[320] Welcome + First Lecture [reproducibility]

Tyler Caraza-Harter

Welcome to the first ever offering of Data Programming II!

Builds on CS ~~301~~ 220. https://stat.wisc.edu/undergraduate-data-science-studies/

CS 220	CS 320
getting results	getting **reproducible** results
writing correct code	writing **efficient** code
using objects	designing **new types** of objects
functions: `f(obj)`	**methods**: `obj.f()`
lists+dicts	graphs+trees
analyzing datasets	**collecting**+analyzing datasets
plots	animated visualizations
tabular analysis	**simple machine learning**

CS 301 content (for review): https://tyler.caraza-harter.com/cs301/fall19/schedule.html

Who am I?

Tyler Caraza-Harter

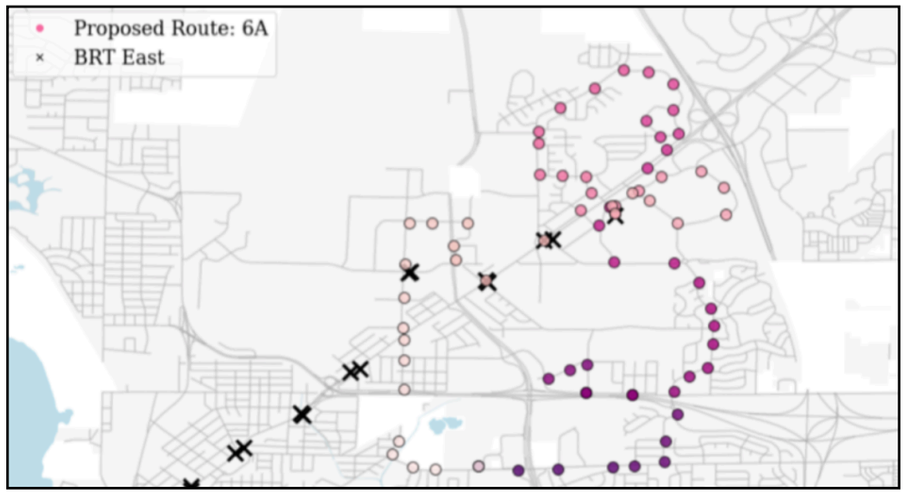
- Long time Badger
- Email: tharter@wisc.edu
- Just call me "Tyler"

Industry experience

- Worked at Microsoft on SQL Server and Cloud
- Other internships/collaborations:
  Qualcomm, Google, Facebook, Tintri

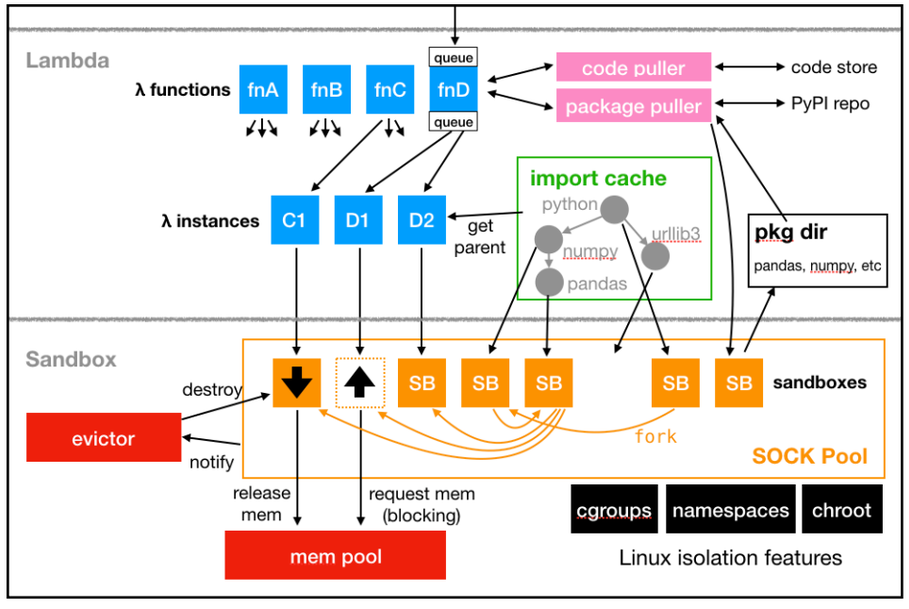
interests

civic "hacking"



Plot by Megan Tabbutt (previous student)

OpenLambda



More: https://wisc-ds-projects.github.io/f19/

Who are You?

Year in school?

- 1st year? 2nd? Junior/senior? Grad student?

Area of study

- Natural science, social science, engineering, statistics, data science, other?

What CS courses have people taken before?

- CS 301 (the import one here)? CS 200? CS 300? CS 354?

Please fill this form: https://forms.gle/kZYhHfhbEhDsRVW88. Why?

- To be helpful
- I'm more likely to round up grades of those who participate
- Help design the exam

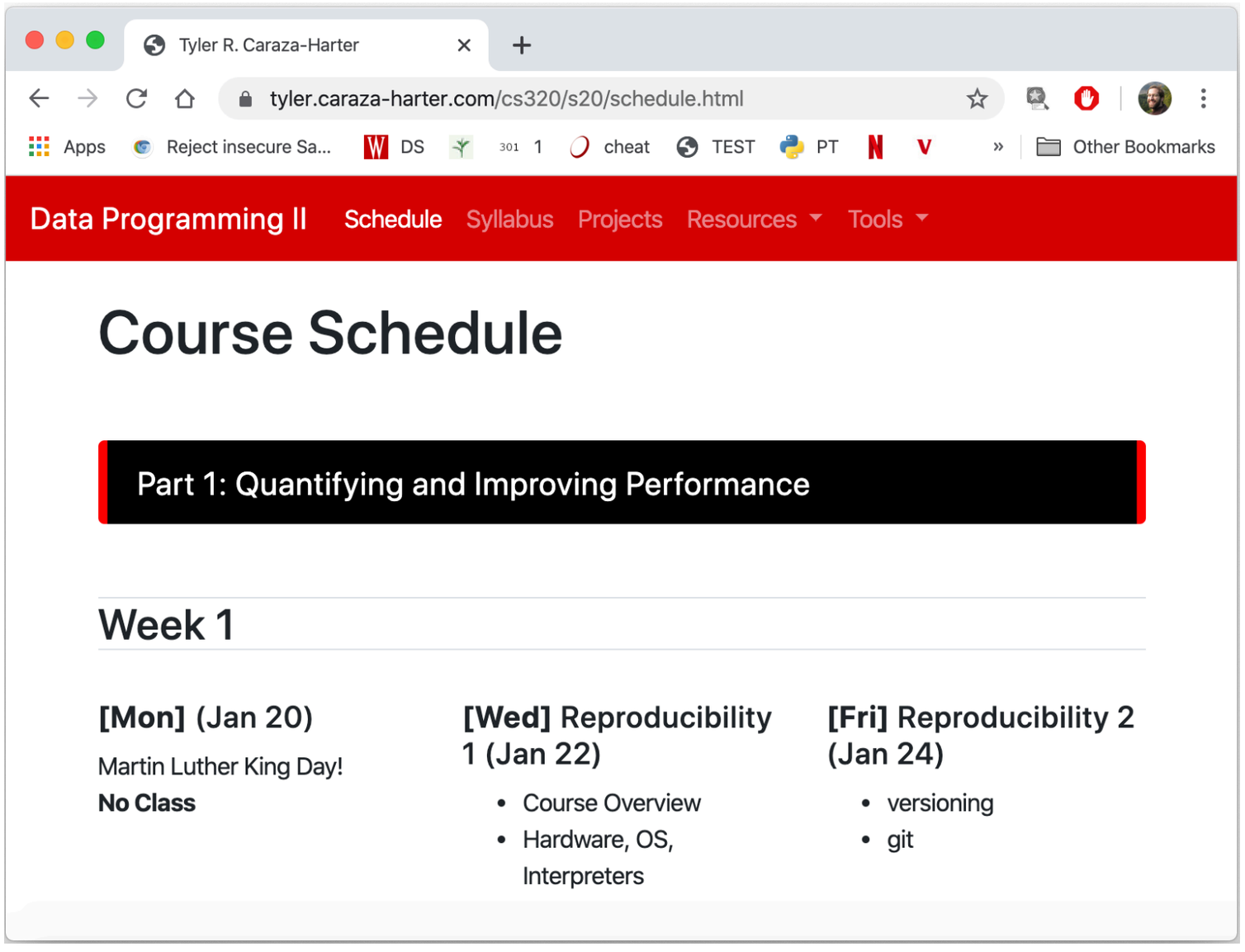
How many questions would you like to be on each exam? *

Your answer

Course Logistics

Course Website

It's here: https://tyler.caraza-harter.com/cs301/fall19/schedule.html



read syllabus carefully and checkout other content

I'll use Canvas for two things only:

- simple grade summaries (not feedback or exam answers)
- general announcements

Other Communication

Piazza

- find link on site
- don't post >5 lines of project-related code (considered cheating)
- pinned post will list office hours (me and our 3 TAs)

no Shelf, sadly, because it's CS 320's first offering
(hopefully some of you will become Shelf mentors)

Forms

- https://tyler.caraza-harter.com/cs320/s20/surveys.html
- Who are you? Feedback Form. Exam Conflicts. Thank you!

extra important for a first-time class offering!

