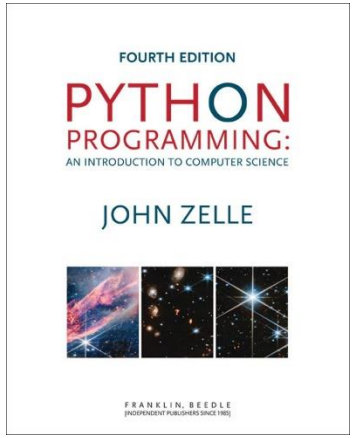
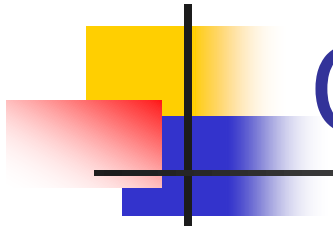
Python Programming: An Introduction to Computer Science

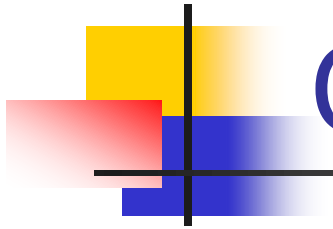


Chapter 1
Computers and Programs



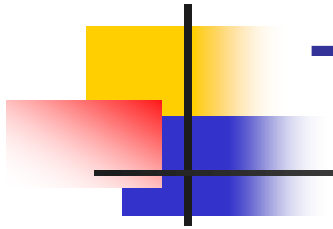
Objectives

- To understand the respective roles of hardware and software in computing systems.
- To learn how information practitioners might use computer programming in their work.
- To understand the basic design of a modern computer and the role played by the operating system.



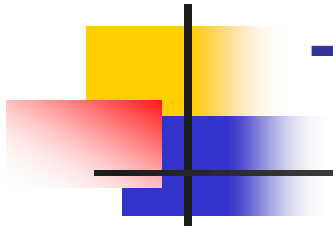
Objectives (cont.)

- To understand the form and function of computer programming languages.
- To begin using the Python programming language.
- To see a typical small program in action.



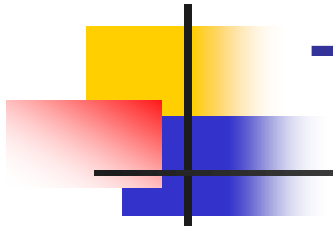
The Universal Machine

- A modern computer can be defined as "a machine that stores and manipulates information under the control of a changeable program."
- Two key elements:
  - Computers are devices for manipulating information.
  - Computers operate under the control of a changeable program.



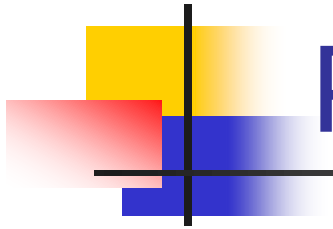
The Universal Machine

- What is a *computer program*?
  - A detailed, step-by-step set of instructions telling a computer what to do.
  - If we change the program, the computer performs a different set of actions or a different task.
  - The machine stays the same, but the program changes!



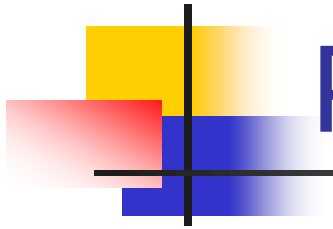
The Universal Machine

- Programs are *executed*, or carried out.
- All computers have the same power, with suitable programming, i.e. each computer can do the things any other computer can do.



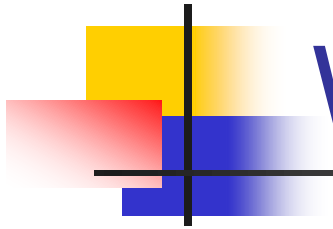
Program Power

- *Software* (programs) rules the *hardware* (the physical machine).
- The process of creating this software is called *programming* or *coding*.
- Why learn to program?
  - Fundamental part of computer science
  - Having an understanding of programming helps you have an understanding of the strengths and limitations of computers.



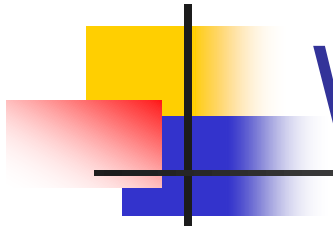
Program Power

- Helps you become a more intelligent user of computers
- It can be fun!
- Form of expression
- Helps the development of problem solving skills, especially in analyzing complex systems by reducing them to interactions between simpler systems.
- Information professionals with programming skills can be more productive.



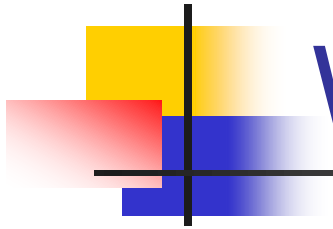
What is Computer Science?

- It is not the study of computers!
  "Computers are to computer science what telescopes are to astronomy." –
  E. Dijkstra
- Computer scientists are interested in "What can be computed?"
- Information practitioners are interested in "How can I use programming to become more effective in my work?"



