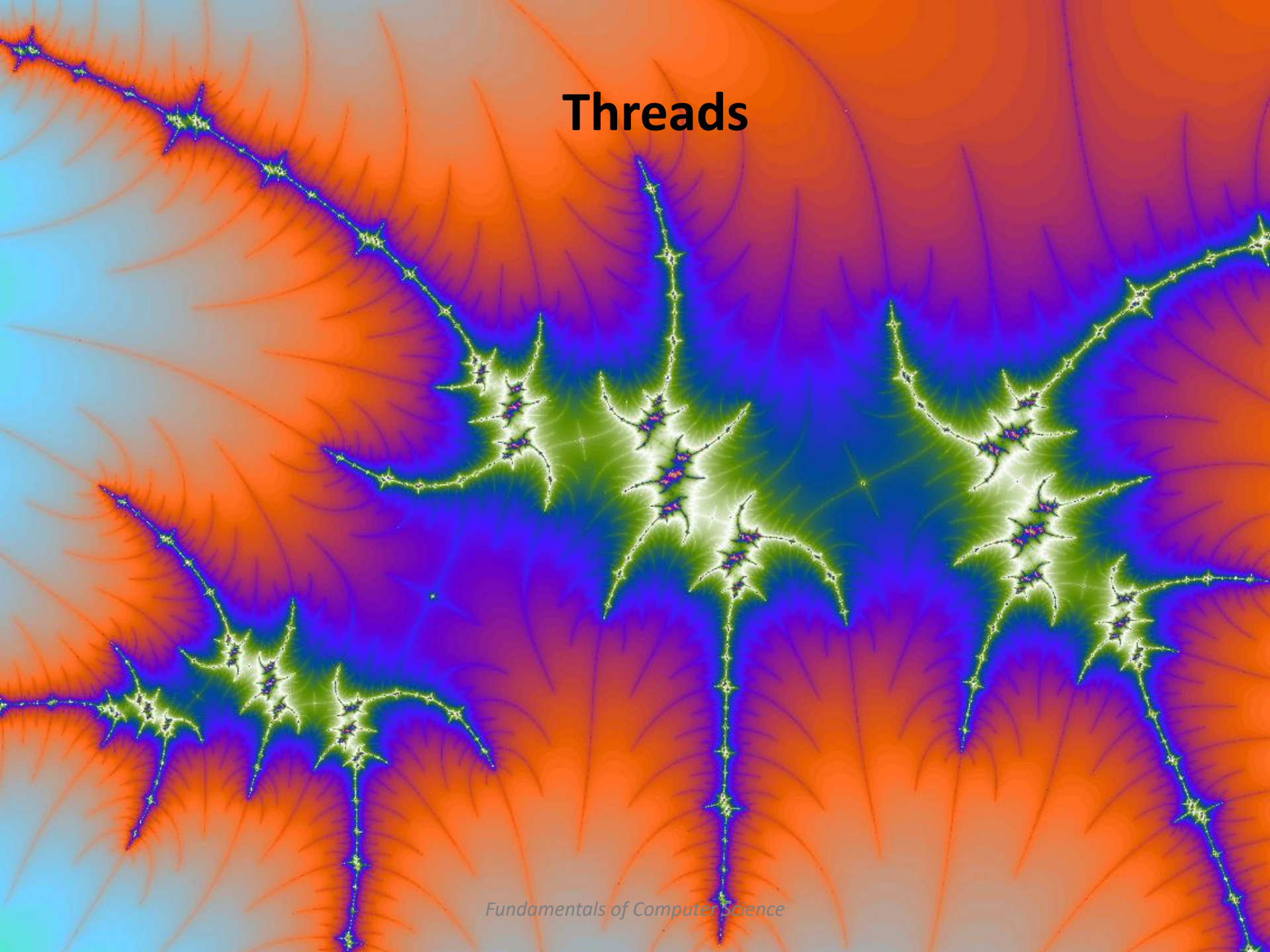
# Threads



# Outline

- Multi-threaded programs
  - Multiple simultaneous paths of execution
    - Seemingly at once (single core)
    - Actually at the same time (multiple cores)
  - Why?
    - Get work done faster (on multi-core machines)
    - Simplify code by splitting up work into parts
    - Remain responsive to user input
  - Threads in Python
    - Creating, starting, sleeping
    - Unpredictability
    - Debugging