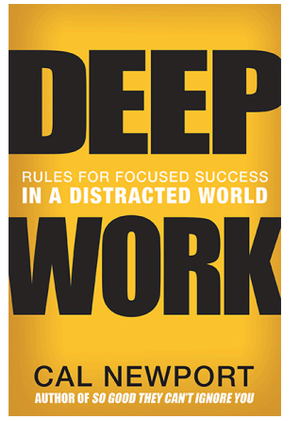
Email

- me: tharter@wisc.edu
- TAs: https://tyler.caraza-harter.com/cs320/s20/contact.html

Course Etiquette

Meetings

1. office hours are walk-in (no need to reserve). I'll help multiple students at once, so don't wait outside
2. email me to schedule individual meetings
3. above options are preferred over drop-ins at other times



Email

4. let us know your NetID (if not from netid@wisc.edu)
5. CC your project partner (when project related)
6. Don't start new email thread if topic is the same
7. Unless urgent, please give me 48 hours to respond before following up (I'll try to be faster usually)
8. Use your judgement about whether to email me or TA first

Graded Work

6 Projects - 10% each

- **format**: notebook, module, or program
- with one partner or alone
- still a `test.py`, but more depends on TA evaluation (more plots)
- ask for specific feedback
  (giving constructive criticism is a priority in CS 320)

2 Exams - 20% each

- multiple choice (how many questions? you decide!)
- one notesheet allowed (printed or handwritten)
- midterm tentatively scheduled for March 11 (evening)

all points get added up and a curve set at the end
(see syllabus for "worst case" scenario)

Academic Misconduct

In Fall 2019, I made the following misconduct reports:

- 23 students for cheating on projects
- 2 past students for sharing solutions from past semesters
- 7 students for cheating on exams

How we'll keep the class fair

- run MOSS on submissions
- randomize exam question order

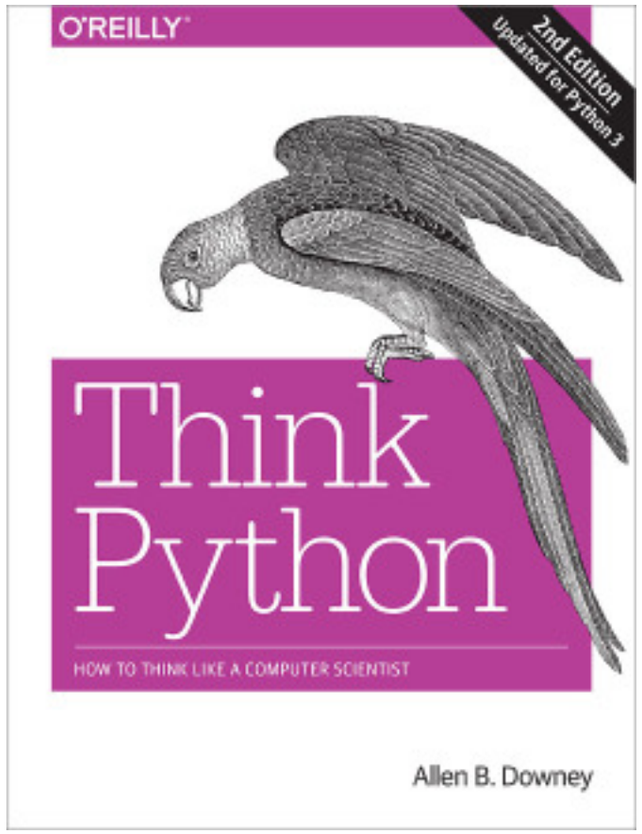
Please talk to me if you're feeling overwhelmed with 320 or your semester in general!

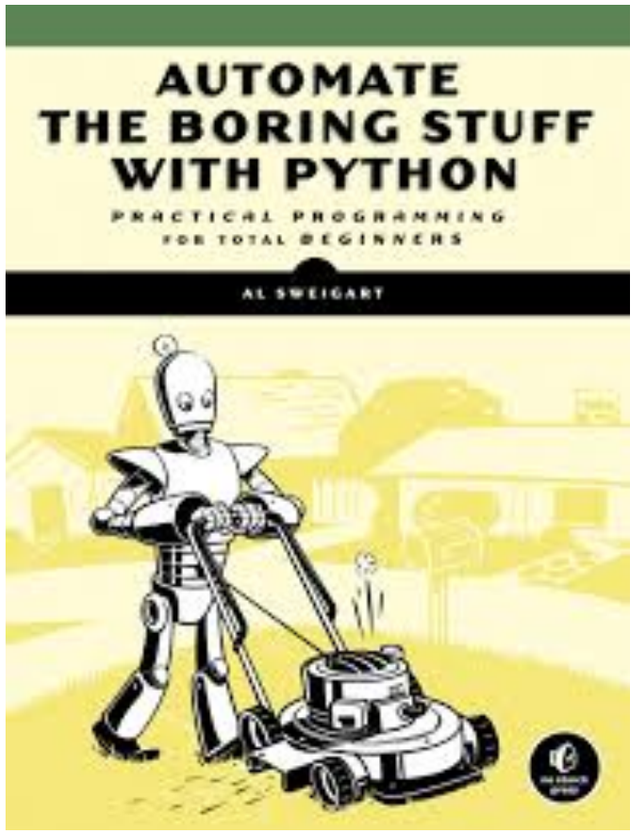
read syllabus to make sure you know what is and isn't OK.
(it might be less obvious than you think)

is it OK?

- **using a general function found on StackOverflow (with citation)**
- **sitting next to your friend during an exam**

Reading: same as 301 and some others...





I'll post links to other online articles and my own notes

Lectures don't assume any reading prior to class

Lecture+Lab

THREE **lectures per week (50 minutes)**

- feel free to bring your laptop
- **rule**: don't do anything more interesting than my lecture

ONE **lab per week (75 minutes)**

- complete lab document (at home prior), or there in person
- bring your laptop (or use lab machines as backup)
- one TA (not your email TA) will be there to answer questions
- **rule:** don't ask for project help until you've done the labs

About Lecture on Friday, Jan 25th...

Data Science Research Bazaar

- 1:30-3pm session on
  Data Science in the City of Madison
- Feel free to attend it in **Research Link** room of **WID** (Discovery Building)
- Let me know if you want to attend other sessions (need special permission from organizers)

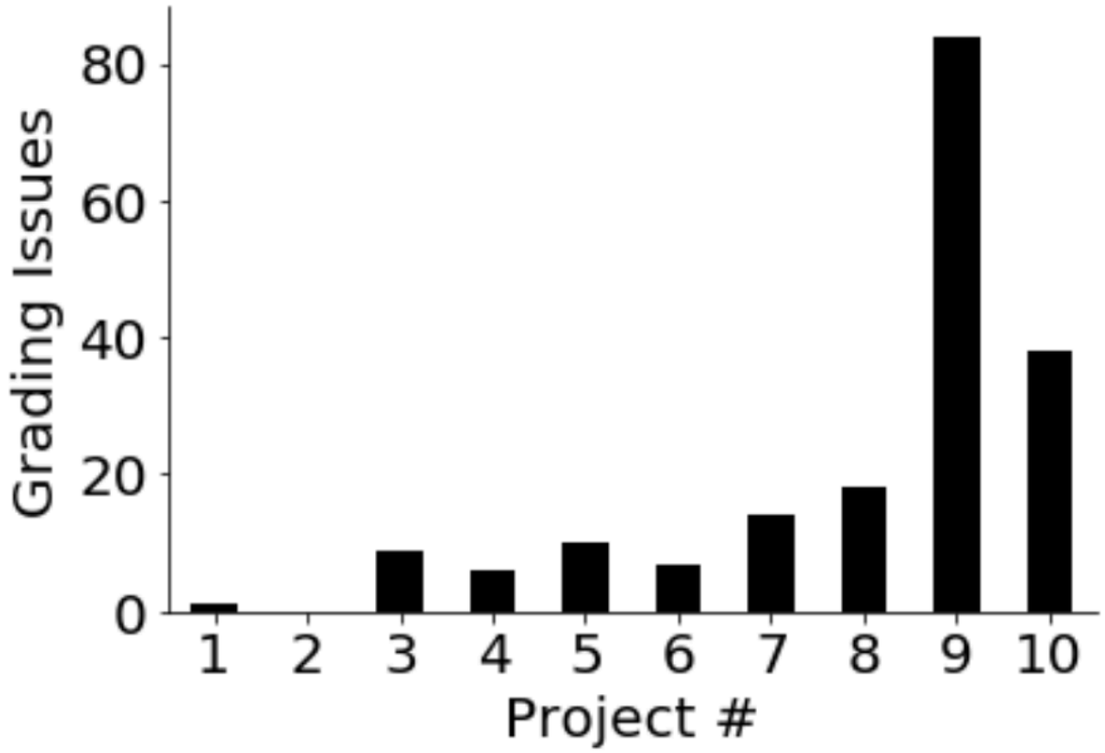
Note: overlaps with afternoon lecture.

Will record morning lecture for afternoon section to watch from home

Today's Lecture:

Reproducibility

Reproducibility (Fall 19 Grading for CS 301)



why was project 9 so problematic?