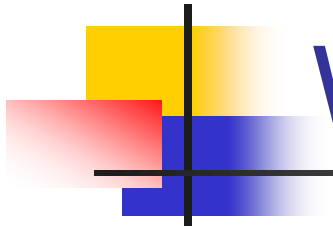
What is Computer Science?

- Design
  - One way to show a particular problem can be solved is to actually design a solution.
  - This is done by developing an *algorithm*, a step-by-step process for achieving the desired result.
  - These programming experiments give us a clearer idea of whether the problem can be practically addressed with a programming solution.



What is Computer Science?

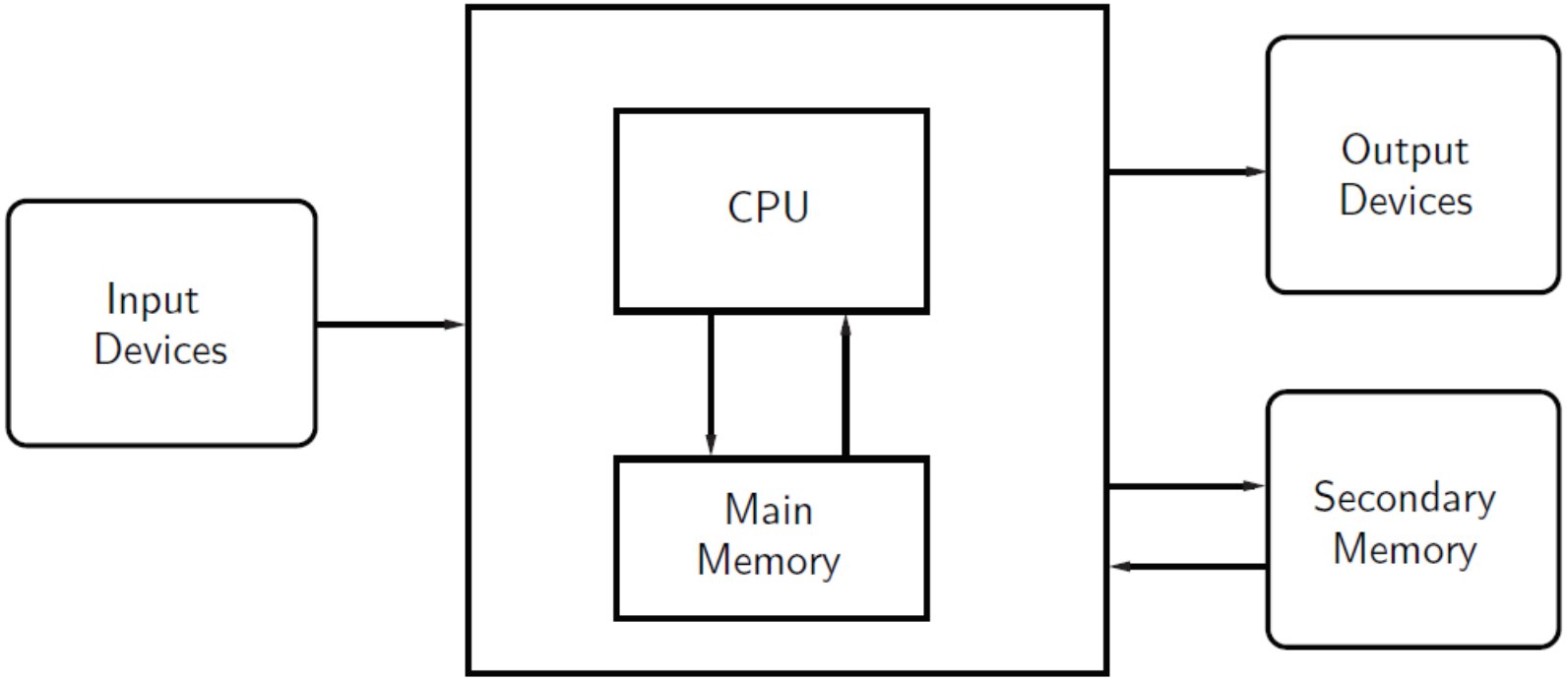
- Analysis
  - Analysis is the process of examining algorithms and problems.
  - Computer scientists want to identify problems that are not solvable from a computing perspective.
  - Information professionals want to identify problems that are not solvable from a computing or a user perspective.

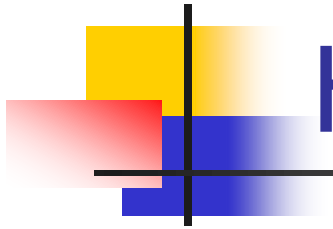


What is Computer Science?

- Experimentation
  - Some problems are too complex for analysis.
  - Implement a system and then study its behavior.
  - This approach works well for both computer scientists and information professionals.