THREADS

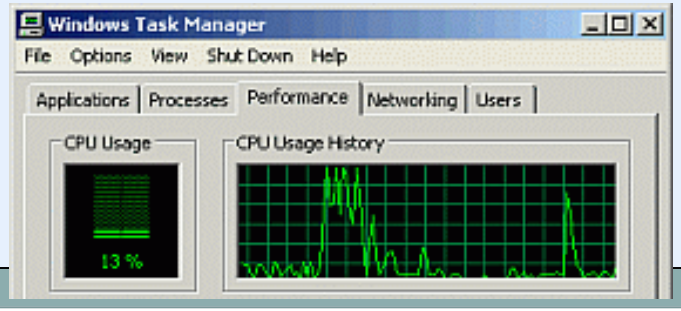
# A Single-Threaded Program: Single Core

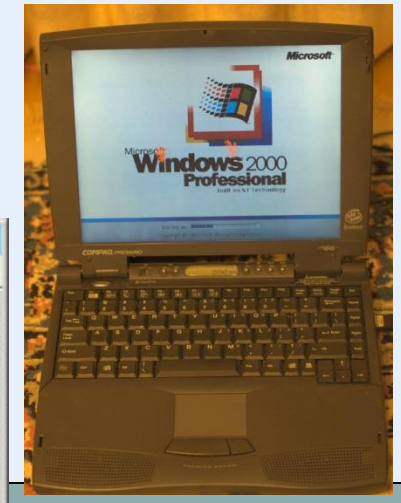
Animal.py

```
class Animal:

    def __init__(self, image="", audio=""):
        self.image = image
        self.audio = audio

    def show(self):
        StdDraw.picture(picture.Picture(self.image), 0.5, 0.5)
        StdAudio.playFile(self.audio)
```

AnimalMap.py

```
map["dog"] = Animal("dog.jpg" , "dog")
map["cat"] = Animal("cat.jpg" , "cat")
map["cow"] = Animal("cow.jpg" , "cow")


while True:
    StdDraw.clear()

    name = input("Enter animal: ")

    animal = map[name]

    if animal != None:
        animal.show()

    StdDraw.show(100)
```




*A single core computer.*

THREADS

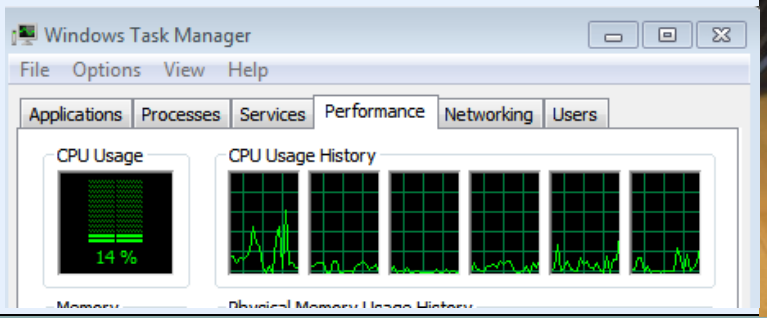
# A Single-Threaded Program: Multi-Core

Animal.py

```
class Animal:

    def __init__(self, image="", audio=""):
        self.image = image
        self.audio = audio

    def show(self):
        StdDraw.picture(picture.Picture(self.image), 0.5, 0.5)
        StdAudio.playFile(self.audio)
```