Reproducibility

All News Images Books Videos More Settings Tools

About 44,700,000 results (0.64 seconds)

Dictionary

Search for a word

re·pro·duc·i·bil·i·ty

/ˌrēprəˌd(y)o͞osəˈbilədē/

noun

noun: **reproducibility**

the ability to be reproduced or copied.
"the reproducibility of reconstructive surgery techniques"

- the extent to which consistent results are obtained when an experiment is repeated.
  "the experiments were conducted numerous times to test the reproducibility of the results"

Discuss: *how might we define "reproducibility" for a data scientist?*

15 new terms to learn today...

reproducibility: others can run our analysis code and get same results

process:

byte:

process memory:

address:

encoding:

CPU:

instruction set:

operating system:

resource:

allocation:

abstraction:

virtual machine:

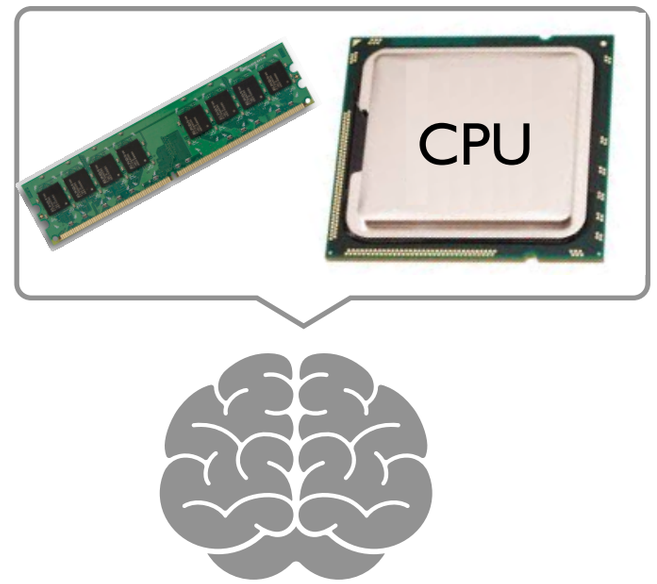
cloud:

ssh:

how many terms do you know already?

Big question: *will my program run on someone else's computer?*
(not necessarily written in Python)

Things to match:

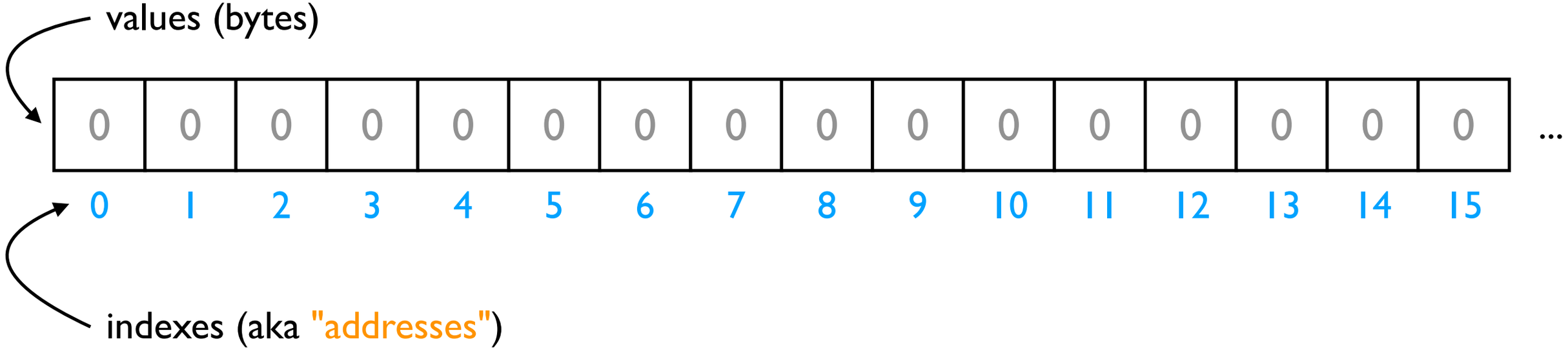


1. Hardware
2. Operating System
3. Dependencies ← next lecture

Hardware: Mental Model of Process Memory

Imagine...

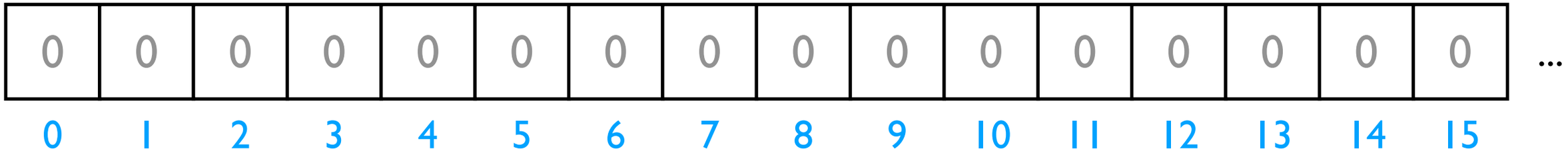
- one huge list, **per each** ~~running program~~ process
- every entry in the list is an integer between 0 and 255 (aka a "byte")



How can we use one giant list to handle the following?

- multiple lists
- variables and other references
- strings
- code

data



Is this really all we have for state?

How can we use one giant list to handle the following?

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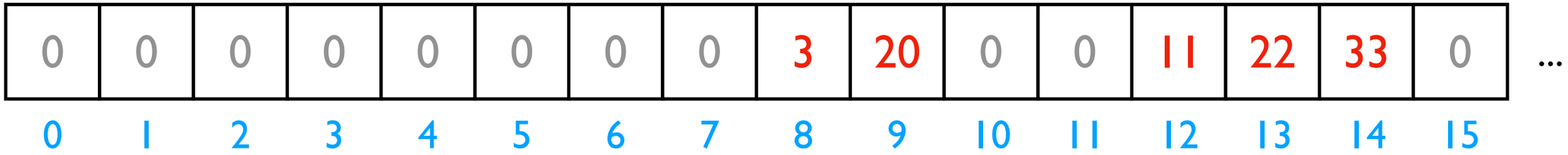

the [3,20] list starts at ~~index~~ address 8 in the giant list

the [11,22,33] list starts at address 12 in the giant list

How can we use one giant list to handle the following?

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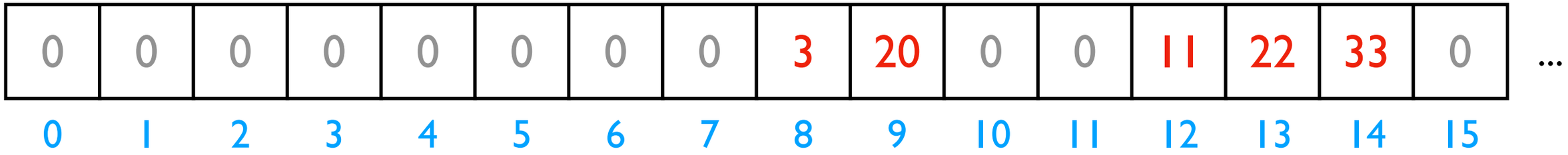
- code



implications for performance...

```
# fast
L2.append(44)
```

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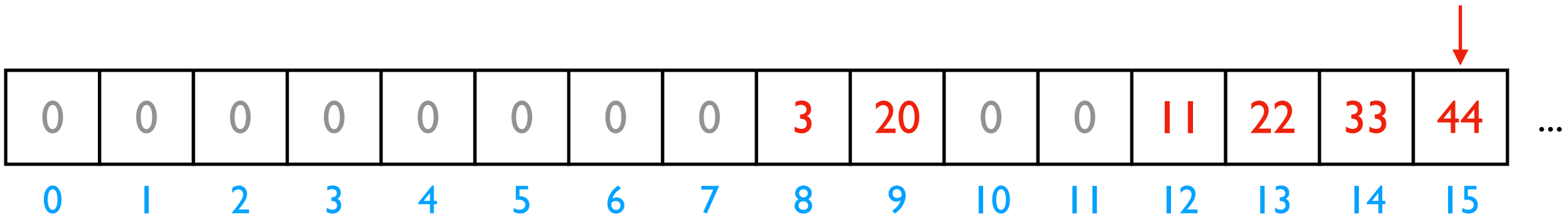

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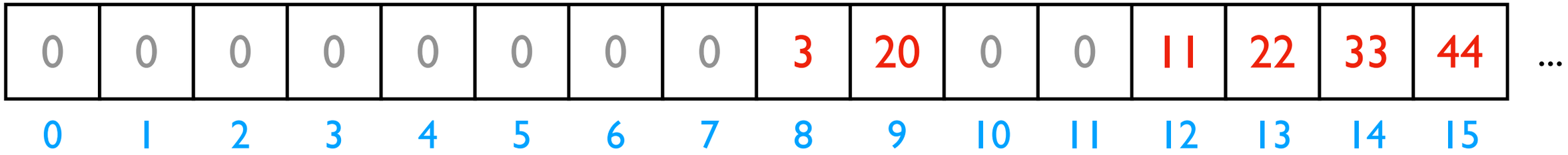

implications for performance...

```
# fast
L2.append(44)

# slow
L2.pop(0)
```

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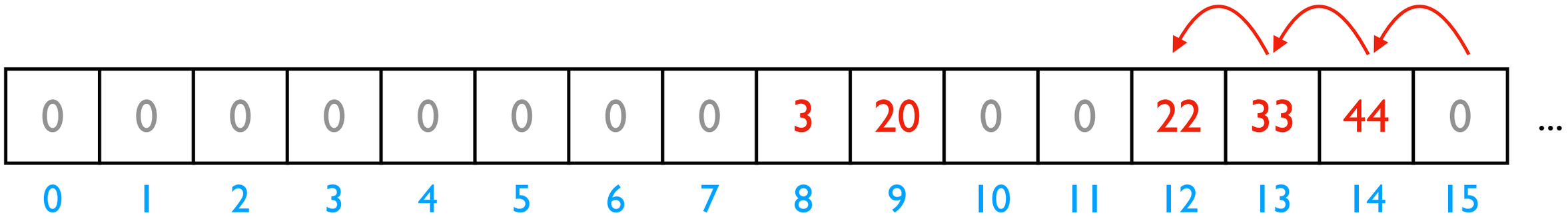

We'll think more rigorously about performance in CS 320 (big-O notation)

```
# fast
L2.append(44)

# slow
L2.pop(0)
```

How can we use one giant list to handle the following?