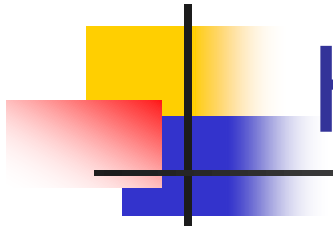
Hardware Basics





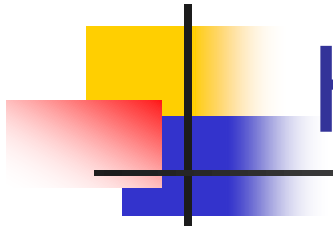
Hardware Basics

- The *central processing unit* (CPU) is the "brain" of a computer.
  - The CPU carries out all the basic operations on the data.
  - Examples: simple arithmetic operations, testing to see if two numbers are equal.



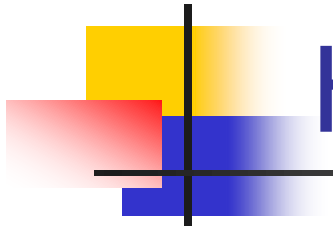
Hardware Basics

- Memory stores programs and data.
  - CPU can only directly access information stored in *main memory* (RAM or Random Access Memory).
  - Main memory is fast, but *volatile*, i.e. when the power is interrupted, the contents of memory are lost.
  - Secondary memory provides more permanent storage: magnetic (hard drive), flash (SSD, USB memory), optical (CD, DVD)



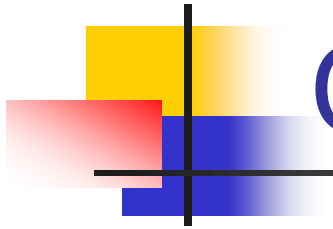
Hardware Basics

- Input devices
  - Information is passed to the computer through keyboards, mice, etc.
- Output devices
  - Processed information is presented to the user through the monitor, printer, etc.
- Some devices act as both input and output devices, e.g. network controller.



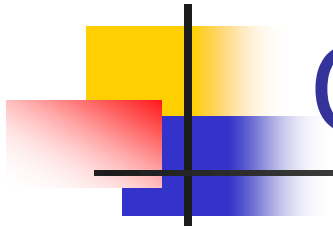
Hardware Basics

- *Fetch-Execute Cycle*
  - First instruction retrieved from memory
  - Decode the instruction to see what it represents
  - Appropriate action carried out.
  - Next instruction fetched, decoded, and executed.
  - Lather, rinse, repeat!



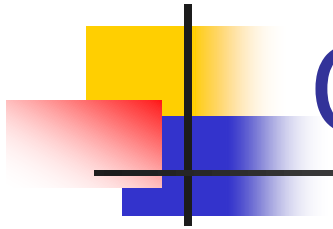
Operating Systems

- Who's in charge of what instructions are executing at a given moment? The *operating system*.
- An OS is a suite of software that controls the various hardware resources of a computer, binding the components together so they act as a unified whole.
- Examples: Windows, MacOS, Linux, ChromeOS, iOS, Android.



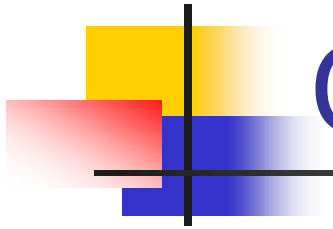
Operating Systems

- The OS manages all of the computer's resources.
- The *bootstrap loader* is a small program initially loaded into RAM when the computer is first turned on or restarted that loads the OS *kernel*.
- The *kernel* is the part of the OS that is always running.



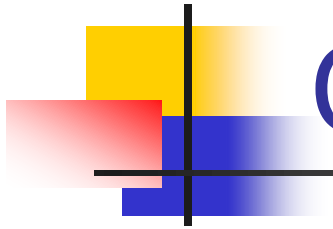
Operating Systems

- The kernel can give up the CPU to allow another program to run, but it will interrupt at regular intervals to retake control.
- Then the kernel can hand off the CPU to another program.
- By doing this switch quickly among multiple loaded programs, this gives the appearance of running the programs simultaneously.



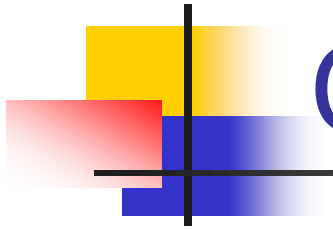
Operating Systems

- Important points
  - Files are used to store data.
    - Files can store audio, images, text, applications (programs), etc.
    - The OS has to keep track of what the contents of the file are somehow. A general way to do this is to indicate the type of data with the file extensions, i.e. mysong.*mp3*.
    - One problem – some operating systems make it hard to see the extension. What if you also have mysong.wav?
    - Tip 1: Do some research to see how to turn on the ability to see the extension in the folders where you'll store your code.



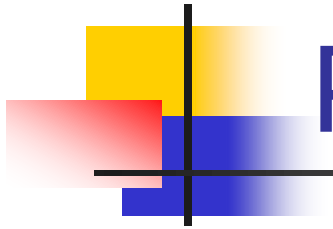
Operating Systems

- The hierarchical structure of directories/folders on your computer is essential to keeping tables on all your information.
  - In addition to your own files, there are a number of operating system-specific files on your computer.
  - Keep your files in your space, let the system keep its files in its space.
  - You will typically have a home or user folder called “Documents”.