AnimalMap.py

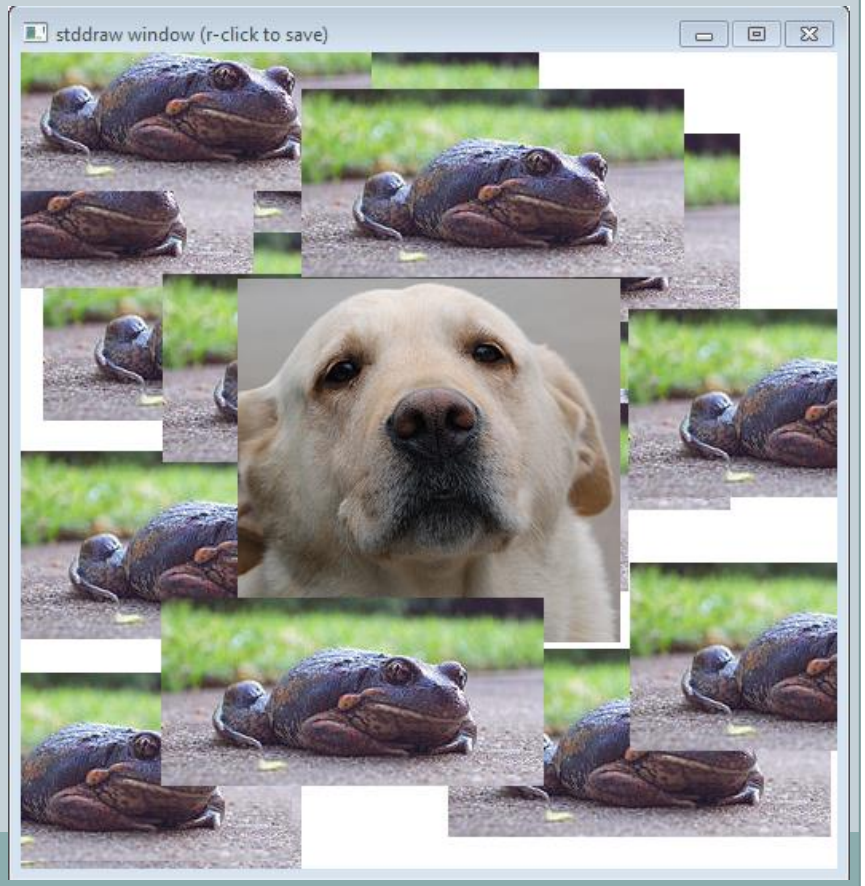
```
map["dog"] = Animal("dog.jpg" , "dog")
map["cat"] = Animal("cat.jpg" , "cat")
map["cow"] = Animal("cow.jpg" , "cow")


while True:
    StdDraw.clear()

    name = input("Enter animal: ")

    animal = map[name]

    if animal != None:
        animal.show()

    StdDraw.show(100)
```




*A multi-core computer.*

# Multi-Threaded Animals

- New “magic” program: AnimalMapDeluxe.py
  - Random frogs!
  - Frogs appear every second
  - User can make requests:
    - "dog", "cat", "cow"
    - Even while frog is appearing



# Creating and Starting a Thread

- Thread
  - A separate path of execution
    - Also: the name of a class in the Python threading library
  - Program creates an object of type `Thread`
- Creating and starting a thread:

```
import threading

var = threading.Thread()
var.start()
```

Simple, but doesn't actually do anything:

- Thread is born
- Thread dies
- End of story

# Making Work for a Thread

- Thread constructor can take parameters
  - Can take the name of a function as its “target”
  - Can take an object and one of its methods as “target”
  - Can also pass in arguments to those functions and methods through “args” parameter

```
def BlastOff ():
    for i in range(10, 0, -1):
        print(i, end=" ")
    print("BLAST OFF!")
```

# Possible Code Execution Order #1

```
                import threading

                def BlastOff ():
9 7 5               for i in range(10, 0, -1):
… 8 6                   print(i, end=" ")
                    print("BLAST OFF!")

                if __name__ == "__main__":
1                   print("prepare for launch")
2                   thread = threading.Thread(target=BlastOff)
3                   thread.start()
4                   print("done with launch")
```

```
% python Launch.py
prepare for launch
done with launch
10 9 8 7 6 5 4 3 2 1 BLAST OFF!
```

# Possible Code Execution Order #2

```
import threading

def BlastOff ():
    for i in range(10, 0, -1):
        print(i, end=" ")
    print("BLAST OFF!")

if __name__ == "__main__":
    print("prepare for launch")
    thread = threading.Thread(target=BlastOff)
    thread.start()
    print("done with launch")
```

9 7 4
… 8 6

1
2
3
5

```
% python Launch.py
prepare for launch
done with launch
10 9 8 7 6 5 4 3 2 1 BLAST OFF!
```

Different execution order: same output

# Possible Code Execution Order #3

```
                import threading

                def BlastOff ():
9 7 4               for i in range(10, 0, -1):
… 8 5                   print(i, end=" ")
                    print("BLAST OFF!")

                if __name__ == "__main__":
1                   print("prepare for launch")
2                   thread = threading.Thread(target=BlastOff)
3                   thread.start()
6                   print("done with launch")
```

```
% python Launch.py
prepare for launch
10 done with launch
9 8 7 6 5 4 3 2 1 BLAST OFF!
```