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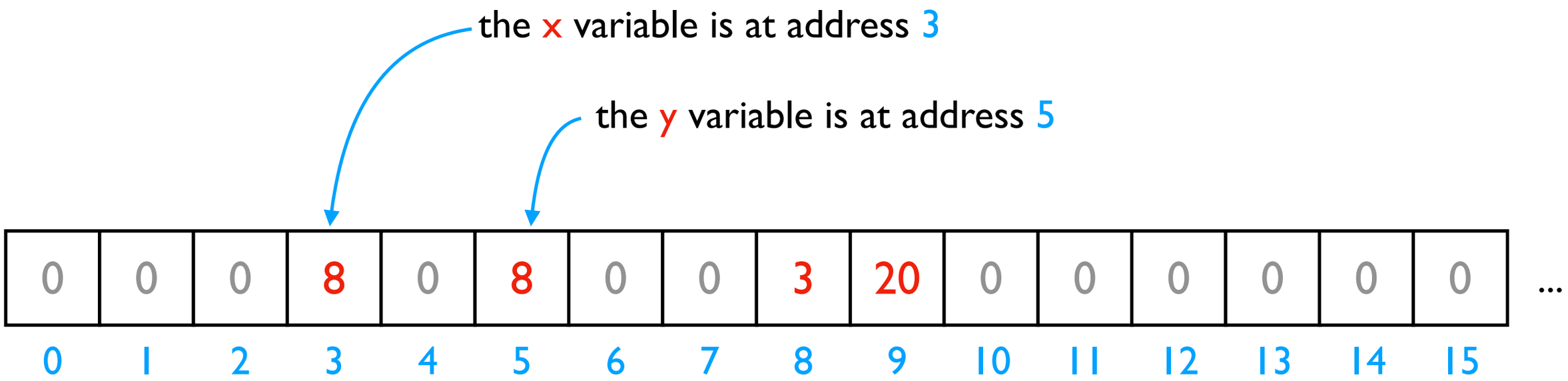

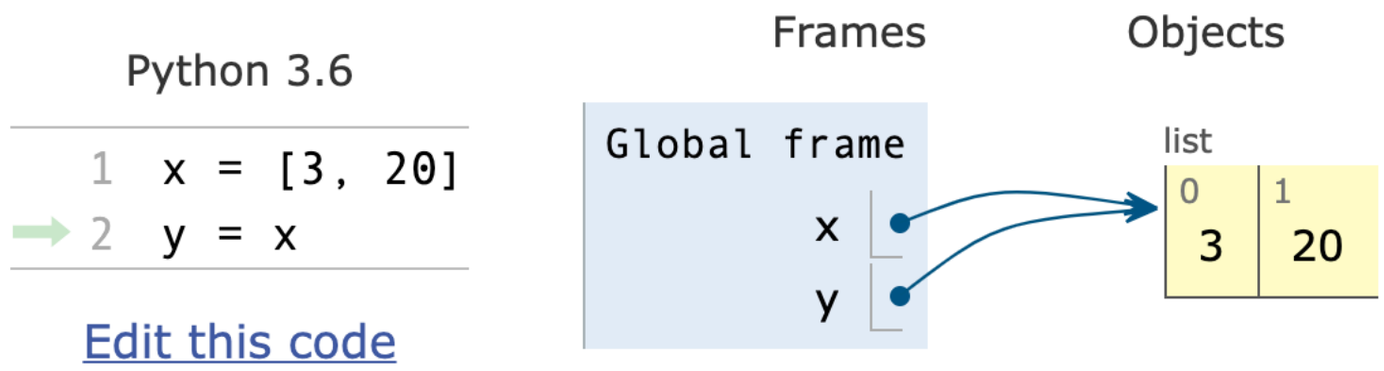

PythonTutor's visualization

How can we use one giant list to handle the following?

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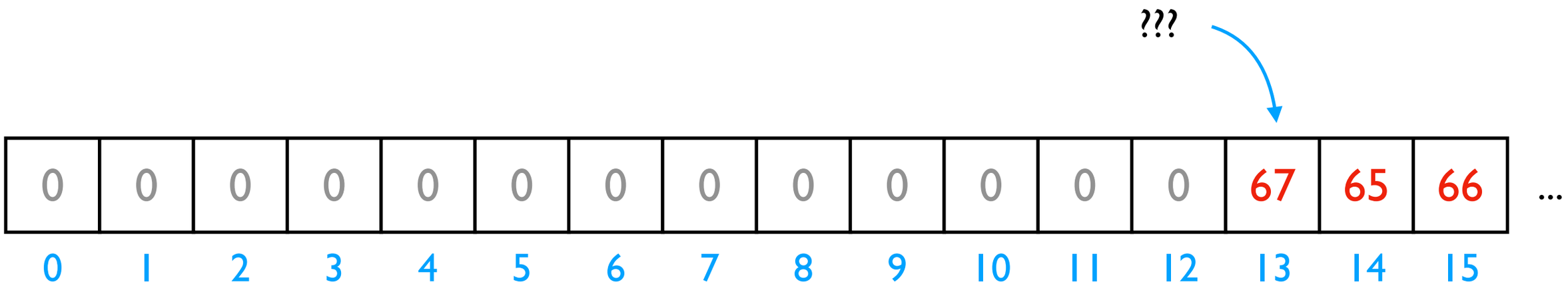
- code



encoding:

code	letter
65	A
66	B
67	C
68	D
...	...

```
f = open("file.txt", encoding="utf-8")
```

How can we use one giant list to handle the following?

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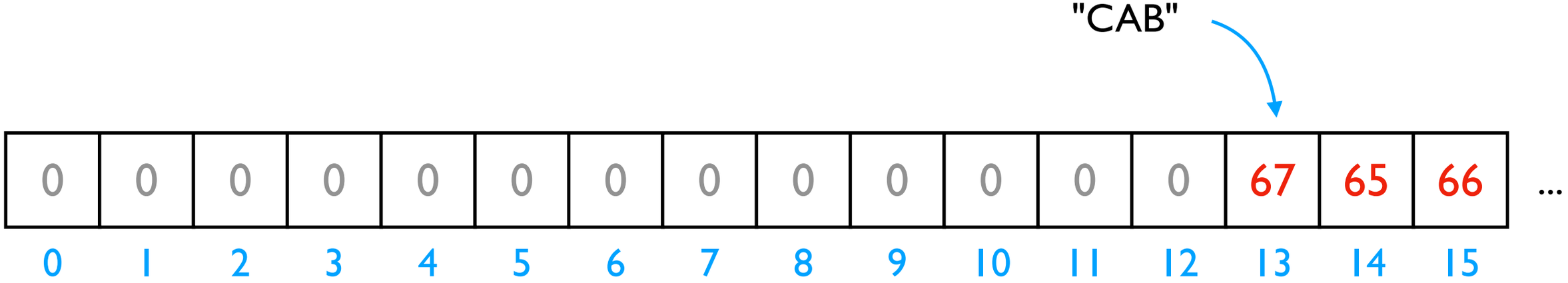
"CAB"



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f = open("file.txt", encoding="utf-8")
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How can we use one giant list to handle the following?

