

[320] Welcome + First Lecture

[reproducibility]

Tyler Caraza-Harter

Introductions

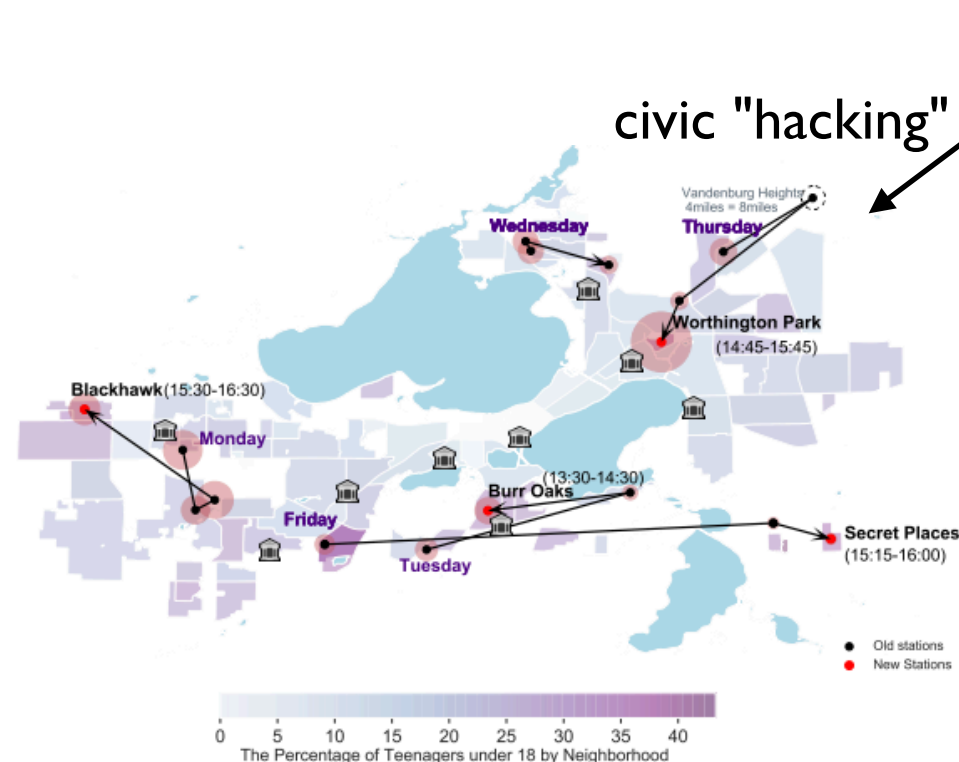
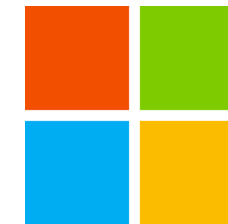
Tyler Caraza-Harter

- Long time Badger
- Email: tharter@wisc.edu
- Just call me “Tyler” (he/him)



Industry experience

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



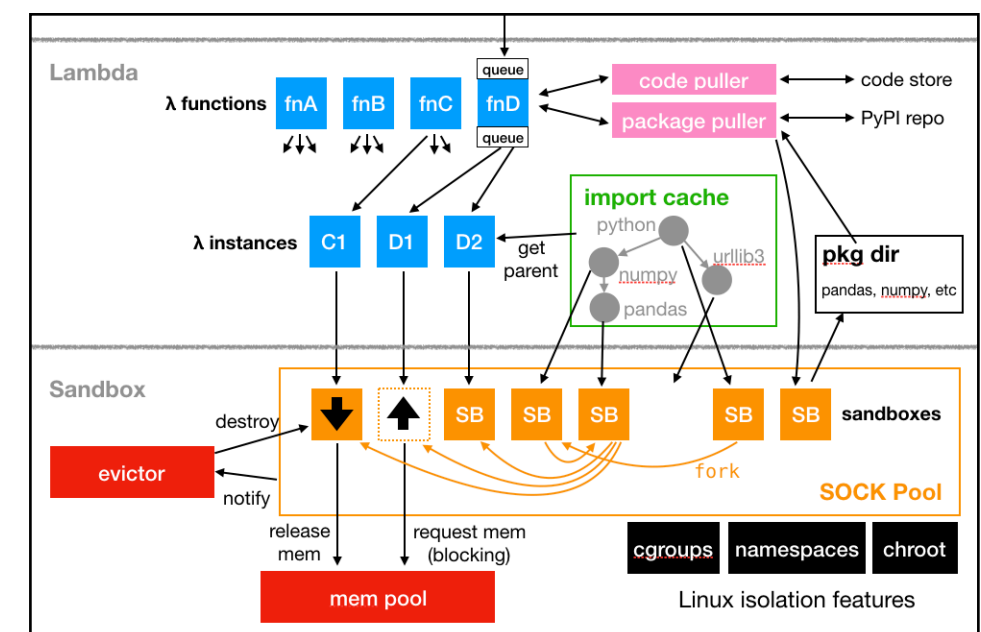
Plot by [Zishan Bai & Dingyi Zhou](#) (previous students)

More: <https://wisc-ds-projects.github.io/f20/>

interests

civic "hacking"

OpenLambda



Who are You?

Year in school?

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

Area of study

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

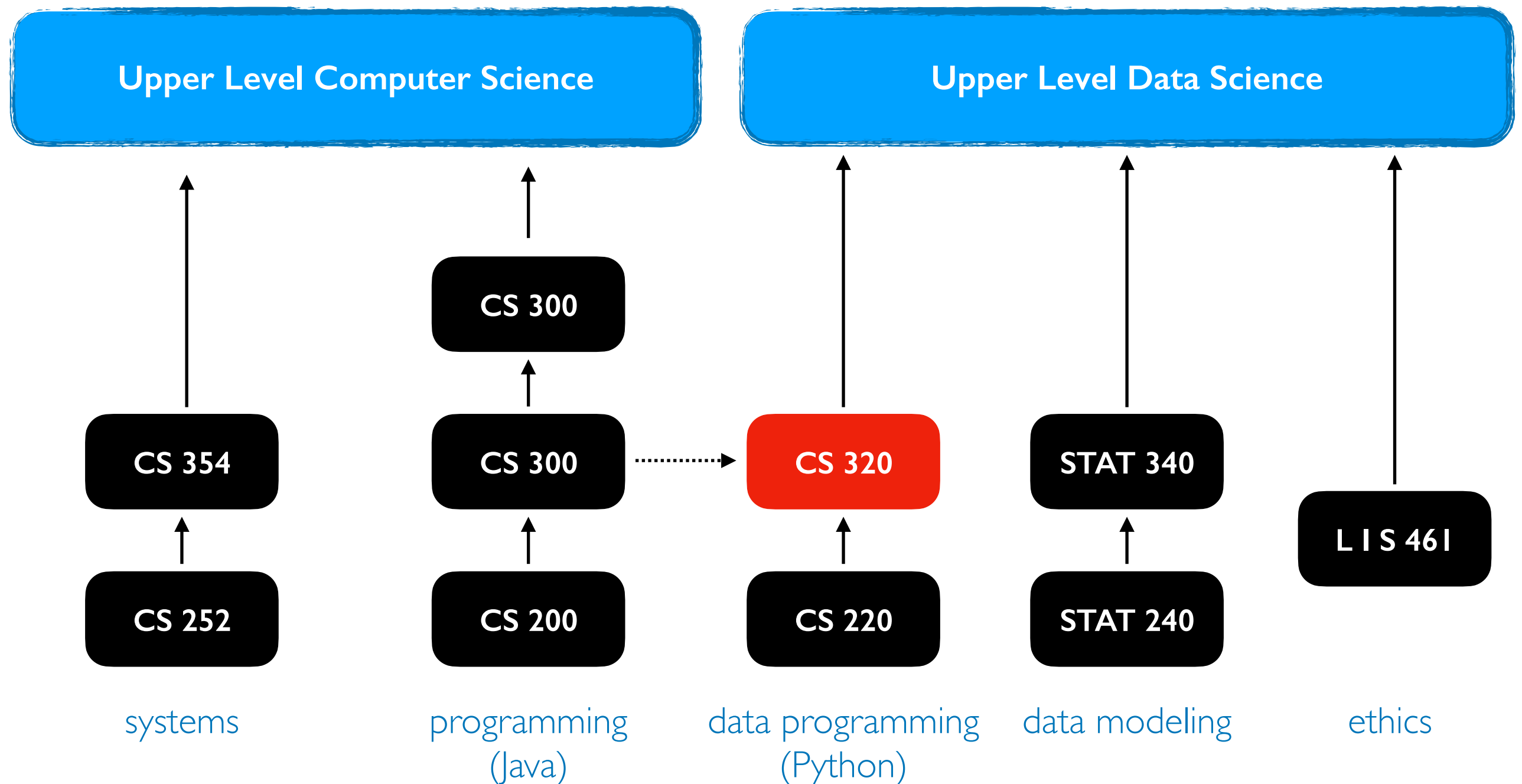
What CS courses have people taken before?