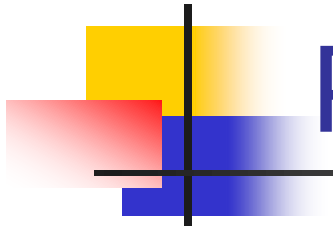
Operating Systems

- Tip 2 – create a directory/folder to store ALL your work for this class. Create it in your home directory, the Desktop, or someplace easy to find.



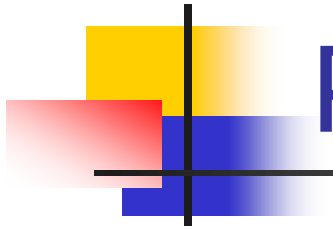
Programming Languages

- Natural language has ambiguity and imprecision problems when used to describe complex algorithms.
  - Programs expressed in an unambiguous, precise way using *programming languages*.
  - Every structure in programming language has a precise form, called its *syntax*
  - Every structure in programming language has a precise meaning, called its *semantics*.



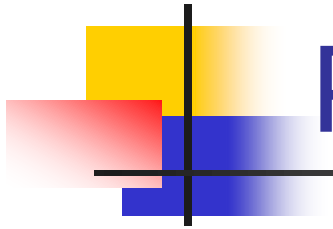
Programming Languages

- Programming language like a code for writing the instructions the computer will follow.
  - Programmers will often refer to their program as *computer code*.
  - Process of writing an algorithm in a programming language often called *coding*.



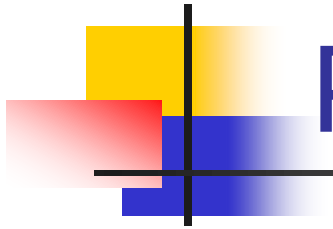
Programming Languages

- *High-level* computer languages
  - Designed to be used and understood by humans
- Low-level language
  - Computer hardware can only understand a very low-level language known as *machine language*



Programming Languages

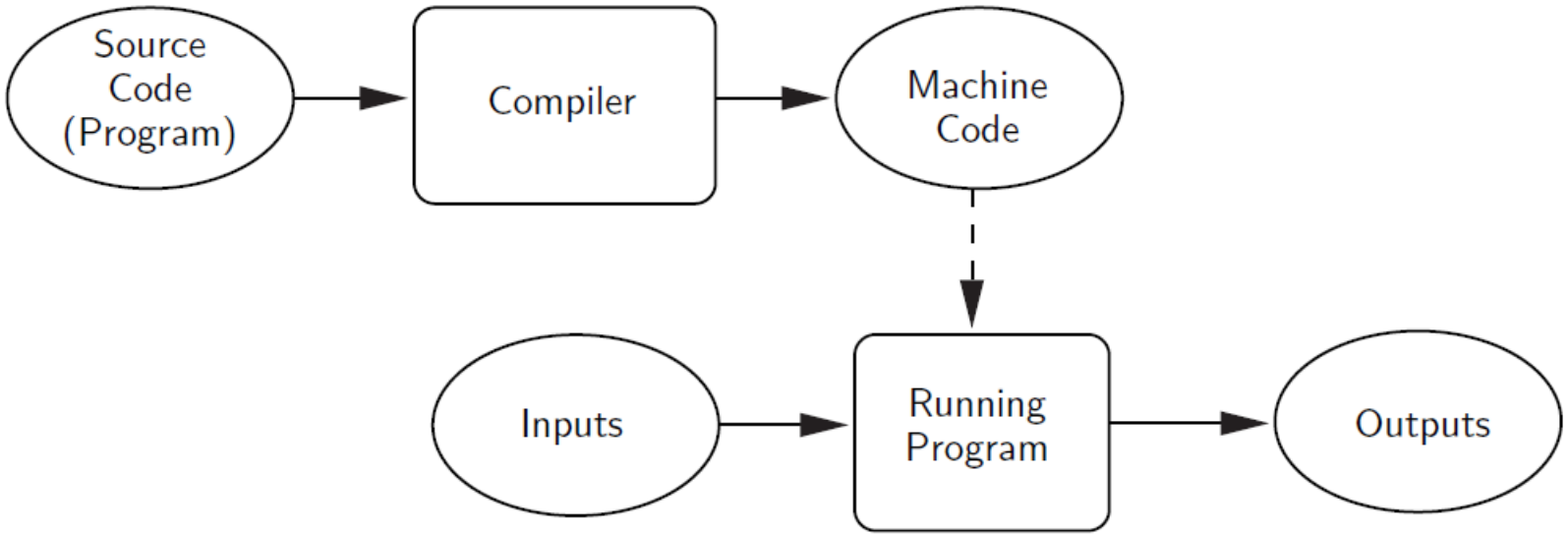
- Add two numbers:
  - Load the number from memory location 2001 into the CPU
  - Load the number from memory location 2002 into the CPU
  - Add the two numbers in the CPU
  - Store the result into location 2003
- In reality, these low-level instructions are represented in *binary* (1's and 0's)

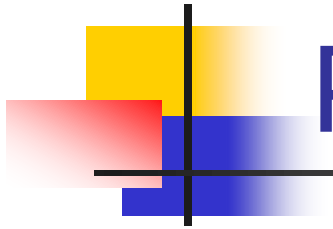


Programming Languages

- High-level language
  c = a + b
- This needs to be translated into machine language that the computer can execute.
- *Compilers* convert programs written in a high-level language into the machine language of a particular computer.