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```
while ????:
    i += 2
     # what line next?
```

operator — operand

0	0	0	0	0	0	0	0	...	...	5	2	33	8	0	0	...
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	

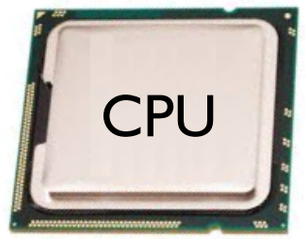
Instruction Set

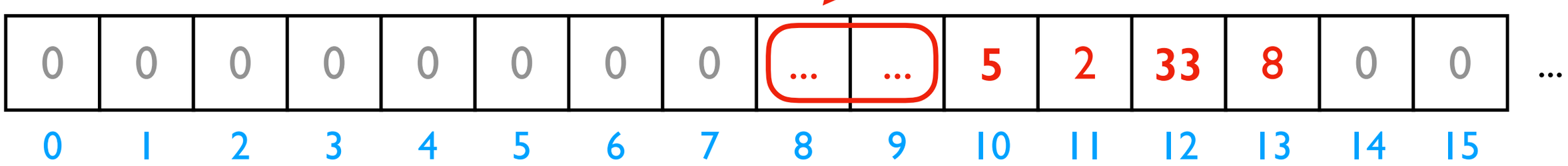
code	operation
5	ADD
8	SUB
33	JUMP
...	...

Hardware: Mental Model of CPU

CPUs interact with memory:

- keep track of what instruction we're on
- understand instruction codes
- much more





Write code in Python 3.6

(drag lower right corner to resize code editor)

```
1
2
3
```

line that just executed

next line to execute

Instruction Set

code	operation
5	ADD
8	SUB
33	JUMP
...	...

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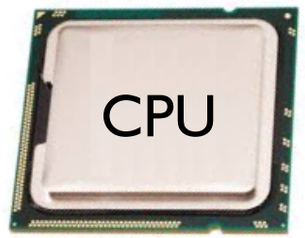
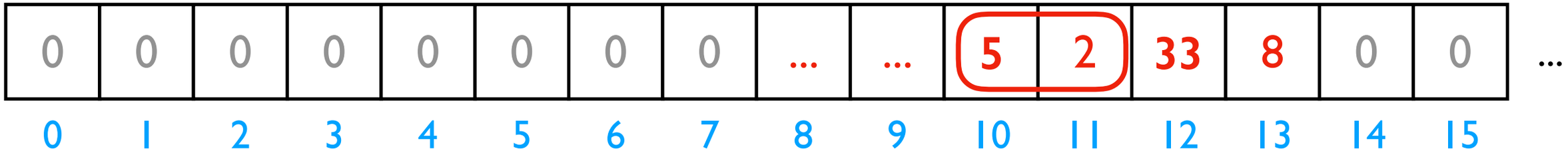


add 2 to variable



Instruction Set

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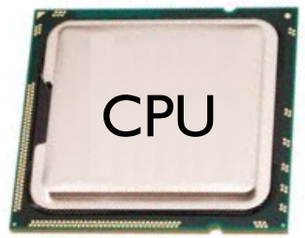
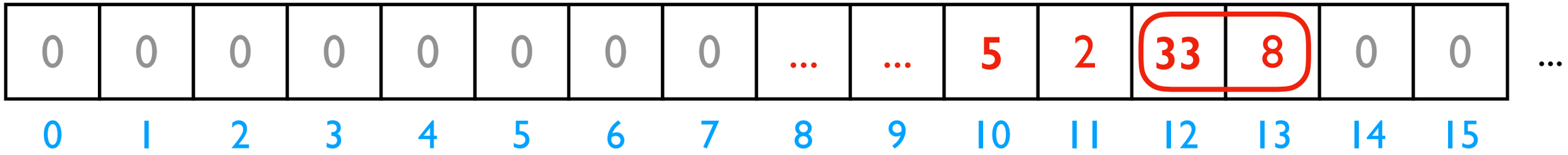


go back to top of loop



Instruction Set

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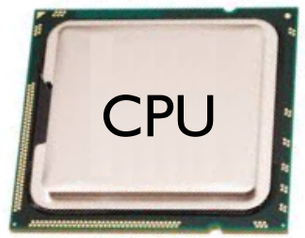
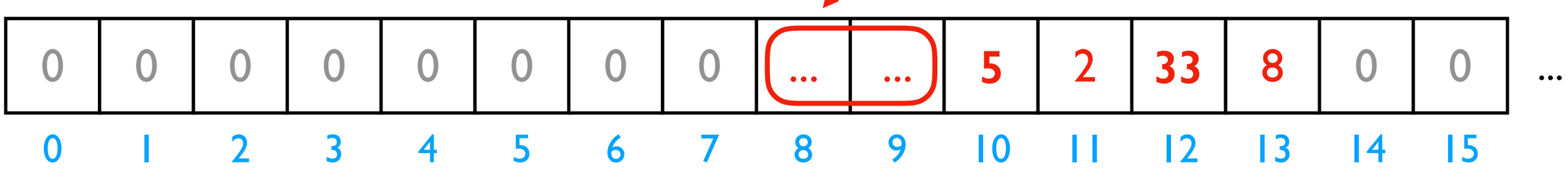


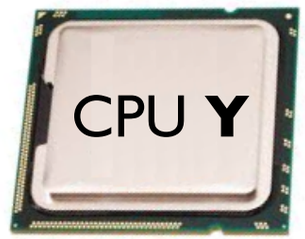


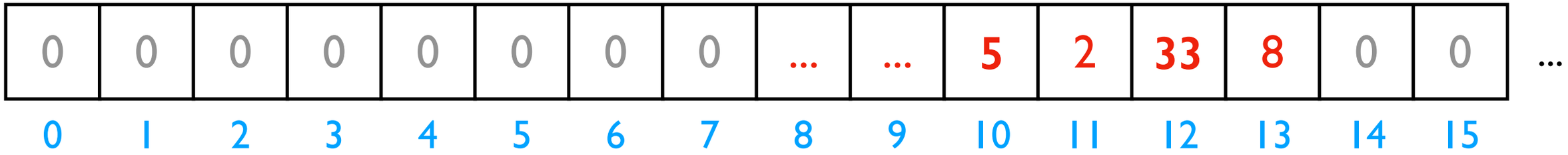
Instruction Set

code	operation
5	ADD
8	SUB
33	JUMP
...	...

Hardware: Mental Model of CPU

a CPU can only run programs that use instructions it understands!





Instruction Set for CPU X

code	operation
5	ADD
8	SUB
33	JUMP
...	...

Instruction Set for CPU Y

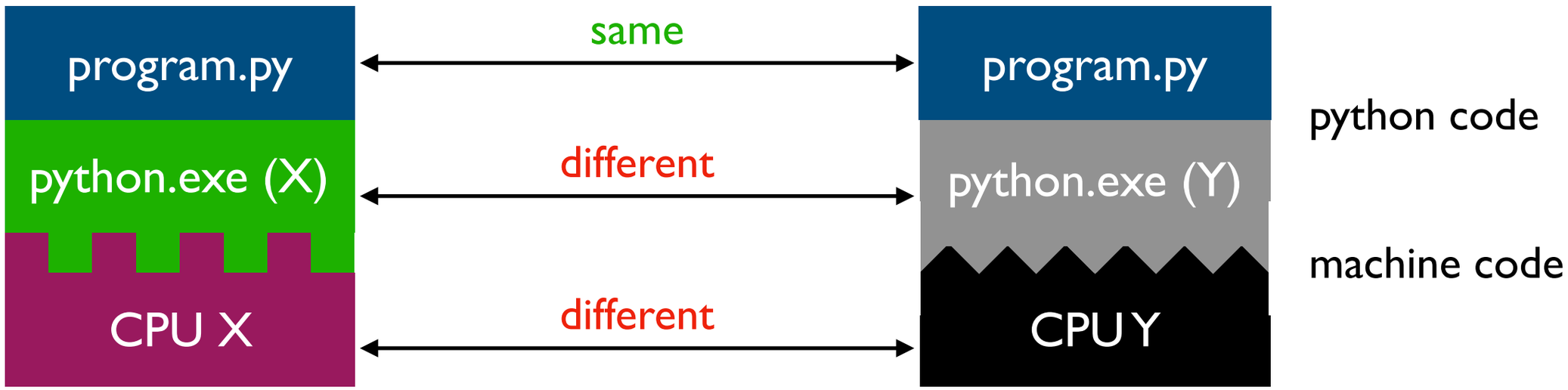
code	operation
5	SUB
8	ADD
33	undefined
...	...

A Program and CPU need to "fit"

A Program and CPU need to "fit"

why haven't we noticed this yet
for our Python programs?

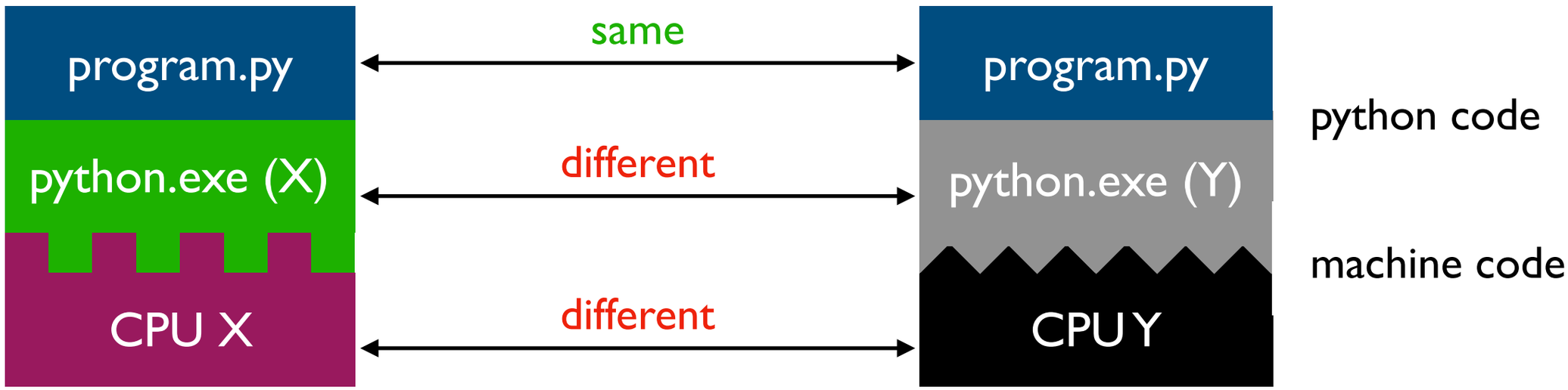
Interpreters



Interpreters (such as python.exe) make it easier to run the same code on different machines

A compiler is another tool for running the same code on different CPUs

Interpreters



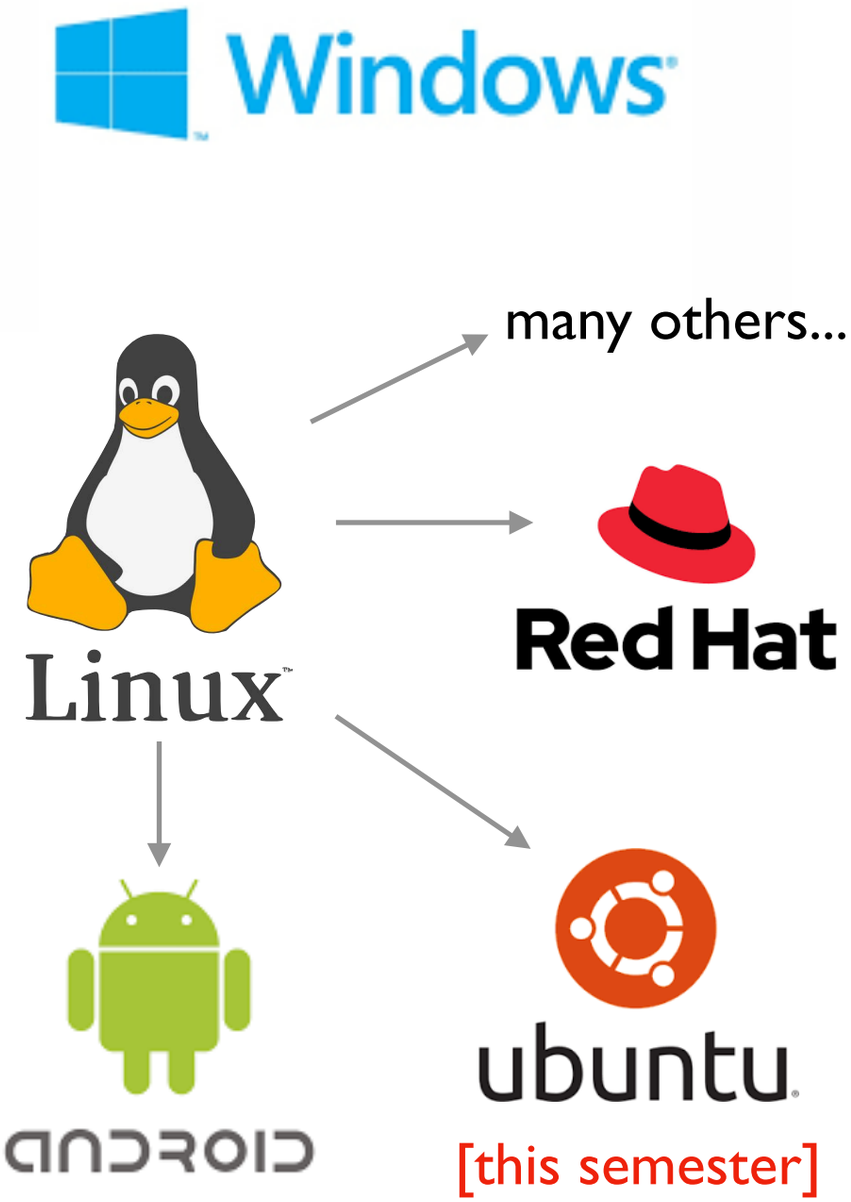
Interpreters (such as python.exe) make it easier to run the same code on different machines

Discuss: *if all CPUs had the instruction set, would we still need a Python interpreter?*

Big question: *will my program run on someone else's computer?*
(not necessarily written in Python)

Things to match:

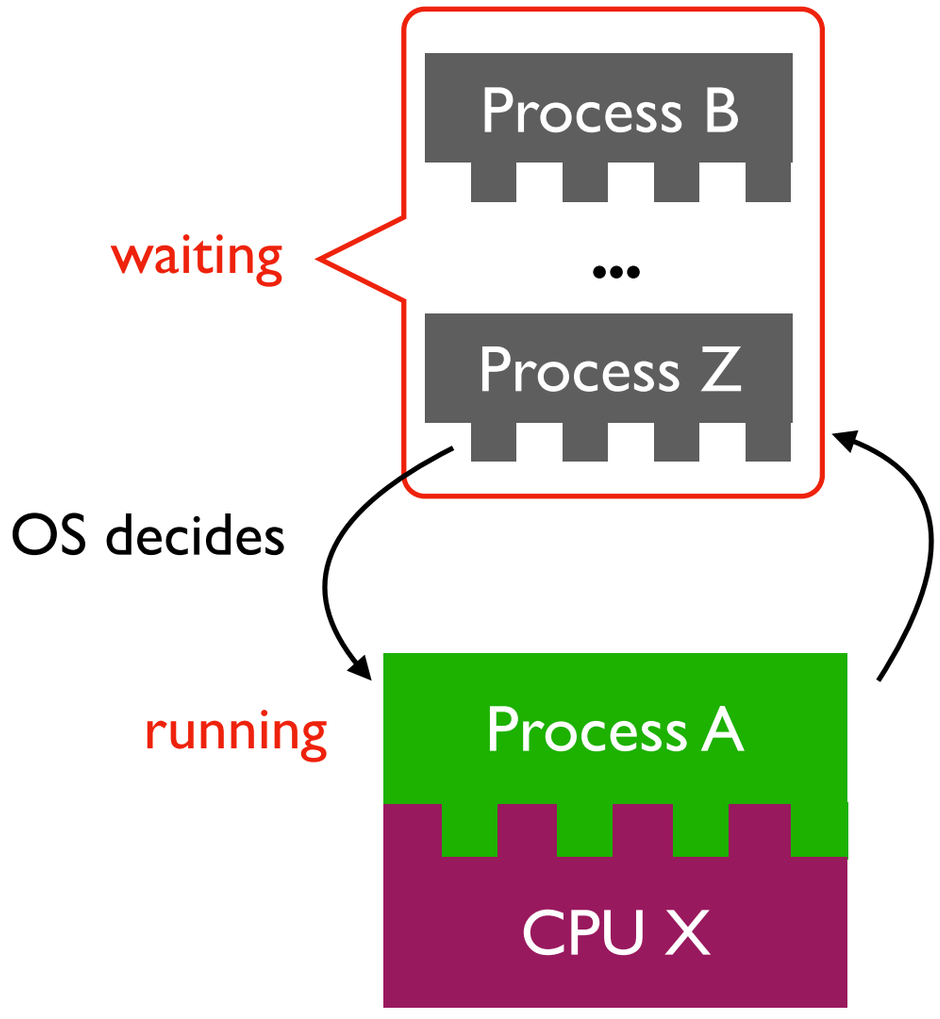
1. Hardware
2. Operating System
3. Dependencies ← next lecture



OS jobs: Allocate and Abstract Resources

[like CPU, hard drive, etc]

1 Allocation



only one process can run on CPU at a time

2 Abstraction