- CS 220/301 (the import one here)? CS 200? CS 300? CS 354?

Please fill this form: <https://forms.gle/LsApPYT5PWaINBNF6>. Why?

- Help me get to know you
- Get participation credit

Related courses



PI (Project I) and other resources will help 320-to-300 students.

Welcome to Data Programming II, in person!

Builds on CS 30+ 220. <https://stat.wisc.edu/undergraduate-data-science-studies/>

CS 220

getting results
writing correct code
using objects
functions: `f(obj)`
lists+dicts
analyzing datasets
plots
tabular analysis

CS 320

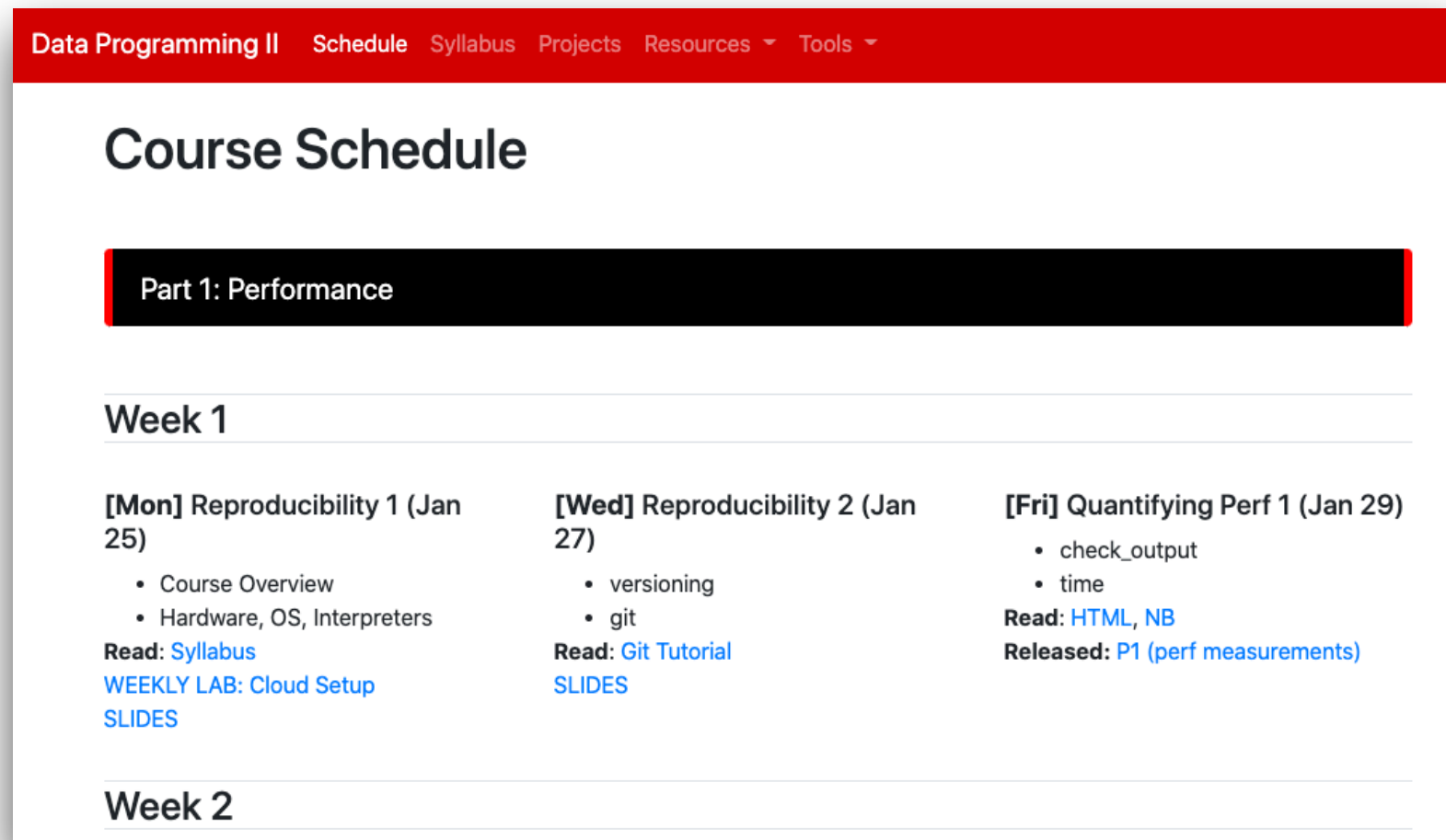
getting **reproducible** results
writing **efficient** code
designing **new types** of objects
methods: `obj.f()`
graphs+trees
collecting+analyzing datasets
animated visualizations
simple machine learning



Course Logistics

Course Website

It's here: <https://tyler.caraza-harter.com/cs320/f21/schedule.html>



The screenshot shows a web page titled "Course Schedule" for "Data Programming II". The navigation bar includes links for "Schedule", "Syllabus", "Projects", "Resources", and "Tools". A black bar highlights "Part 1: Performance". Under "Week 1", there are three columns for different days: Monday (Reproducibility 1), Wednesday (Reproducibility 2), and Friday (Quantifying Perf 1). Each column lists topics, a "Read" link, and a "Released" link. Week 2 is also listed but empty.

Week 1	Week 2
[Mon] Reproducibility 1 (Jan 25) <ul style="list-style-type: none">• Course Overview• Hardware, OS, Interpreters Read: Syllabus WEEKLY LAB: Cloud Setup SLIDES	
[Wed] Reproducibility 2 (Jan 27) <ul style="list-style-type: none">• versioning• git Read: Git Tutorial SLIDES	
[Fri] Quantifying Perf 1 (Jan 29) <ul style="list-style-type: none">• check_output• time Read: HTML , NB Released: P1 (perf measurements)	

← read syllabus carefully
and checkout other content

I'll also use **Canvas** for four things:

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

Scheduled Activities

Lectures

- 3 times weekly
- feel free to bring a laptop
- will generally be recorded+posted online
(questions will be recorded -- feel free to save until after if you aren't comfortable being recorded)
- Fill "Reflect on Lecture" each time:
<https://tyler.caraza-harter.com/cs320/f21/surveys.html>

Lab

- Weekly on Mondays
- Bring a laptop
- Mostly self guided (320 staff will be there to answer questions)
- Focus is on project prep
- Feel free to use extra time to collaborate with team

Class organization: People

Teams

- you'll be randomly assigned to a team of 4-7 students
- teams will last the whole semester
- some types of collaboration with team members are allowed (not required) on graded work, such as projects+quizzes
- most collaboration with non-team members is not allowed

Staff

1. Instructor
2. Teaching Assistants (grad students)
3. Mentors (undergrads)

we all provide office hours, and you can attend any that you prefer!

Class organization: People

Teams

- you'll be randomly assigned to a team of 4-7 students
- teams will last the whole semester
- some types of collaboration with team members are allowed (not required) on graded work, such as projects+quizzes
- most collaboration with non-team members is not allowed

Staff

1. Instructor
2. Teaching Assistants
 - **head TA**: in charge of projects
 - **team TA**: primary contact for team, same whole semester
 - **grader TA**: reviews projects (rotates weekly)
3. Mentors
 - **team mentor**: meets weekly with your team, same whole semester

we all provide office hours, and you can attend any that you prefer!