Programming Languages

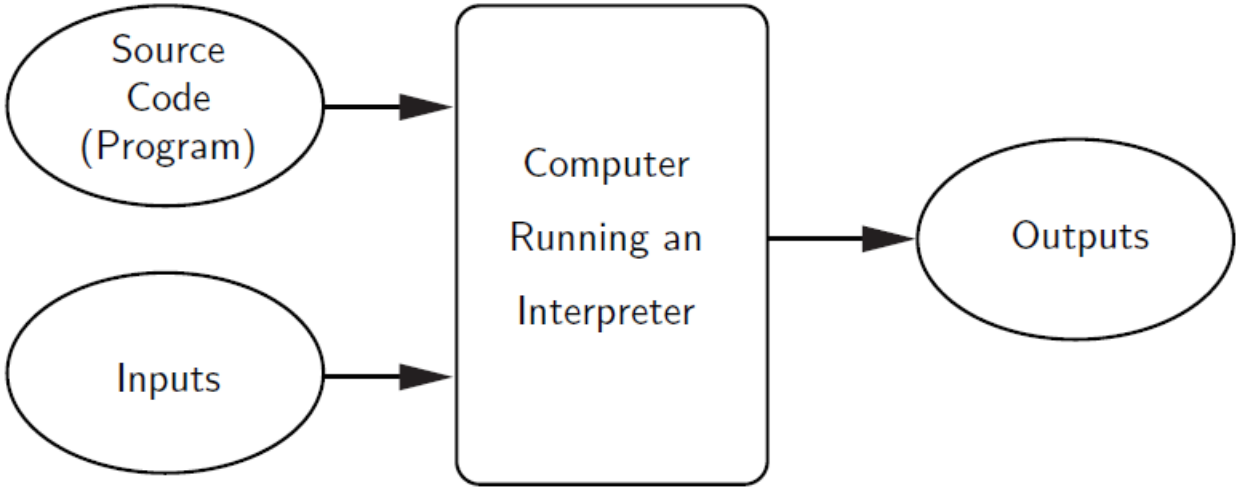


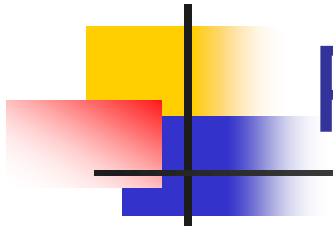


Programming Languages

- *Interpreters* simulate a computer that understands a high-level language.
- The source program is not translated into machine language all at once.
- An interpreter analyzes and executes the source code instruction by instruction.

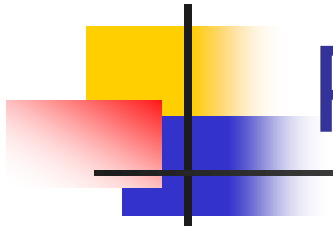
Programming Languages





Programming Languages

- Compiling vs. Interpreting
  - Once program is compiled, it can be executed over and over without the source code or compiler. If it is interpreted, the source code and interpreter are needed each time the program runs
  - Compiled programs generally run faster since the translation of the source code happens only once.

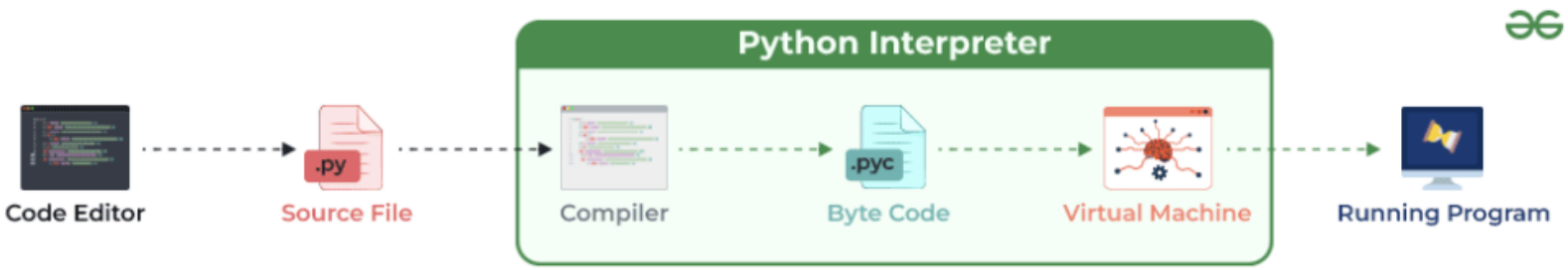


Programming Languages

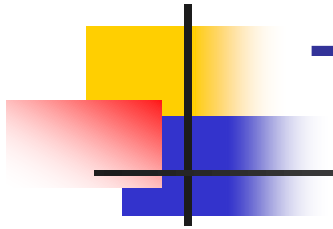
- Interpreted languages are part of a more flexible programming environment since they can be developed and run interactively
- Interpreted programs are more *portable*, meaning the executable code produced from a compiler for a Windows machine won't run on a Mac, without recompiling. If a suitable interpreter already exists, the interpreted code can be run with no modifications.