Different execution order: different output

# Possible Code Execution Order #4

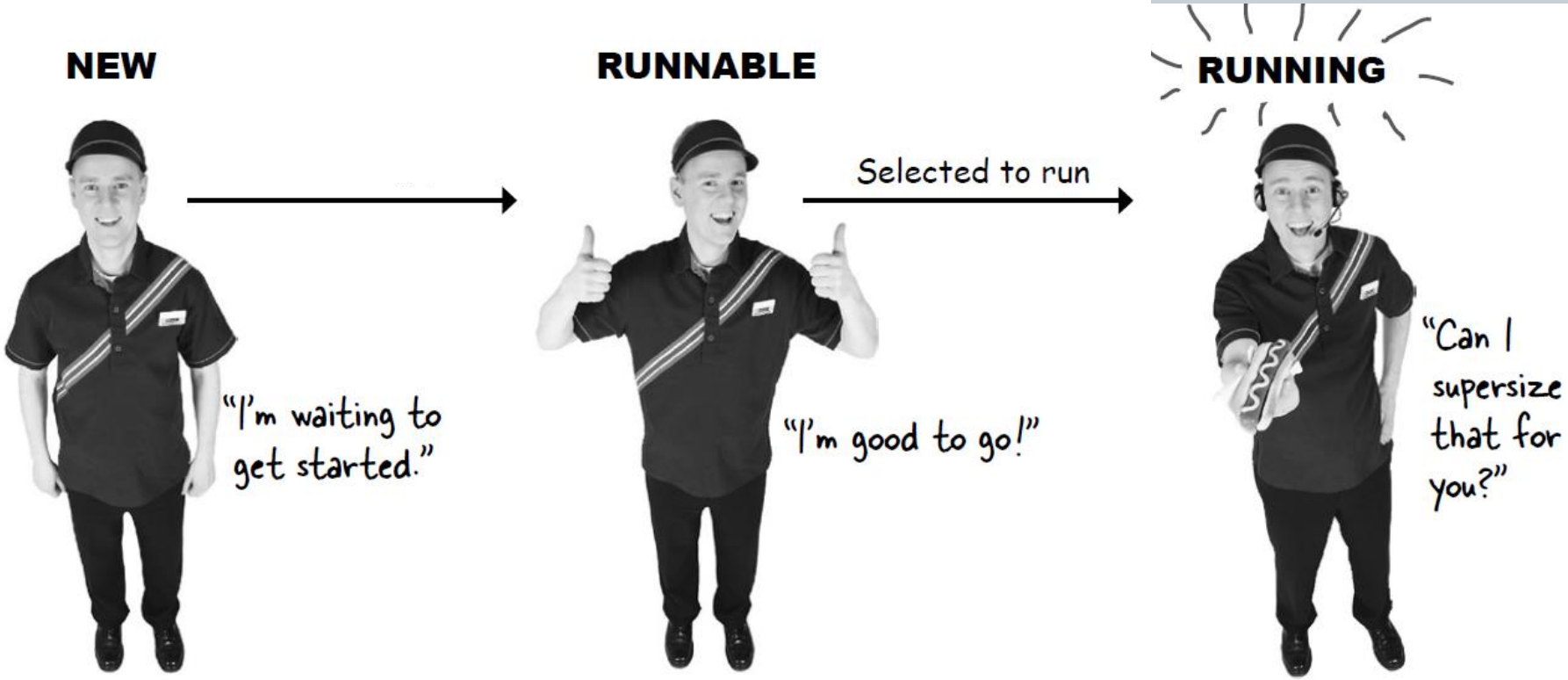
```
                import threading

                def BlastOff ():
9 6 4               for i in range(10, 0, -1):
… 7 5                   print(i, end=" ")
                    print("BLAST OFF!")

                if __name__ == "__main__":
1                   print("prepare for launch")
2                   thread = threading.Thread(target=BlastOff)
3                   thread.start()
8                   print("done with launch")
```

Lots more possible execution orders!