Other Communication

Piazza

- find link on site
- don't post >5 lines of project-related code (considered cheating)

Forms

- <https://tyler.caraza-harter.com/cs320/f21/surveys.html>
- Who are you? Feedback Form. Thank you!
Reflect on Lecture. Grading Issues.

Email

- me: tharter@wisc.edu
- TAs: <https://tyler.caraz-harter.com/cs320/f21/contact.html>

Course Etiquette

Meetings

1. office hours are drop-in (no need to reserve)
2. email me to schedule individual meetings

Email

3. let us know your NetID (if not from netid@wisc.edu)
4. don't start new email thread if topic is the same
5. CC team members when appropriate
6. unless urgent, please give me 48 hours to respond before following up (I'll try to be faster usually)
7. use your judgement about whether to email me or TA first
8. if general question, consider using piazza instead

Graded Work: Projects+Participation

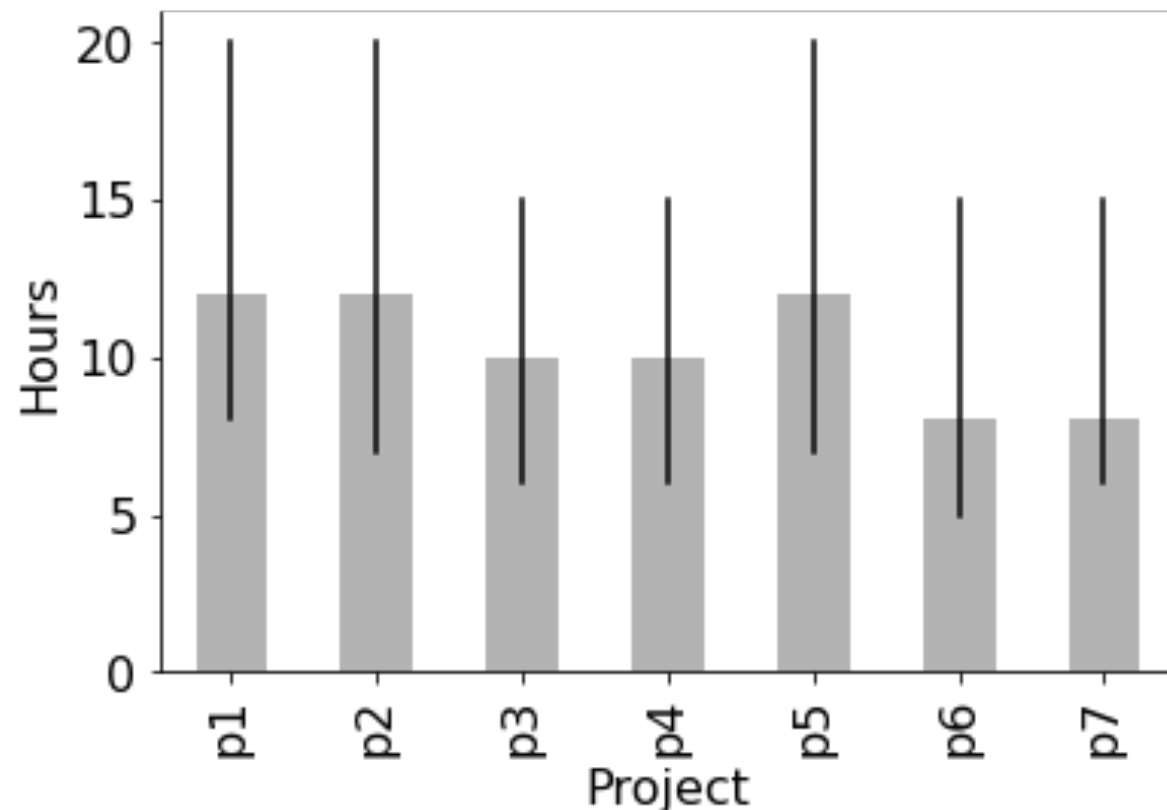
Participation - 3%

- class surveys
- project specification fixes
- timely reporting of grading issues

7 Projects - 8% each

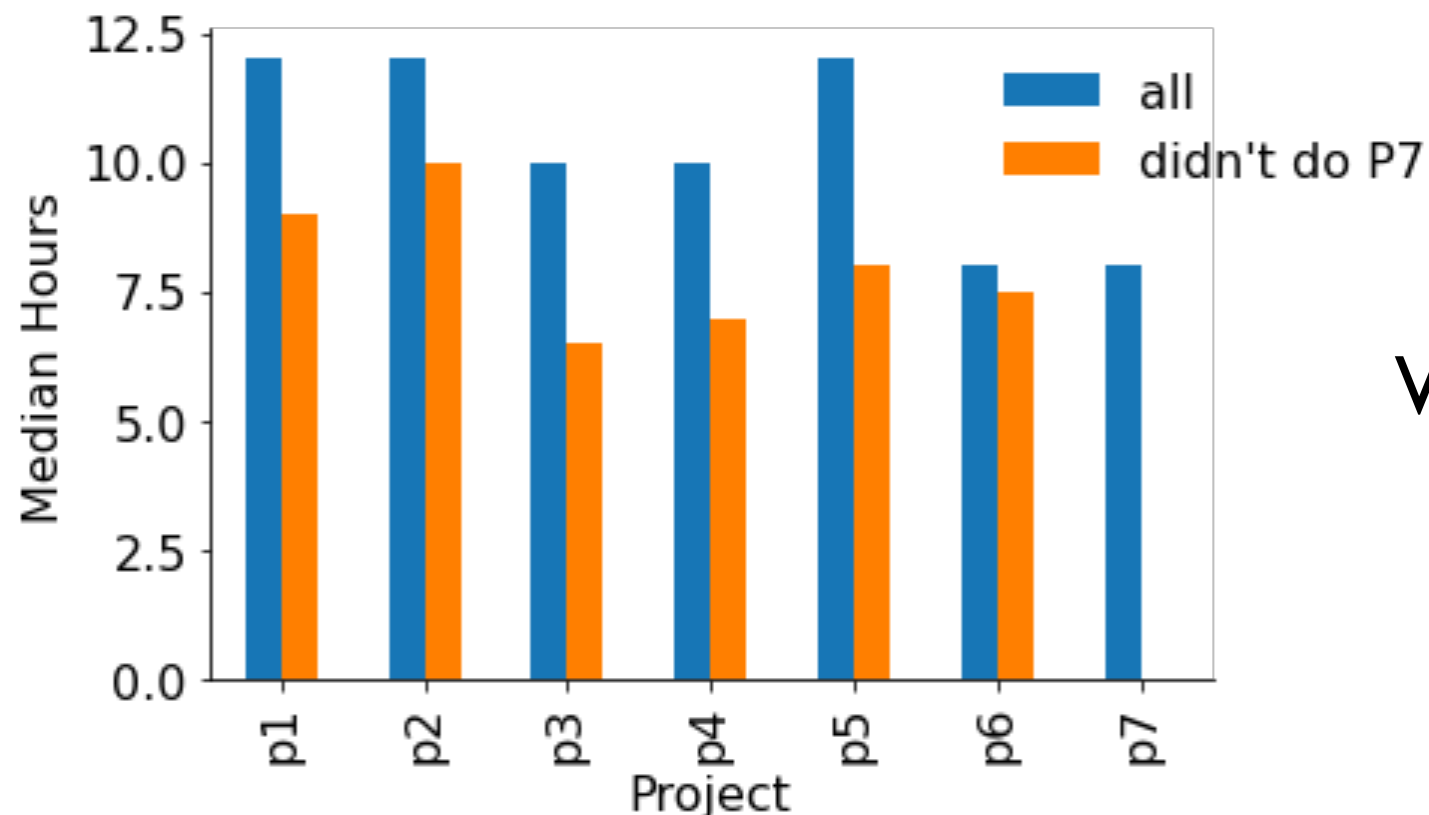
- **format:** notebook, module, or program
- part 1: you can optionally collaborate with team
- part 2: must be individually (only help from 320 staff)
- still a `tester.py`, but more depends on TA evaluation (more plots)
- ask for specific feedback
(giving constructive criticism is a priority in CS 320)

Time Commitment



Observations

- 10-12 hours per project is typical
- 20% of students sometimes spend 20+ hours on some
- students who were faster earlier were less likely to complete the course



Weekly Expectations

- 4 hours - lecture/lab
- 6 hours - project coding
- 2 hours - reading/quizzes/etc

Graded Work: Exams/Quizzes

Eleven Online Quizzes - 1% each

- focus on material about one week old
- no time limit
- on Canvas, open book/notes
- can take together AT SAME TIME
with team members (no other human help)

One Midterm - 10%

- individual, multi-choice, 40 minutes
- one page notes, both sides
- in class

One Final - 20%

- individual, multi-choice, 2 hours
- one page notes, both sides

Academic Misconduct

Read syllabus to make sure you know what is and isn't OK.