CPython is the Standard Python

- CPython is both compiled AND interpreted.
- This balances execution speed with portability.
- See article: *Internal working of Python*



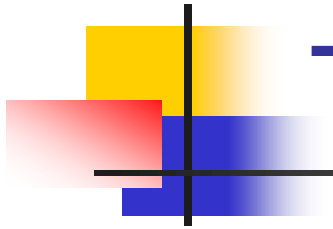
Internal Working of Python



The Magic of Python

When you start Python, you will see something like:

```
Python 3.11.4 (tags/v3.11.4:d2340ef, Jun  7 2023, 05:45:37) [MSC v.1934 64 bit (AMD64)] on win32
Type "help", "copyright", "credits" or "license()" for more information.
>>>
```



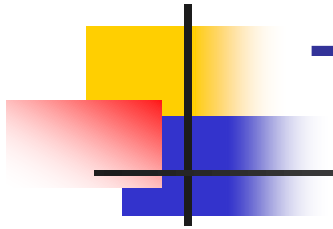
The Magic of Python

- The ">>>" is a Python *prompt* indicating that Python is ready for us to give it a command. These commands are called *statements*.
- ```
  >>> print("Hello, world")
  Hello, world
  >>> print(2+3)
  5
  >>> print("2+3=", 2+3)
  2+3= 5
  >>>
  ```
  ```

The Magic of Python

- Usually, we want to execute several statements together that solve a common problem. One way to do this is to use a *function*.
-
```
>>> def hello():
        print("Hello")
        print("Computers are Fun")

>>>
```



The Magic of Python

```
>>> def hello():
        print("Hello")
        print("Computers are Fun")

>>>
```

- The first line tells Python we are *defining* a new function called `hello`.
- The following lines are indented to show that they are part of the `hello` function.
- The blank line (hit enter twice) lets Python know the definition is finished.

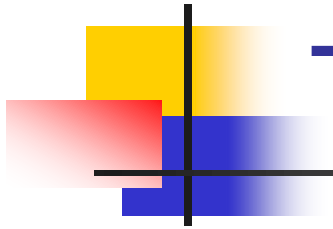
The Magic of Python

```
>>> def hello():
        print("Hello")
        print("Computers are Fun")

>>>
```

- Notice that nothing has happened yet! We've defined the function, but we haven't told Python to perform the function!
- A function is *invoked* (or *called*) by typing its name.

```
>>> hello()
Hello
Computers are Fun
>>>
```



The Magic of Python

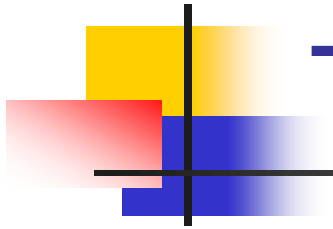
- What's the deal with the ()'s?
- Commands can have changeable parts called *parameters* (or *arguments*) that are placed between the ()'s.
-
```
>>> def greet(person):
        print("Hello",person)
        print ("How are you?")

>>>
```

The Magic of Python

```
>>> greet("Terry")
Hello Terry
How are you?
>>> greet("Paula")
Hello Paula
How are you?
>>>
```

- When we use parameters, we can customize the output of our function.



The Magic of Python

- When we exit the Python prompt, the functions we've defined cease to exist!
- Programs are usually composed of functions, *modules*, or *scripts* that are saved on disk so that they can be used again and again.
- A *module file* is a text file created in text editing software (saved as "plain text") that contains function definitions.
- An *integrated development environment (IDE)* is designed to help programmers write programs and usually includes automatic indenting, highlighting, etc.

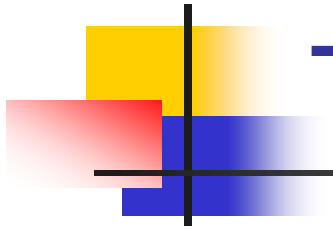
The Magic of Python

```
# File: chaos.py
# A simple program illustrating chaotic behavior

def main():
    print("This program illustrates a chaotic function")
    x = float(input("Enter a number between 0 and 1: "))
    for i in range(10):
        x = 3.9 * x * (1 - x)
        print(x)