```
f = open("file.txt")
data = f.read()
f.close()
```

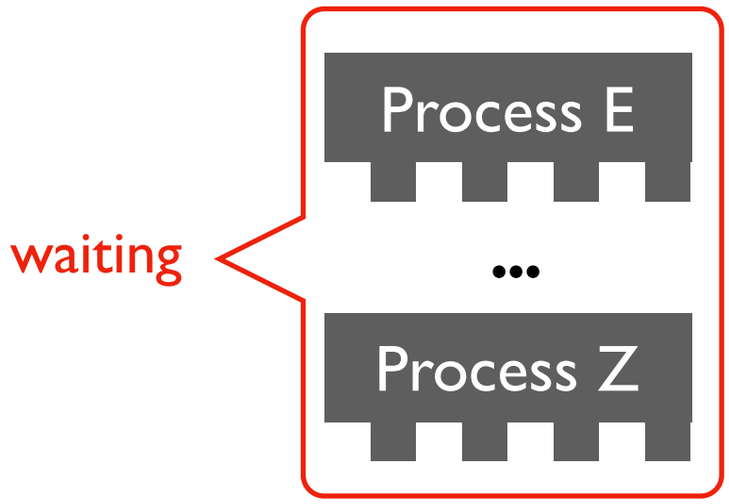
convenient

Operating System

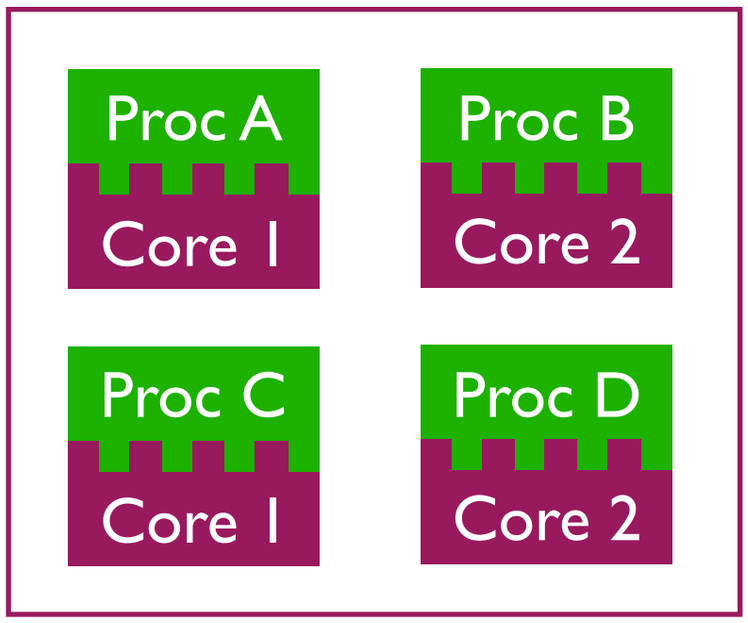
inconvenient

ignorant of files/directories

Parallelism -- more later this semester...



running processes



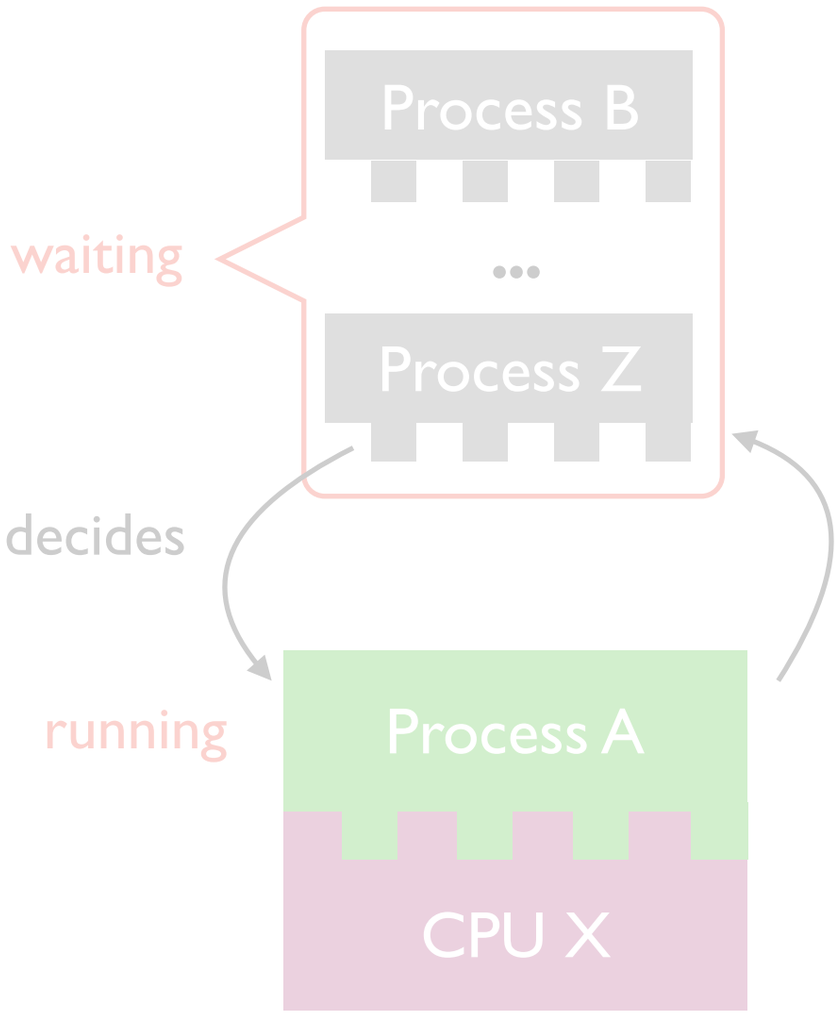
most modern CPUs actually contain multiples CPUs (called "cores") on a single chip

Later: *how can we write programs that run in parallel, going faster by using multiple cores?*

OS jobs: Allocate and Abstract Resources

[like CPU, hard drive, etc]

1 Allocation



only one process can run on CPU at a time

2 Abstraction