It's not obvious!

Since Fall 2019, I have made the following misconduct reports:

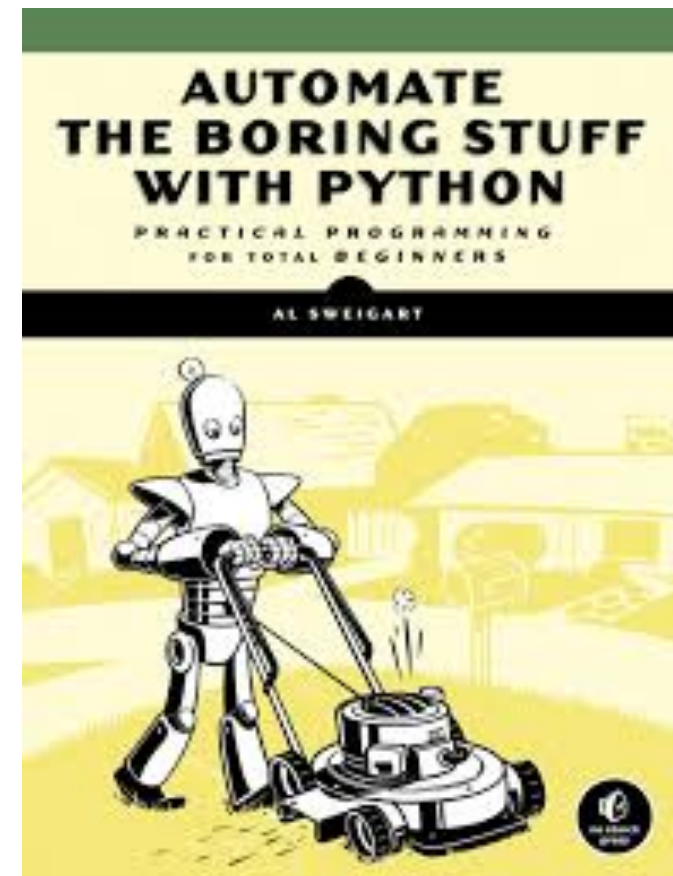
- **33** students for cheating on projects
- **2** past students for sharing solutions from past semesters
- **7** students for cheating on exams

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!

Reading: same as 220/301 and some others...



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

Lectures don't assume any reading prior to class

Tips for 320 Success

1. Just show up!
 - ➡ Get 100% on participation and don't miss quizzes
2. Use office hours
 - ➡ we're idle after a project release and swamped before a deadline
3. Do labs before projects
4. Take the lead on group collaboration
5. Learn debugging
6. Run the tester often
7. If you're struggling, reach out -- the sooner, the better

Any questions?

Today's Lecture:

Reproducibility

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)ŏʊsəˈbɪlədē/

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

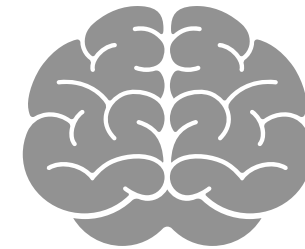
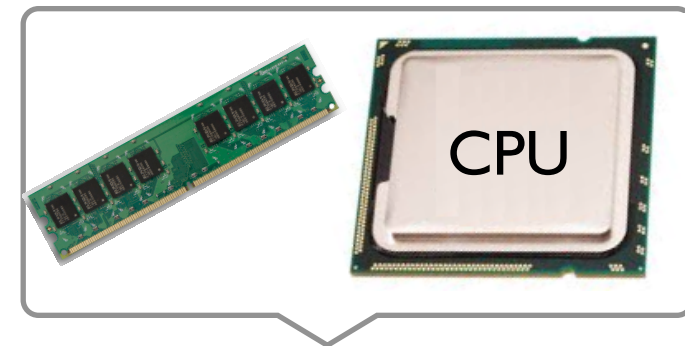
Hardware

2

Operating System

3

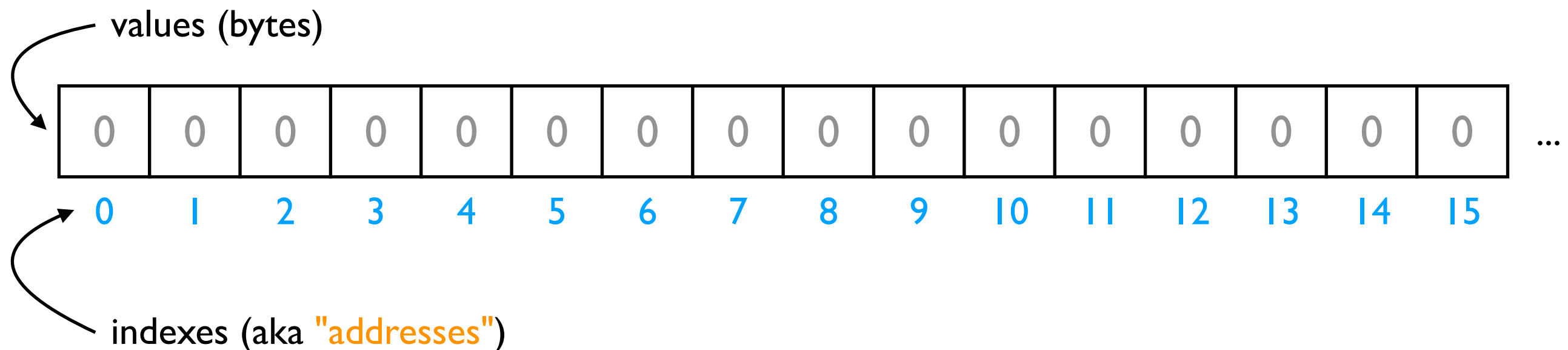
Dependencies ← next lecture



Hardware: Mental Model of Process Memory

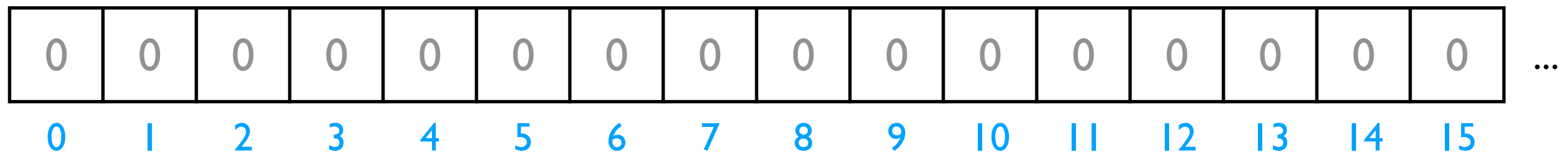
Imagine...

- 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?

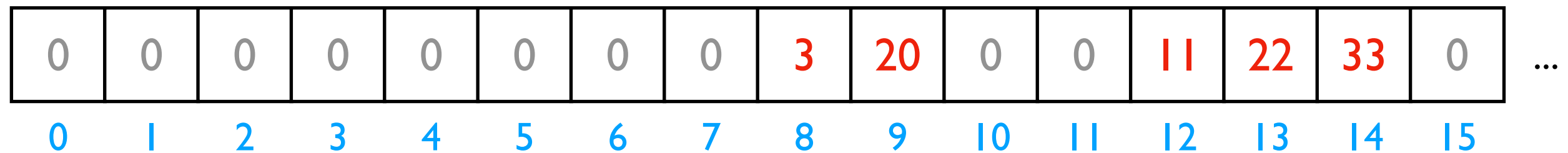
- multiple lists
 - variables and other references
 - strings
 - code
- data



Is this really all we have for state?