main()
```

- We'll use *filename.py* when we save our work to indicate it's a Python program.
- In this code we're defining a new function called **main**.
- The main() at the end tells Python to run the code.

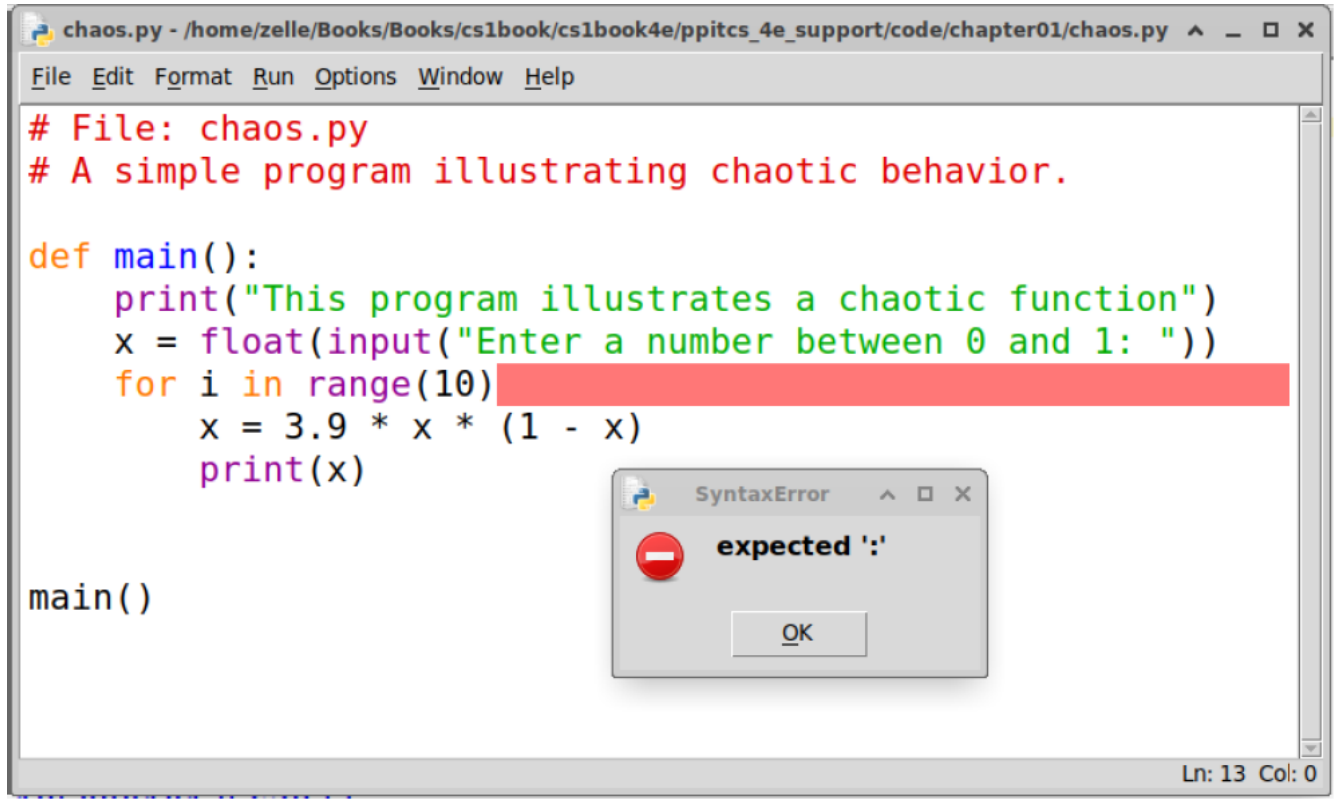


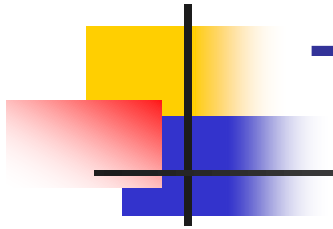
The Magic of Python

```
>>>
This program illustrates a chaotic function
Enter a number between 0 and 1: .5
0.975
0.0950625
0.335499922266
0.869464925259
0.442633109113
0.962165255337
0.141972779362
0.4750843862
0.972578927537
0.104009713267
>>>
```

The Magic of Python

- What happens if you leave out the ":"?

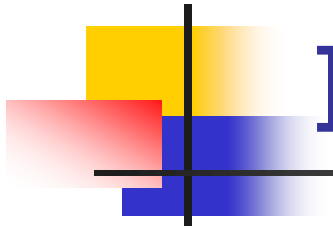




The Magic of Python

- Traceback messages
  - This tells us the error is somewhere on line six...

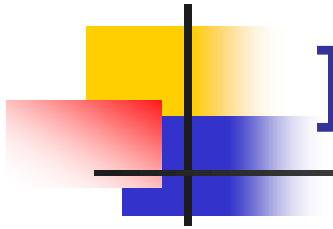
```
This program illustrates a chaotic function
Traceback (most recent call last):
  File "C:/Users/terry/Desktop/chaos.py", line 10, in <module>
    main()
  File "C:/Users/terry/Desktop/chaos.py", line 6, in main
    x = floar(input("Enter a number between 0 and 1: "))
NameError: name 'floar' is not defined. Did you mean: 'float'?
```



Inside a Python Program

```
""" A simple program illustrating chaotic behavior."""
```

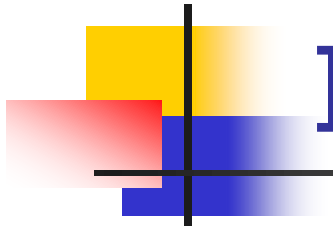
- Lines that start with # are called *comments*
- Intended for human readers and ignored by Python
- Python skips text from # to end of line
- """ Triple-quoted text lines are called DocStrings"""
- DocStrings are the professional programmer way to begin a Python program (module)



Inside a Python Program

