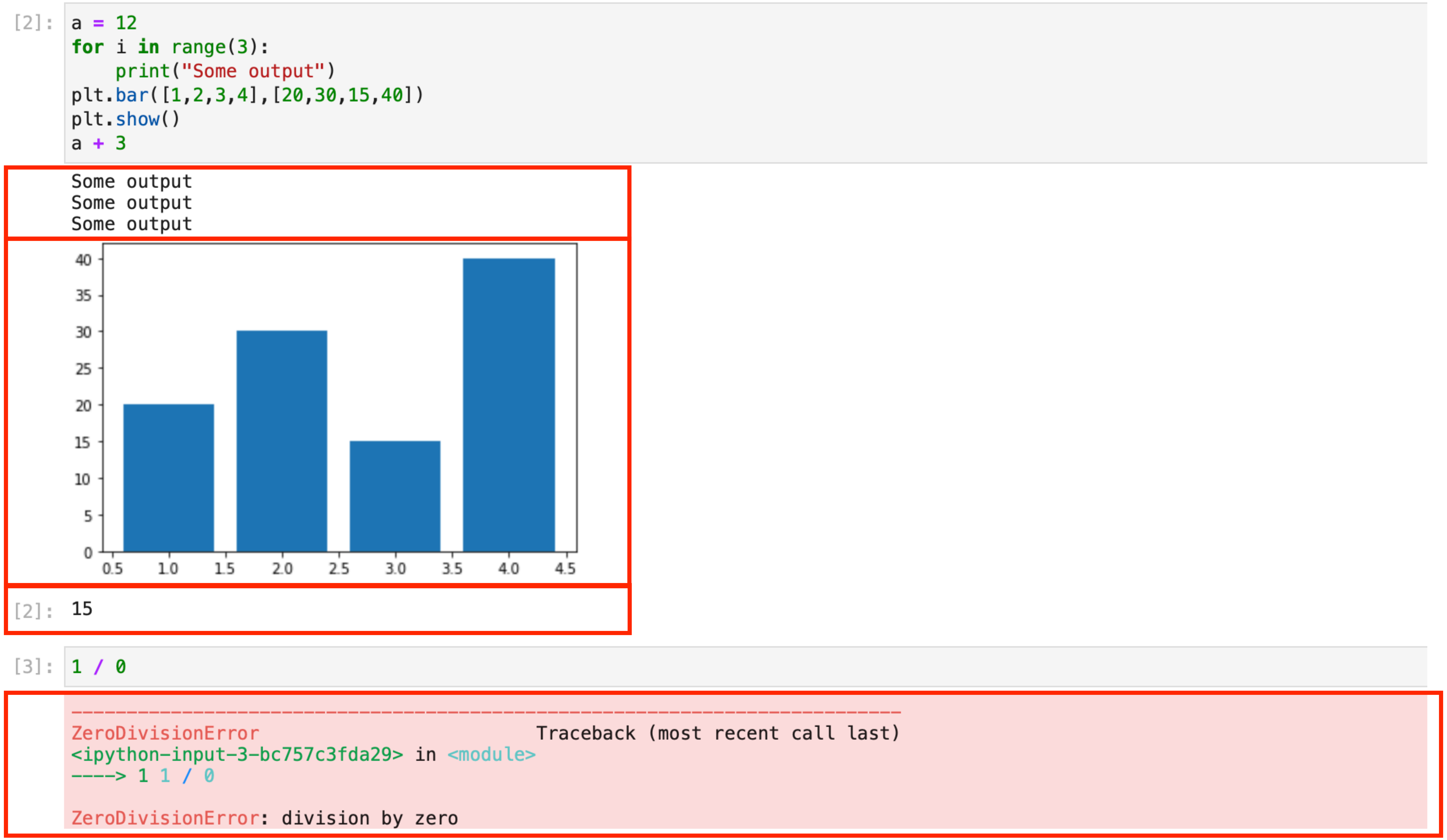
Python in a Notebook

- Richer results (e.g. images, tables)
- Can more easily edit past code
- Re-execute any cell, whenever