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

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



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?

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

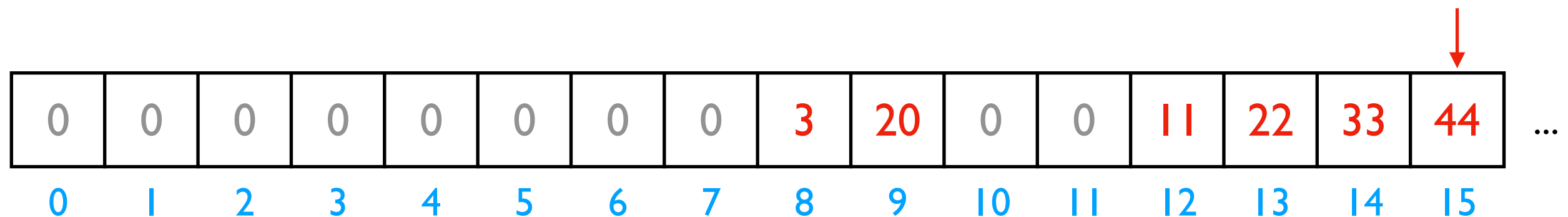
0	0	0	0	0	0	0	0	3	20	0	0	11	22	33	0	...
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	

implications for performance...

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

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

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



implications for performance...

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L2.append(44)
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How can we use one giant list to handle the following?

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

0	0	0	0	0	0	0	0	3	20	0	0	11	22	33	44	...
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	

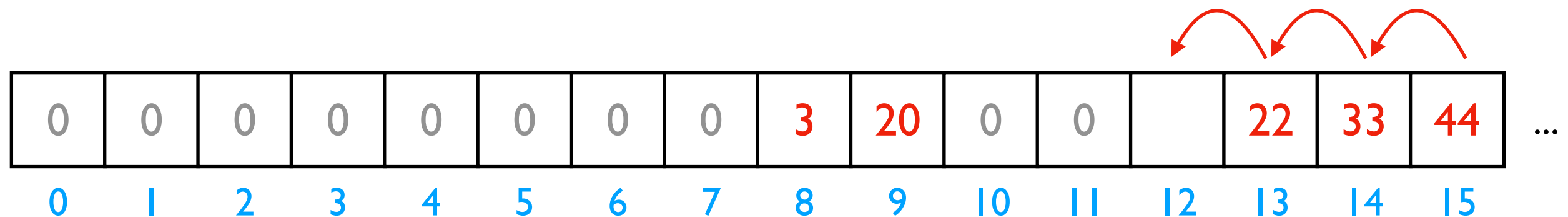
implications for performance...

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

```
# slow  
L2.pop(0)
```

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

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



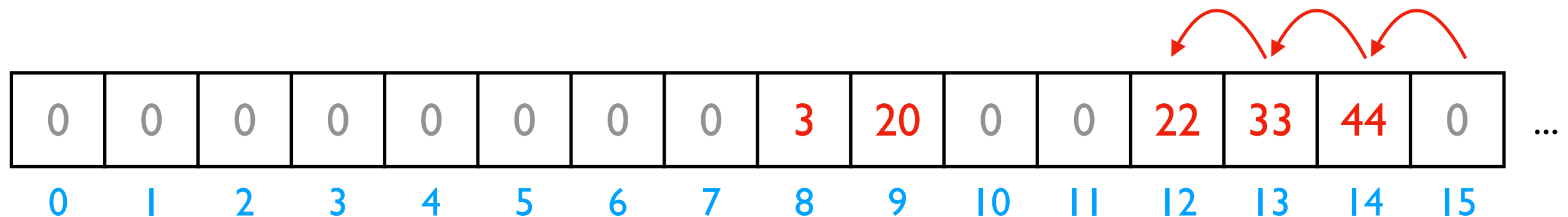
implications for performance...

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

```
# slow  
L2.pop(0)
```

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

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



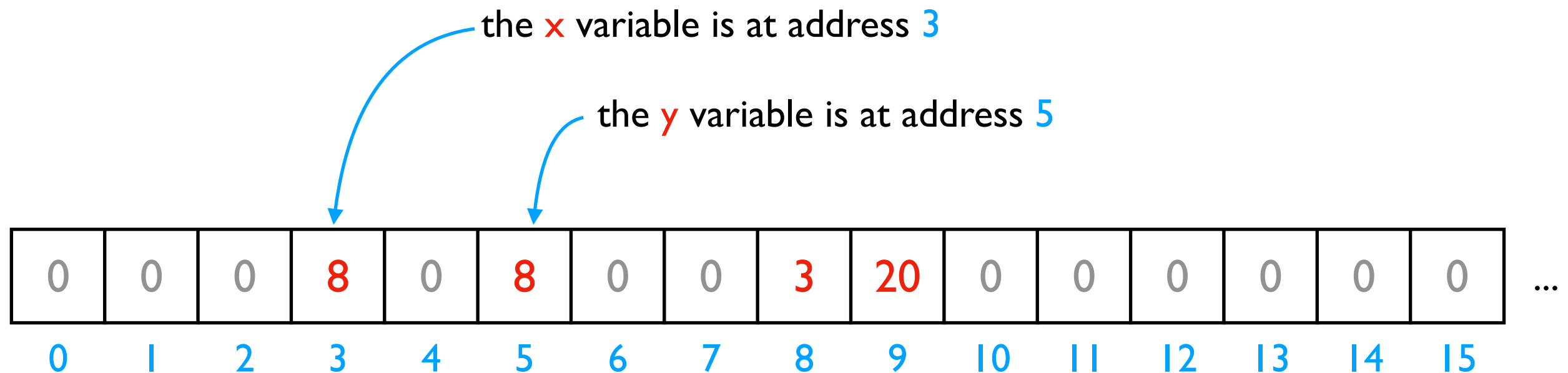
We'll think more rigorously about performance in CS 320 (big-O notation)

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

```
# slow  
L2.pop(0)
```

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

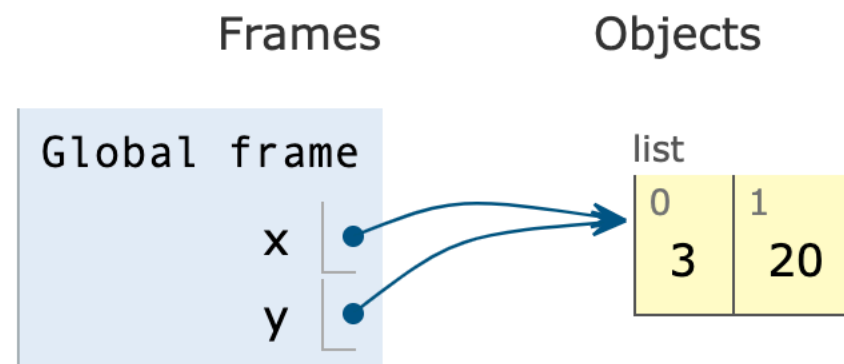
- multiple lists
- **variables and other references**
- strings
- code



Python 3.6

```
1 x = [3, 20]
2 y = x
```

[Edit this code](#)