```
f = open("file.txt")
data = f.read()
f.close()
```

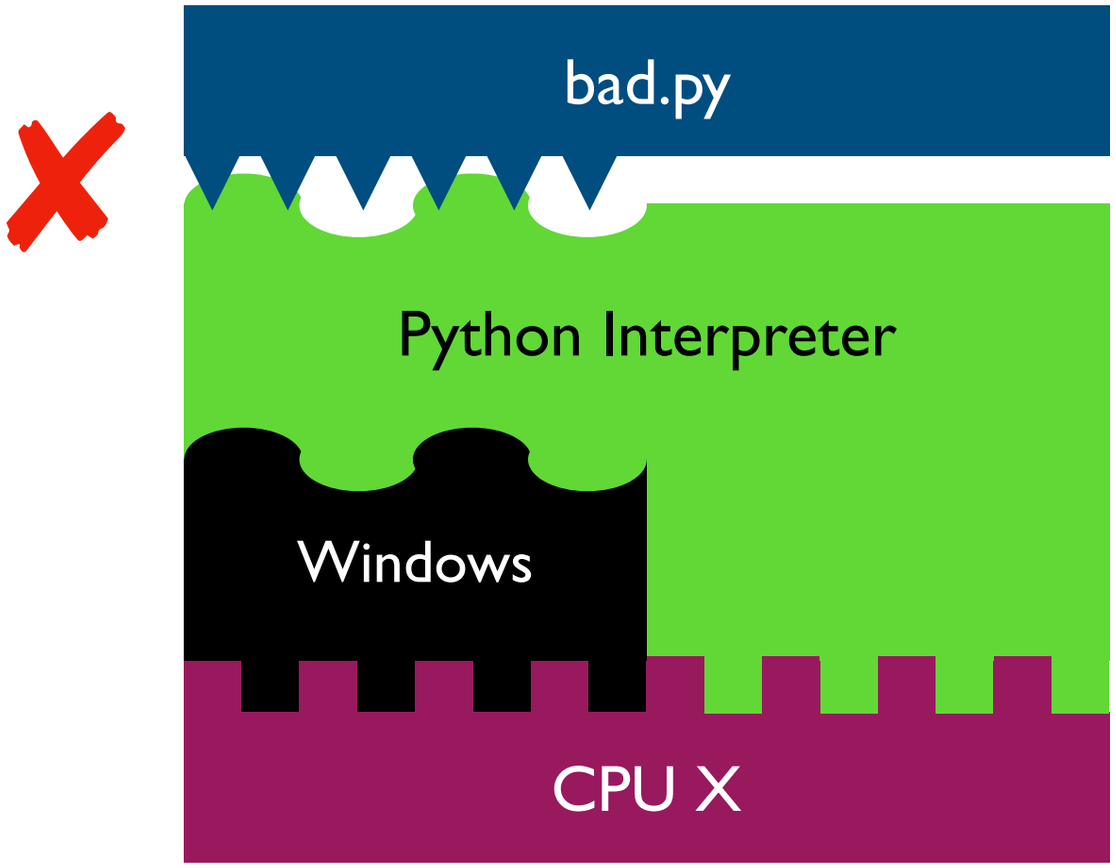
convenient

Operating System

inconvenient

ignorant of files/directories

Harder to reproduce on different OS...

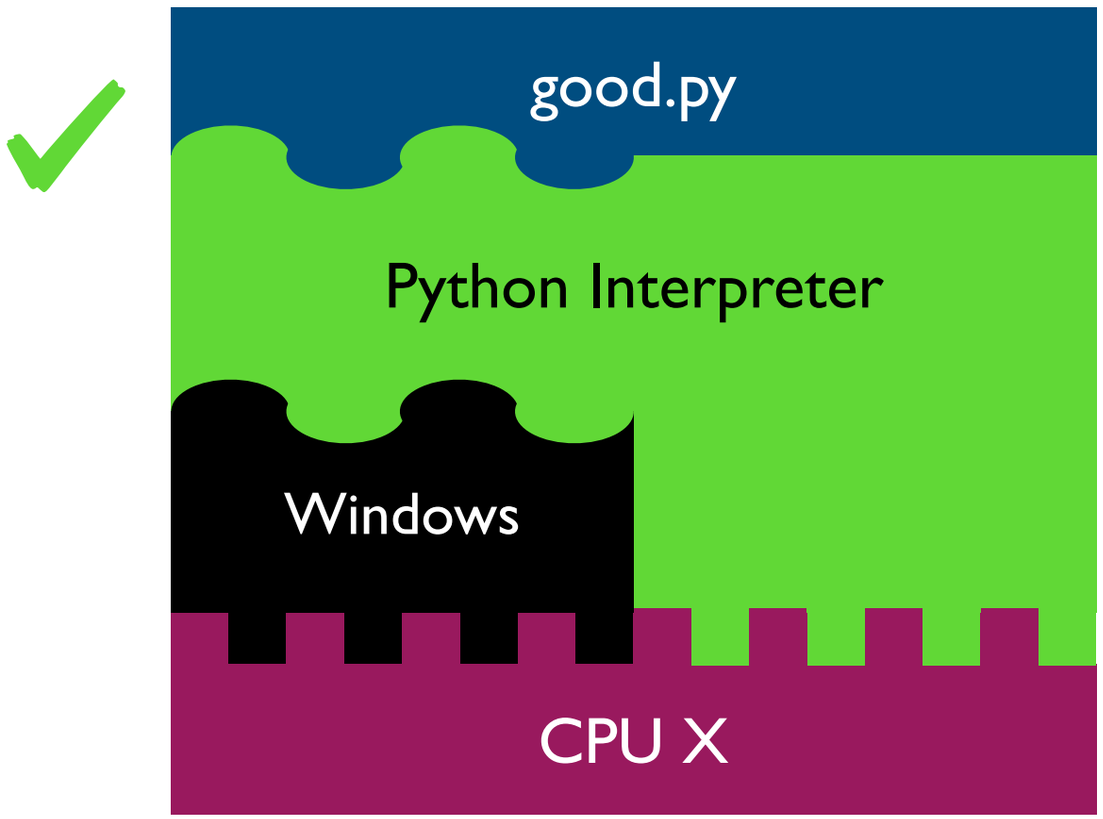