Multiple Types of Output

- stdout: where print commands go
- stderr: where error messages go
- display: special output channel used to show rich outputs
- output: same as display but used to display the value of the last line of a cell

Multiple Types of Output



```
[2]: a = 12
     for i in range(3):
         print("Some output")
     plt.bar([1,2,3,4],[20,30,15,40])
     plt.show()
     a + 3
```

stdout

```
Some output
Some output
Some output
```

display

output

```
[2]: 15
```

```
[3]: 1 / 0
```

stderr

```
---------------------------------------------------------------------------
ZeroDivisionError                         Traceback (most recent call last)
<ipython-input-3-bc757c3fda29> in <module>
----> 1 1 / 0

ZeroDivisionError: division by zero
```

Print function

- `print(“Welcome, Jane")`
- Can also print variables:

```
name = "Jane"
print("Welcome,", name)
```

Python Variables and Types

- No type declaration necessary
- Variables are names, not memory locations

```
a = 0
a = "abc"
a = 3.14159
```

- Don't worry about types, but think about types
- Strings are a type
- Integers are as big as you want them
- Floats can hold large numbers, too (double-precision)

Python Strings

- Strings can be delimited by single or double quotes
  - `"abc"` and `'abc'` are exactly the same thing
  - Easier use of quotes in strings: `"Joe's"` or `'He said "Stop!"'`
- Triple quotes allow content to go across lines and preserves linebreaks

  -
    ```
    """This is another
    string"""
    ```
- String concatenation: `"abc" + "def"`
- Repetition: `"abc" * 3`
- Special characters: `\n \t` like Java/C++

Python Math and String "Math"

- Standard Operators: +, -, *, /, %
- Division "does what you want" (new in v3)
  - `5 / 2 = 2.5`
  - `5 // 2 = 2 # use // for integer division`
- Shortcuts: `+=, -=, *=`
- No `++, --`
- Exponentiation (Power): `**`
- Order of operations and parentheses: (`4 - 3 - 1` vs. `4 - (3 - 1)`)
- `"abc" + "def"`
- `"abc" * 3`

Comments in Python

- `#` for single-line comments
  - everything after # is ignored
  - `a = 3 # this is ignored`
  - # this is all ignored
- Triple-quoted strings also used for comments (technically, any string can be)
  - A literal string without assignment, etc. is basically a no-op
  - `"""This is a string, often used as a comment"""`

  -
    ```
    """This string
    has multiple
    lines"""
    ```

Identifiers

- A sequence of letters, digits, or underscores, but…
- Also includes unicode "letters", spacing marks, and decimals (e.g. Σ)
- Must begin with a letter or underscore (_)
- Why not a number?

Identifiers

- A sequence of letters, digits, or underscores, but…
- Also includes unicode "letters", spacing marks, and decimals (e.g. `Σ`)
- Must begin with a letter or underscore (_)
- Why not a number? Ambiguity, `8j` is a complex number, `8e27` is a float
- Case sensitive (`a` is different from `A`)
- Conventions:
  - Identifiers beginning with an underscore (_) are reserved for system use
  - Use underscores (`a_long_variable`), **not** camel-case (`aLongVariable`)
  - Keep identifier names less than 80 characters
- Cannot be reserved words

Reserved Words and Reassigning builtins

- Some words cannot serve as identifiers (called keywords in Python)

  -
    ```
    import keyword
    keyword.kwlist
    ```

  -
    ```
    ['False', 'None', 'True', 'and', 'as', 'assert', 'async',
    'await', 'break', 'class', 'continue', 'def', 'del',
    'elif', 'else', 'except', 'finally', 'for', 'from',
    'global', 'if', 'import', 'in', 'is', 'lambda', 'nonlocal',
    'not', 'or', 'pass', 'raise', 'return', 'try', 'while',
    'with', 'yield']
    ```

  -
    ```
    False = True # SyntaxError
    ```
- Some other words (python's builtins) can, but this can cause problems