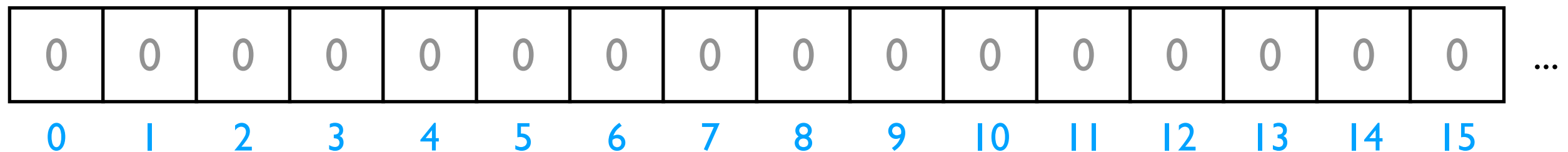


PythonTutor's visualization

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

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

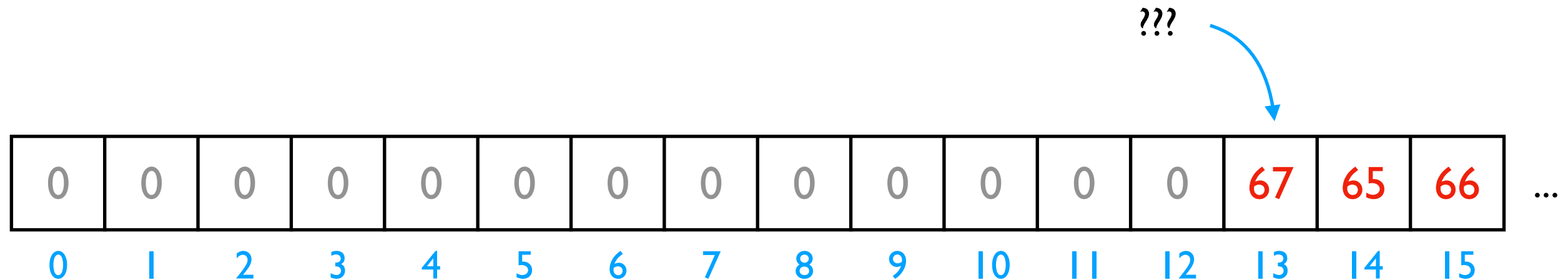
discuss: how?



Is this really all we have for state?

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

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



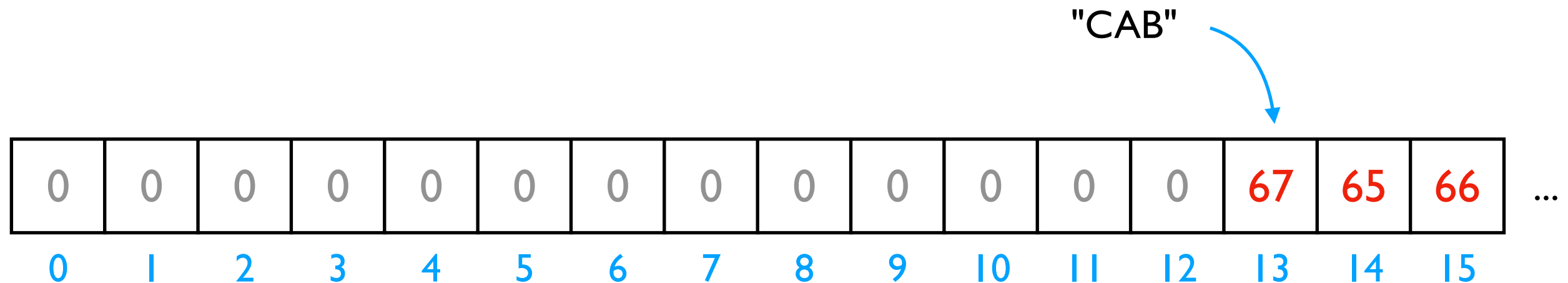
encoding:

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?

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



encoding:

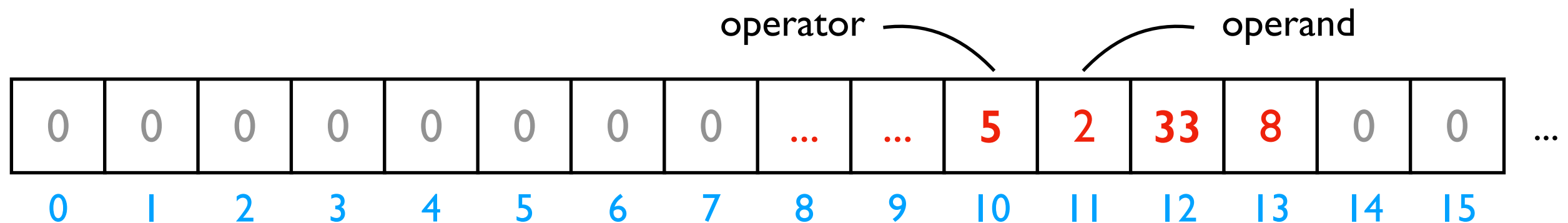
code	letter
65	A
66	B
67	C
68	D
...	...

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

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

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

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

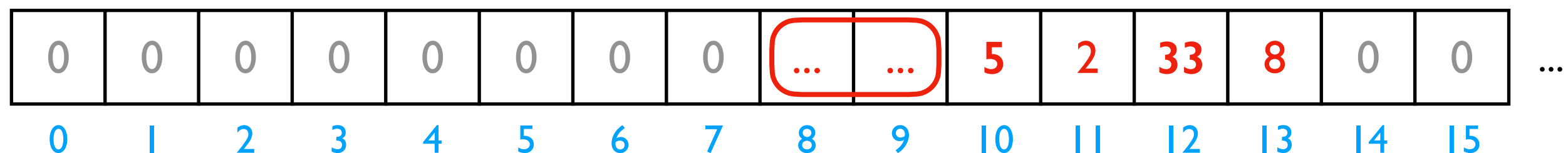
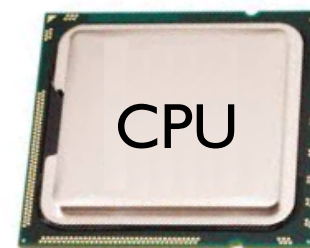