Exact order depends on: ***thread scheduler***

```
% python Launch.py
prepare for launch
10 9 done with launch
8 7 6 5 4 3 2 1 BLAST OFF!
```

# Thread States: Startup



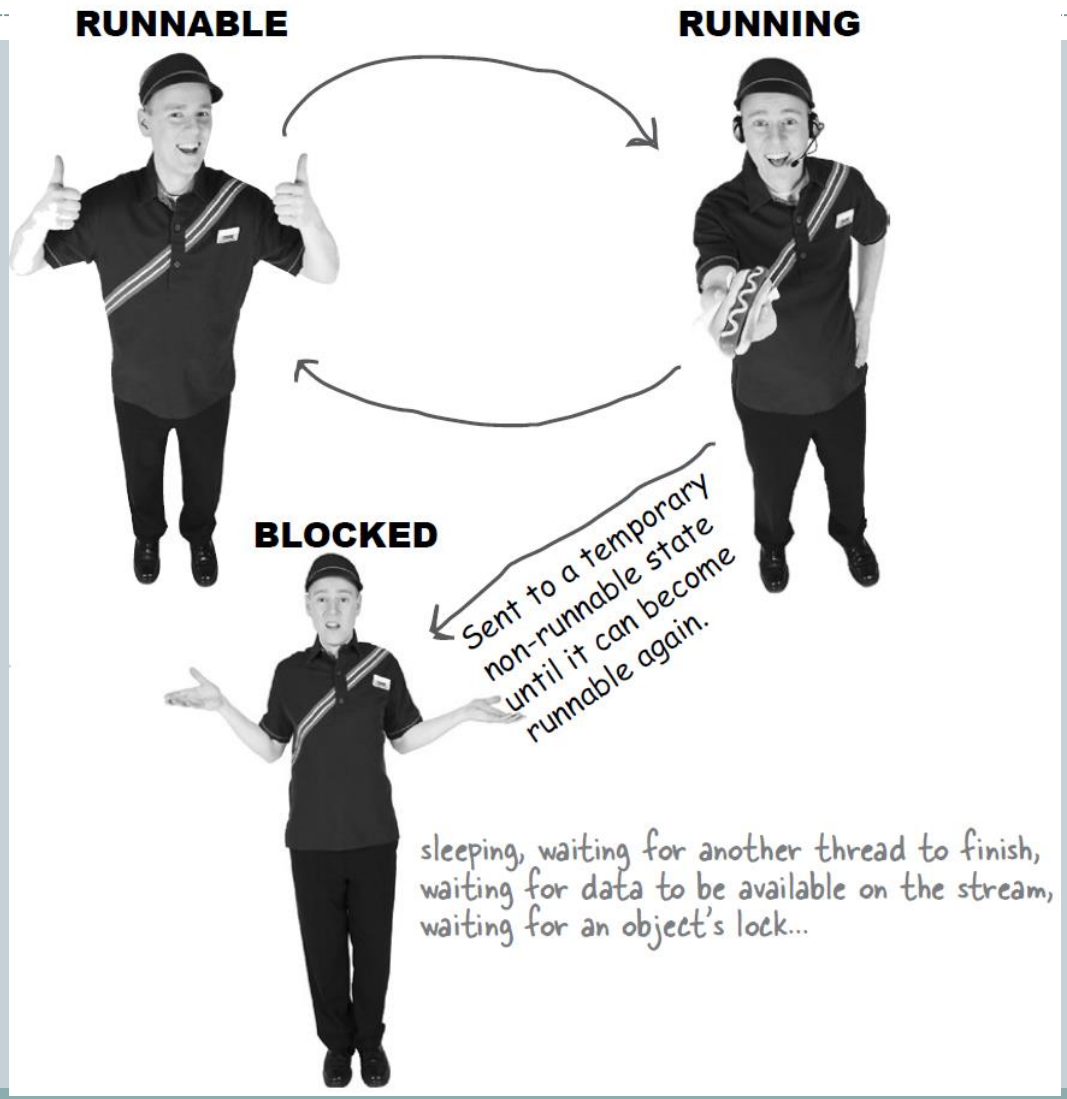

```
t = threading.Thread(target=r)    t.start()
```

Just a normal object on the heap

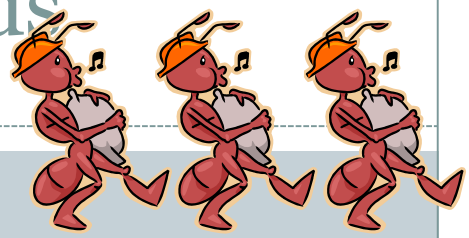
Waiting to be selected by the ***thread scheduler***