  -
    ```
    int = 34
    int("12") # TypeError
    ```

Programming Principle: Use Meaningful Identifiers

- Show intention:
  - Bad: `var34`
  - Good: `time_difference`
- Easy pronunciation: Not `egészségedre` (perhaps ok if you're Hungarian)
- Simple but technical:
  - Bad: `in_order_list_of_jobs`
  - Good: `job_queue`
- Be consistent:
  - Bad: `user_list` and `groups`
  - Good: `user_list` and `group_list`

Types

- Don't worry about types, but think about types
- Variables can "change types"

  -
    ```
    a = 0
    a = "abc"
    a = 3.14159
    ```
- Actually, the **name** is being moved to a different value
- You can find out the type of the value stored at a variable `v` using `type(v)`
- Some literal types are determined by subtle differences
  - `1` vs `1.` (integer vs. float)
  - `1.43` vs `1.43j` (float vs. imaginary)
  - `'234'` vs `b'234'` (string vs. byte string)

Type Conversion

- Python converts integers to floats when types are mixed
  - `1 + 3.4 # evaluates to 4.4 (float)`
- Functions can return different types than inputs
  - `round(3.9) # evaluates to 4 (int)`
- Can do explicit type conversion
  - `int(3.9) # evaluates to 3 (int)`
  - `float(123) # evaluates to 123. (float)`
  - `int("123") # evaluates to 123 (int)`
  - `str(123) # evaluates to "123" (string)`

Numeric Precision

- Integers have infinite precision and are as big as you want them
  - `93326215443944152681699238856266700490715968264381621468592963895217599993229915608941463976156518286253697920827223758251185210916864000000000000000000000000`
- Floats do not have infinite precision but still hold large numbers (double-precision)
  - `9.33262154439441e+157`
  - Python keeps 17 significant digits
  - Python by default only prints up to 12 (many times less)
- Python has support for infinite precision (Decimal)
- How might this work; how could you store a floating point number with infinite precision using python?

Expression Rules

- Involve
  - Literals (`1, "abc"`),
  - Variables (`a, my_height`), and
  - Operators (`+,-*,/,//,**`)
- Spaces are **irrelevant** within an expression
  - `a +           34 # ok`
- Standard precedence rules
  - Parentheses, exponentiation, mult/div, add/sub
  - **Left to right** at each level
- Also **boolean** expressions

Assignment

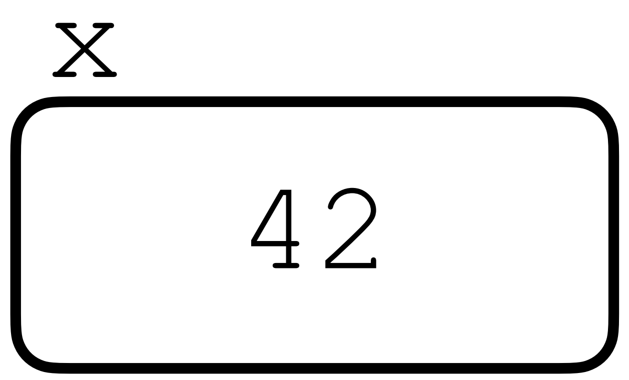
- The = operator
- Can assign a literal, another variable, or any expression
  - `a = 34`
  - `b = a`
  - `c = (a + b) ** 2`
- Cannot use this operator in the middle of an expression, like in C++
- However, Python 3.8 added a new operator (the "walrus") that allows this

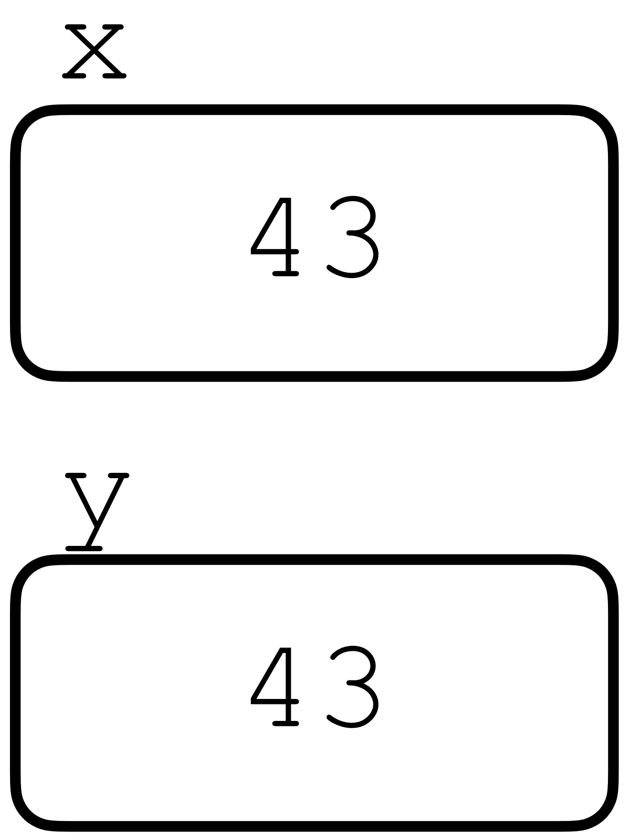
Assignment

- Other languages: set aside memory space for value and give that space a name; space can be updated with a new value