Instruction Set	code	operation
	5	ADD
	8	SUB
	33	JUMP

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 XXXXXXXXXX
  2 XXXXXXXXXX
  3 XXXXXXXXXX
```

→ line that just executed

→ next line to execute

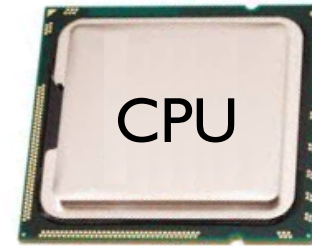
Instruction Set

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

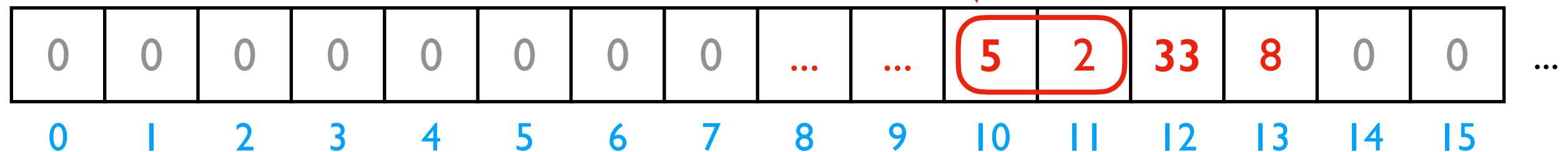
Hardware: Mental Model of CPU

CPU's interact with memory:

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



add 2 to variable

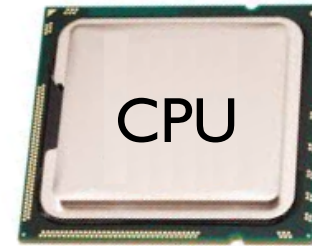


Instruction Set	code	operation
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	33	JUMP

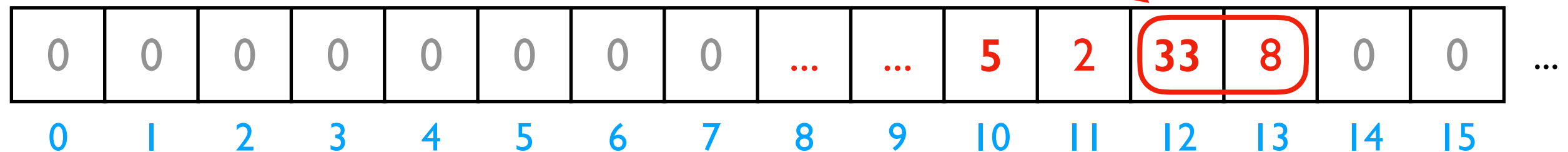
Hardware: Mental Model of CPU

CPU's interact with memory:

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go back to top of loop

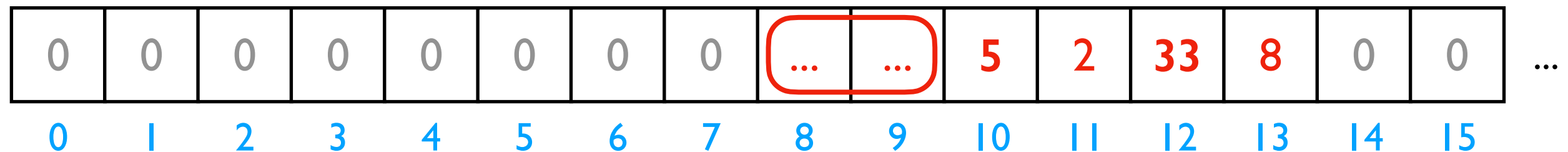
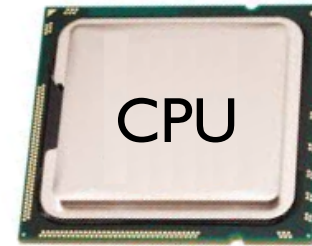


Instruction Set	code	operation
	5	ADD
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	33	JUMP

Hardware: Mental Model of CPU

CPUs interact with memory:

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



Instruction Set	code	operation
	5	ADD
	8	SUB
	33	JUMP

Hardware: Mental Model of CPU

discuss: what would happen if a
CPU tried to execute an
instruction for a different CPU?

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
for **CPU X**