```
def main():
```

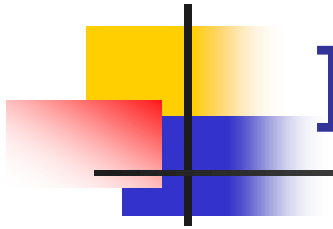
- Beginning of the definition of a function called *main*
- Since our program has only this one module, it could have been written without the *main* function.
- The use of *main* is customary and considered to be a best practice.



Inside a Python Program

```
print("This program illustrates a chaotic function")
```

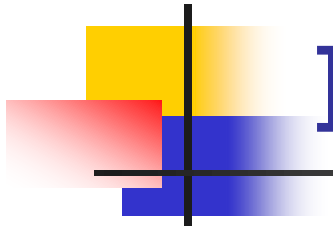
- This line causes Python to print a message introducing the program.



Inside a Python Program

```
x = eval(input("Enter a number between 0 and 1: "))
```

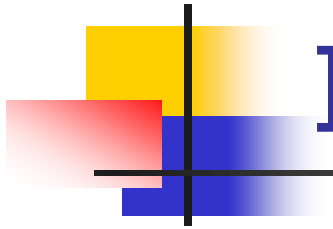
- x is an example of a *variable*
- A variable is used to assign a name to a value so that we can refer to it later.
- The quoted information is displayed, and the number typed in response is stored in x.



Inside a Python Program

```
for i in range(10):
```

- For is a *loop* construct
- A loop tells Python to repeat the same thing over and over.
- In this example, the following code will be repeated 10 times.



Inside a Python Program

```
x = 3.9 * x * (1 - x)
print(x)
```

- These lines are the *body* of the loop.
- The body of the loop is what gets repeated each time through the loop.
- The body of the loop is identified through indentation.
- The effect of the loop is the same as repeating these two lines 10 times!

Inside a Python Program

```
for i in range(10):
    x = 3.9 * x * (1 - x)
    print(x)
```

- These are equivalent!

```
x = 3.9 * x * (1 - x)
print(x)
x = 3.9 * x * (1 - x)
print(x)
x = 3.9 * x * (1 - x)
print(x)
x = 3.9 * x * (1 - x)
print(x)
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print(x)
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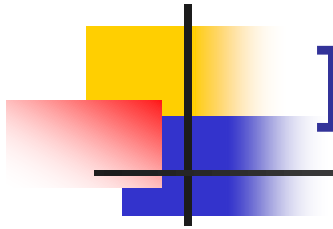
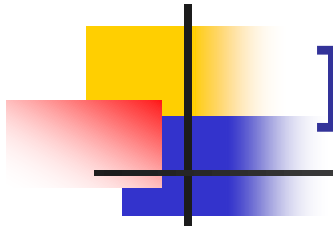
print(x)
x = 3.9 * x * (1 - x)
print(x)
```



Inside a Python Program

```
x = 3.9 * x * (1 - x)
```

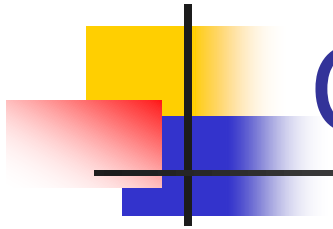
- This is called an *assignment* statement
- The part on the right-hand side (RHS) of the "=" is a mathematical expression.
- * is used to indicate multiplication
- Once the value on the RHS is computed, it is stored back into (*assigned*) into x



Inside a Python Program

```
main()
```

- This last line tells Python to *execute* the code in the function *main*

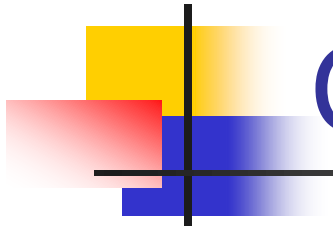


Chaos and Computers

- The chaos.py program:

```
def main():
    print("This program illustrates a chaotic function")
    x = eval(input("Enter a number between 0 and 1: "))
    for i in range(10):
        x = 3.9 * x * (1 - x)
        print(x)
main()
```

- For any given input, returns 10 seemingly random numbers between 0 and 1
- It appears that the value of x is *chaotic*



Chaos and Computers

- The function computed by program has the general form $kx(1-x)$ where k is 3.9
- This type of function is known as a logistic function.
- Models certain kinds of unstable electronic circuits and population variation under limiting conditions.
- Very small differences in initial value can have large differences in the output.

Chaos and Computers

```
Input:    0.25          Input:    0.26
0.73125                 0.75036
0.76644140625           0.73054749456
0.698135010439          0.767706625733
0.82189581879           0.6954993339
0.570894019197          0.825942040734
0.955398748364          0.560670965721
0.166186721954          0.960644232282
0.540417912062          0.147446875935
0.9686289303            0.490254549376
0.118509010176          0.974629602149
```