```
int x = 42;
```

```
x = x + 1;
int y = x;
```

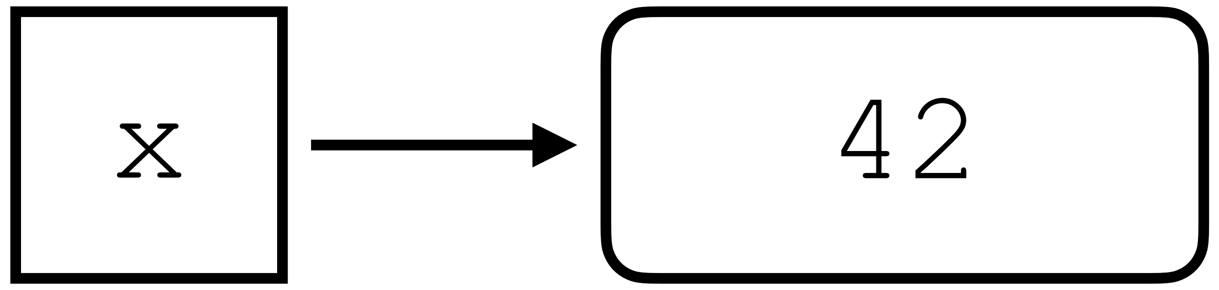




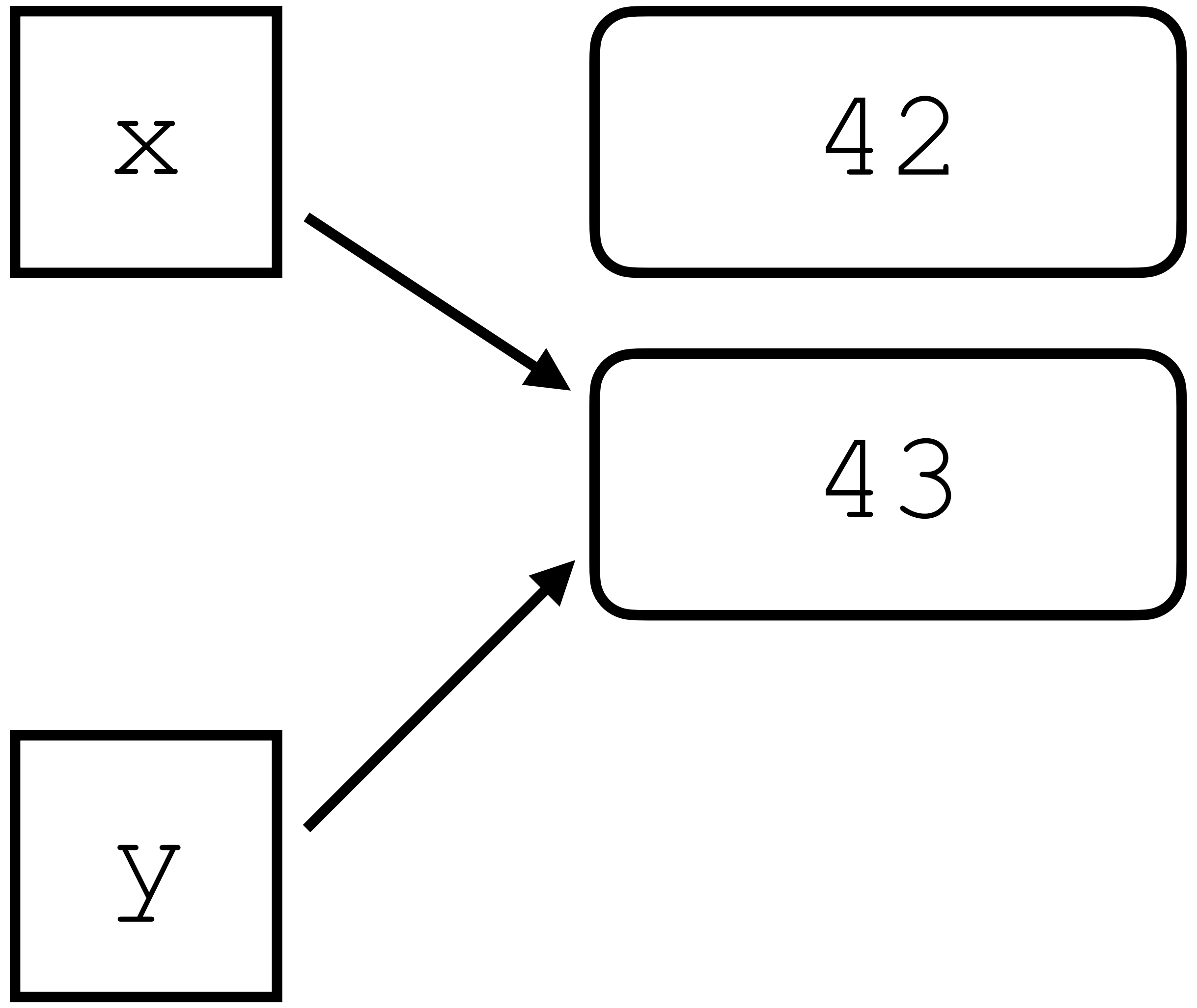
Assignment

- Python variables are actually **pointers** to objects (names for values)