Actually running on the CPU

# Thread States



# Launching Multiple Threads

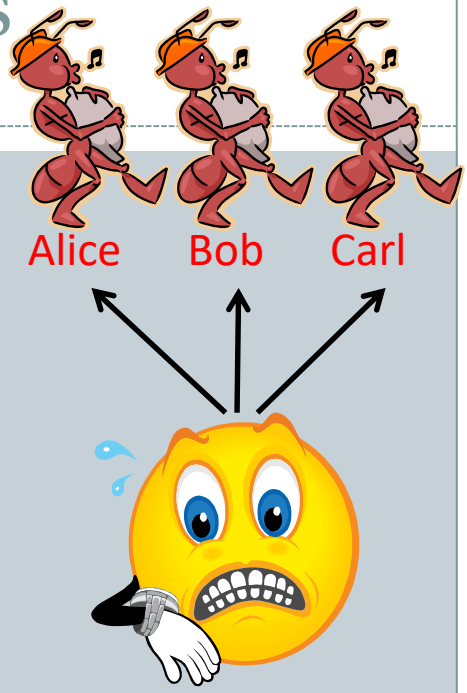


- Main program: launch > 1 threads
  - Split work into multiple parts

```
import threading
import sys

def BlastOff ():
    for i in range(10, 0, -1):
        print(str(i) + " ", end="")
    print("BLAST OFF!")

if __name__ == "__main__":
    N = int(sys.argv[1])

    print("prepare for multi launch")
    threads = []
    for index in range(N):
        x = threading.Thread(
        threads.append(x)
        x.start()
    print("done with launch")
```

```
% python MultiLaunch.py 3
prepare for multi launch
10 10 10 done launching
9 9 9 8 8 7 8 6 7 5 7 4 6 3 6 2 5 1 5 BLAST OFF!
4 4 3 3 2 2 1 BLAST OFF!
1 BLAST OFF!
```

# Important Thread Tricks




- Main thread can wait for workers
  - e.g. Merge results from workers
  - Call `join()` on the thread object

- Passing data to/from a worker
  - `Thread()` constructor is passed a `Runnable` object
  - Add any instance variables / methods you want
    - Input: send as parameters to constructor
    - Output: add some get data method(s)
  - But: you must keep track of object sent to `Thread()`

# Parallel Fibonacci Calculator

```
class FibWorker:

    def __init__(self, num):
        self.num = num
        self.result = 0

    def getResult(self):
        return self.result

    def run(self):
        self.result = self.fib(self.num)

    def fib(self, n):
        if n == 0:
            return 0
        if n == 1:
            return 1
        return self.fib(n-1) + self.fib
```

**Get the input**, what we'll calculate once somebody says go!

Somebody **getting the output**. Should only be called after the thread is known to be done.

Method that we're using when we call `.start()` on a `Thread` that has been passed this object and method.

# Parallel Fibonacci Calculator

```
from FibWorker import FibWorker
import threading
import sys

if __name__ == "__main__":
    threads = []
    workers = []
    for i in range(1, len(sys.argv)):
        workers.append(FibWorker(int(sys.argv[i])))
        threads.append(threading.Thread(target=workers[i-1].run()))
        threads[i-1].start()
    for i in range(1, len(sys.argv)):
        threads[i-1].join()
        print("fib(" + sys.argv[i] + ") = ", end = "")
        print(workers[i-1].getResult())
```

We are keeping track of two parallel arrays, one for threads and one for worker objects.

Setup worker with its job.

Once a thread is done, we know it has a good output value.