```
f = open("/data/file.txt")
...
```

The Python interpreter mostly lets you
[Python Programmer] ignore the CPU you run on.

But you still need to work a bit to "fit" the code to the OS.

Harder to reproduce on different OS...

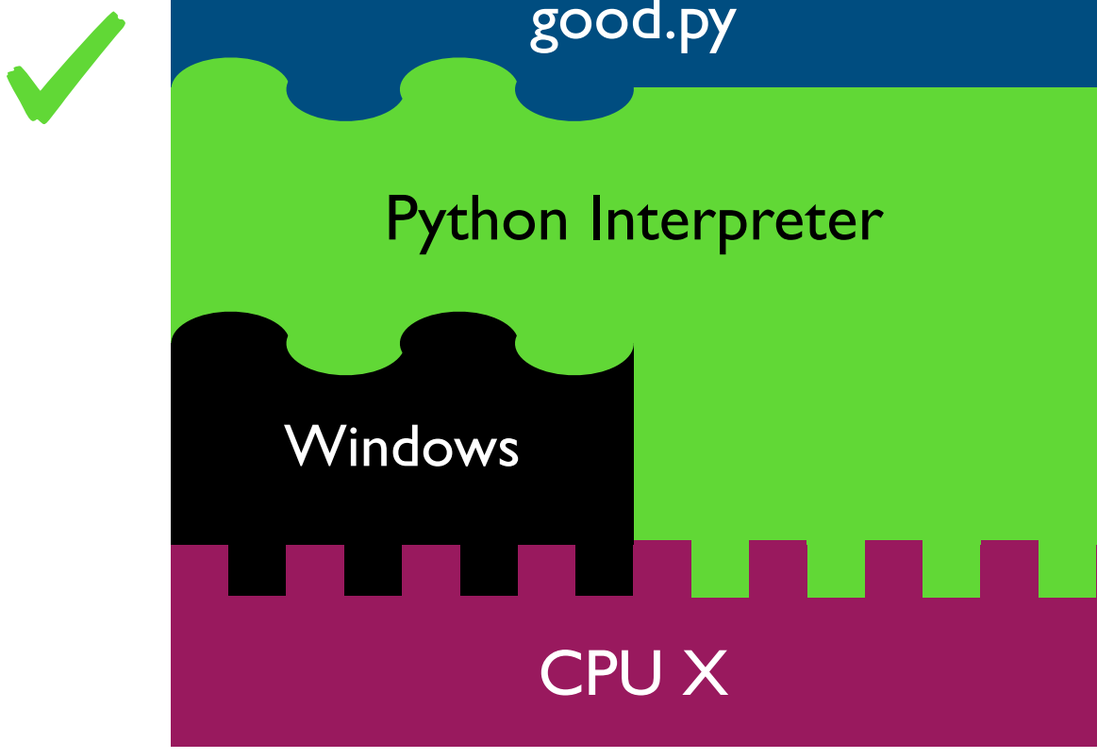



```
f = open("c:\data\file.txt")
...
```

The Python interpreter mostly lets you
[Python Programmer] ignore the CPU you run on.

But you still need to work a bit to "fit" the code to the OS.

Harder to reproduce on different OS...



solution 1:

```
f = open(os.path.join("data", "file.txt"))
...
```

solution 2:

tell anybody reproducing your results to use the same OS!

tradeoffs?

The Python interpreter mostly lets you
[Python Programmer] ignore the CPU you run on.

But you still need to work a bit to "fit" the code to the OS.

VMs (Virtual Machines)

popular virtual machine software

Microsoft Hyper-V

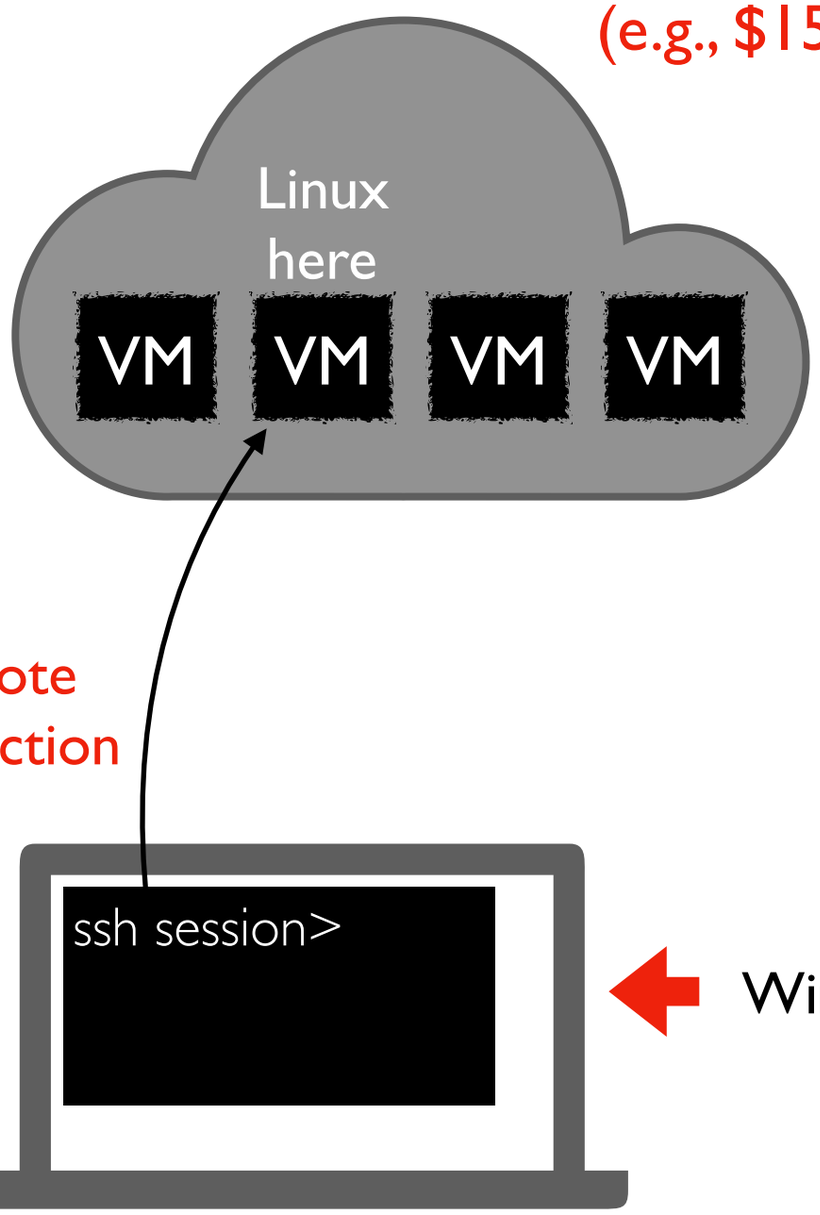
Mac Operating System

Physical Machine
[CPU, memory, etc]

With the right virtual machines created and operating systems installed, you could run programs for Mac, Linux, and Windows -- at the same time without rebooting!

The Cloud

cloud providers let you rent VMs
in the cloud on hourly basis
(e.g., $15 / month)



Windows, Mac, whatever

`ssh user@best-linux.cs.wisc.edu`

run in PowerShell/
bash to access CS lab

popular cloud providers

amazon web services™

Microsoft Azure

Google Cloud Platform

we'll use GCP virtual
machines this semester
[setup in Lab 1]

https://docs.microsoft.com/en-us/windows-server/administration/openssh/openssh_install_firstuse

Lecture Recap: Reproducibility

Big question: *will my program run on someone else's computer?*

Things to match:

1. Hardware ← a program must fit the CPU; `python.exe` will do this, so `program.py` won't have to
2. Operating System ← we'll use Ubuntu Linux on virtual machines in the cloud
3. Dependencies ← next time: versioning

Recap of 15 new terms

reproducibility: others can run our analysis code and get same results

process: a running program

byte: integer between 0 and 255

process memory: a big "list" of bytes, per process, for all state

address: index in the big list

encoding: pairing of ~~letters~~ characters with numeric codes

CPU: chip that executes instructions, tracks position in code

instruction set: pairing of CPU instructions/ops with numeric codes

operating system: software that allocates+abstracts resources

resource: time on CPU, space in memory, space on SSD, etc

allocation: the giving of a resource to a process

abstraction: hiding inconvenient details with something easier to use

virtual machine: "fake" machine running on ~~real~~ physical machine
allows us to running additional operating systems

cloud: place where you can rent virtual machines and other services

ssh: secure shell -- tool that lets you remotely access another machine