```
x = 42
```



```
x = x + 1
y = x
```



Augmented Assignment

- Shorthand for mutation of a variable's value stored back in the same variable
- `i += 1 # same thing as i = i + 1`
- `+=`, `-=`, `*=`, `/=`, `//=`, `**=`
- Python does not have `++` or `--`

Simultaneous Assignment

- Feature that doesn't appear in many other languages
- Allows multiple expressions to be assigned to different variables with one assignment
  - `a, b = 34 ** 2, 400 / 24`
- Commas separate the variables and expressions
- Most useful for swapping variables
  - `a, b = b, a`
- How does this usually work?

Simultaneous Assignment

- In most languages, this requires another variable

  -
    ```
    x_old = x
    x = y
    y = x_old
    ```
- Simultaneous assignment leaves less room for error:
  - `x,y = y,x`
- Also useful for unpacking a collection of values:

  -
    ```
    dateStr = "03/08/2014"
    monthStr, dayStr, yearStr = dateStr.split("/")
    ```

Assignment Expressions

- AKA the "walrus" operator `:=`
- Names a value that can be used but also referenced in the rest of the expression
- `(my_pi := 3.14159) * r ** 2 + a ** 0.5/my_pi`
- Use cases: if/while statement check than use, comprehensions
- Supported in Python 3.8+

Assignment Expressions

- Contentious discussion on adding to the language
  - "There should be one-- and preferably only one --obvious way to do it"
  - Leads to different coding styles
- Adopted, and community moving on to best practices