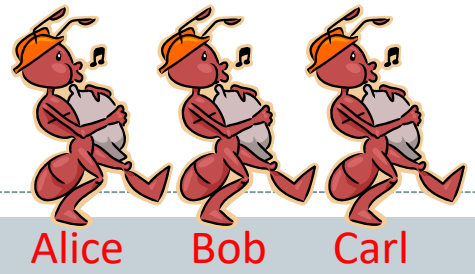
# Sleeping


- Making a thread take a nap
  - Specify nap time in seconds
    - Guaranteed to sleep at least this long
      - Maybe longer though
    - Allows other threads to enter running state
    - Polite behavior when you've got nothing to do
    - `time.sleep(sec)`

```
while not StdDraw.hasNextKeyTyped():
   # Burns an entire core to do nothing!
char ch = StdDraw.nextKeyTyped()
```

```
import time

while not StdDraw.hasNextKeyTyped():
    time.sleep(.001)
char ch = StdDraw.nextKeyTyped()
```

# Naming Threads




- Threads can be given a name
  - Helpful for debugging
  - "name" parameter to `Thread()` constructor

```
if __name__ == "__main__":
    N = int(sys.argv[1])

    print("prepare for multi launch")
    threads = []
    for index in range(N):
        x = threading.Thread(name='B'+str(index), target=BlastOffSleep)
        threads.append(x)
        x.start()
    print("done with launch")
```

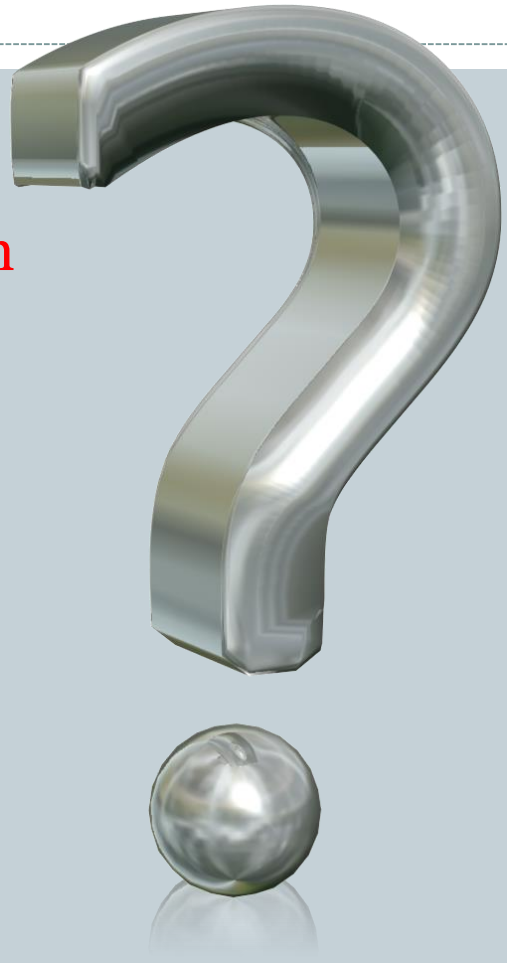
# A Sleepy Named Worker

```
def BlastOffSleep ():
    myName = threading.currentThread().getName()
    for i in range(10, 0, -1):
        print(str(i) + "(" + myName + ")", end="")
        time.sleep(1)
    print("BLAST OFF!")
```

```
% python MultiLaunchSleep.py 3
prepare for multi launch
10(B0) done launching
10(B2) 10(B1) 9(B0) 9(B1) 9(B2) 8(B0) 8(B1) 8(B2) 7(B0) 7(B1) 7(B2)
6(B1) 6(B0) 6(B2) 5(B0) 5(B2) 5(B1) 4(B0) 4(B1) 4(B2) 3(B0) 3(B1)
3(B2) 2(B0) 2(B1) 2(B2) 1(B0) 1(B1) 1(B2) BLAST OFF! (B0)
BLAST OFF! (B1)
BLAST OFF! (B2)
```

# Summary

- Python Thread
  - Multiple simultaneous paths of execution
    - Really simultaneous (multiple cores)
    - Simply seem that way (single core)
- Important thread skills:
  - Implementing a worker class
  - Starting a thread
  - Making a thread sleep
  - Waiting for a thread to finish
  - Getting input to a thread
  - Getting output from a thread



# Your Turn

- Create a function that:
  - Draws something using `StdDraw` in unit box
  - Sleeps at least 500ms
  - Changes something about the drawing
  - Repeats forever
  - Don't worry about erasing
    - Don't call `StdDraw.clear()`
  - I'll integrate into my `ThreadZoo` program and run this next lecture class

- Open Moodle, go to CSCI 136, Section 11
- Open the dropbox for today – Activity 4 - Threads
- Drag and drop your program file to the Moodle dropbox
- You get: 1 point if you turn in something, 2 points if you turn in something that is correct.