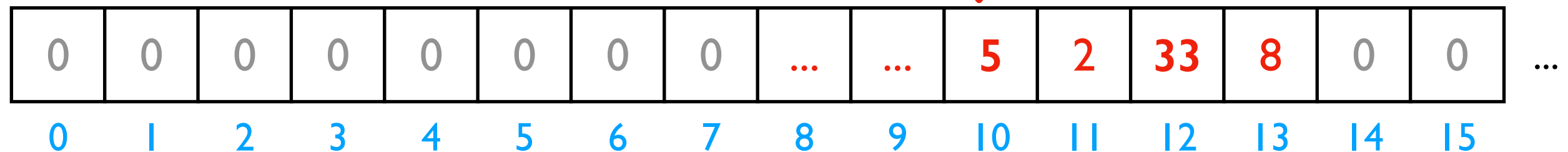
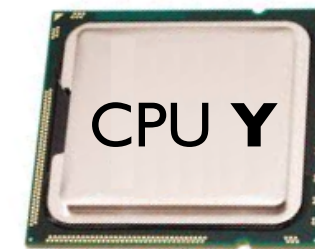
code	operation
5	ADD
8	SUB
33	JUMP
...	...

Instruction Set
for **CPU Y**

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

Hardware: Mental Model of CPU

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



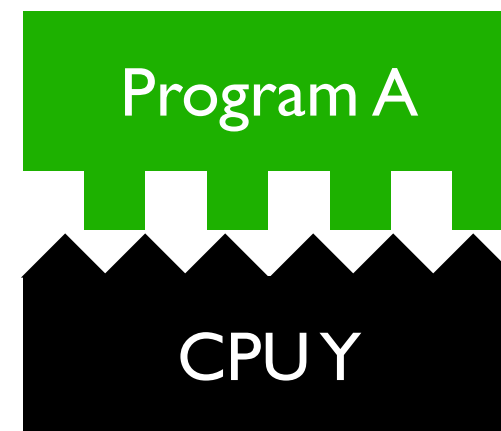
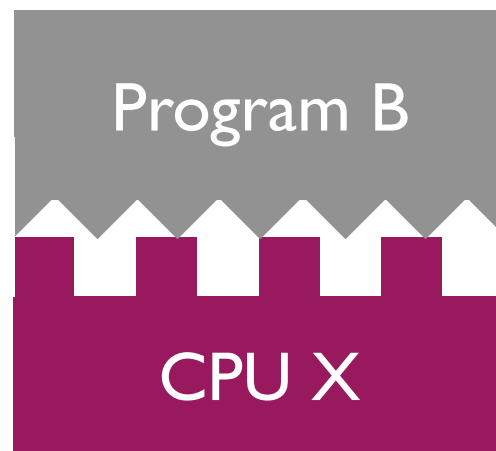
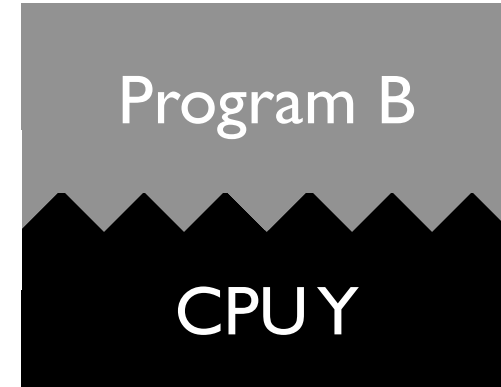
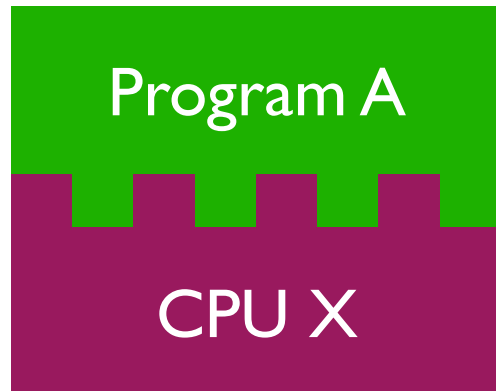
Instruction Set
for **CPU X**

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"

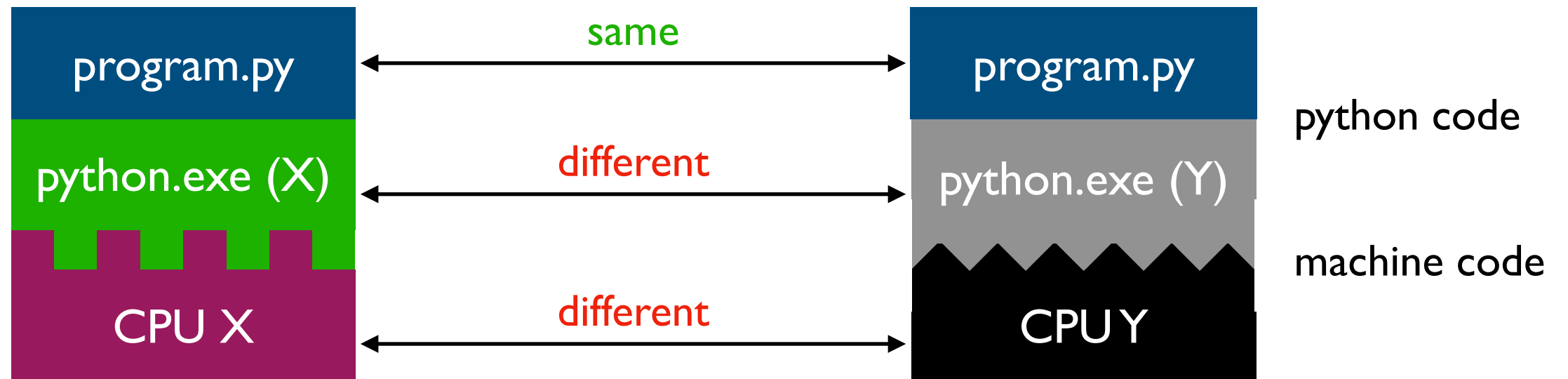


A Program and CPU need to "fit"



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

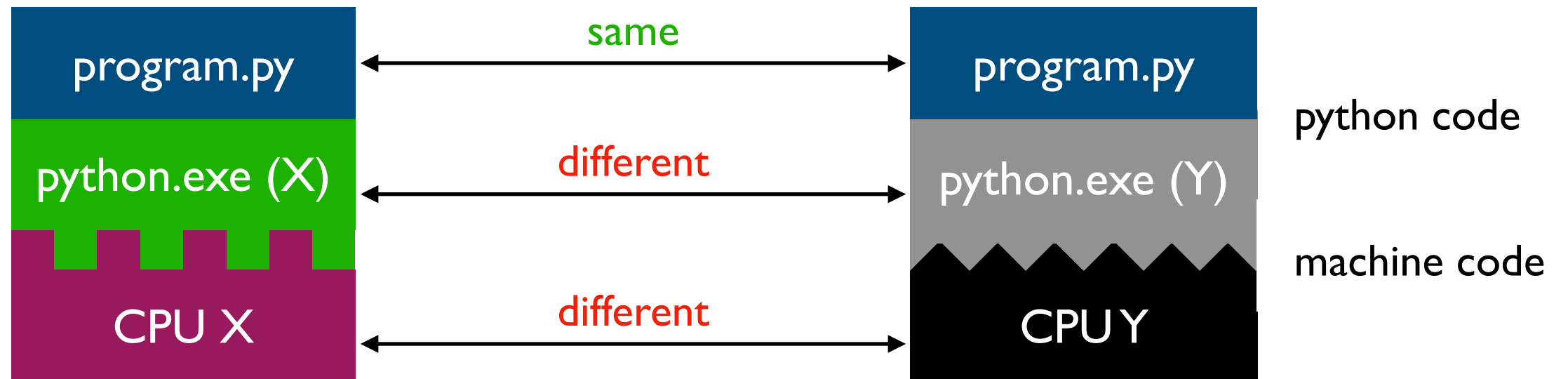
Interpreters



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

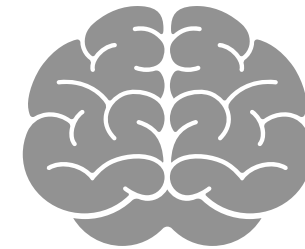
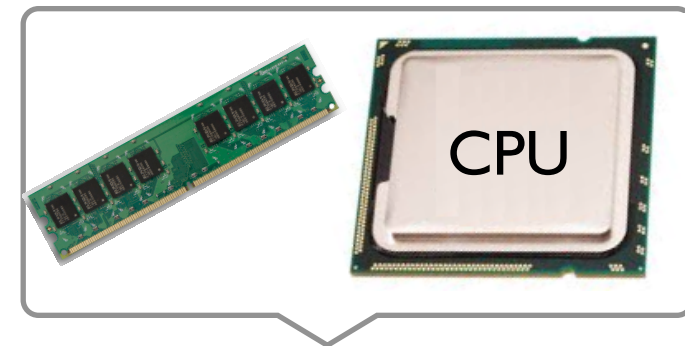
Hardware

2

Operating System

3

Dependencies ← next lecture



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

Things to match:

1

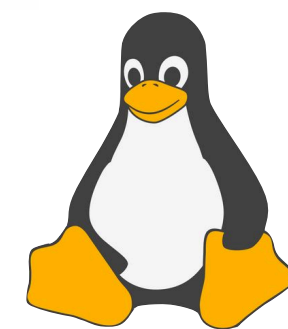
Hardware

2

Operating System

3

Dependencies ← next lecture



Linux™

many others...



Red Hat



ANDROID



ubuntu.

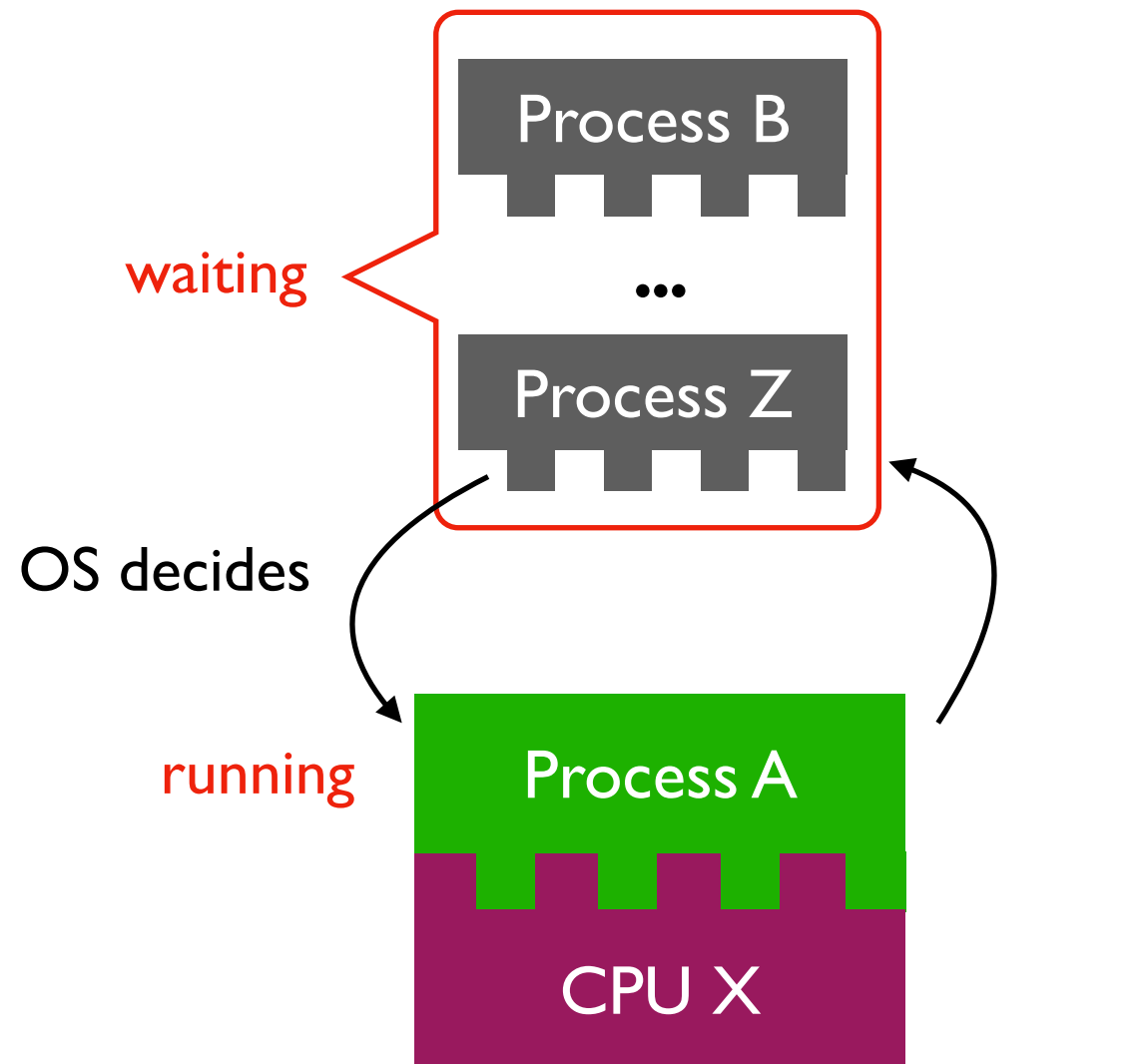
[this semester]

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

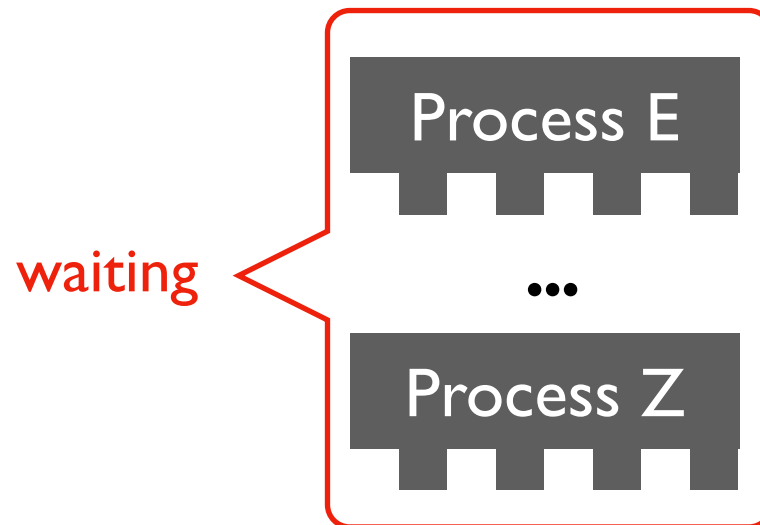
Operating System

inconvenient

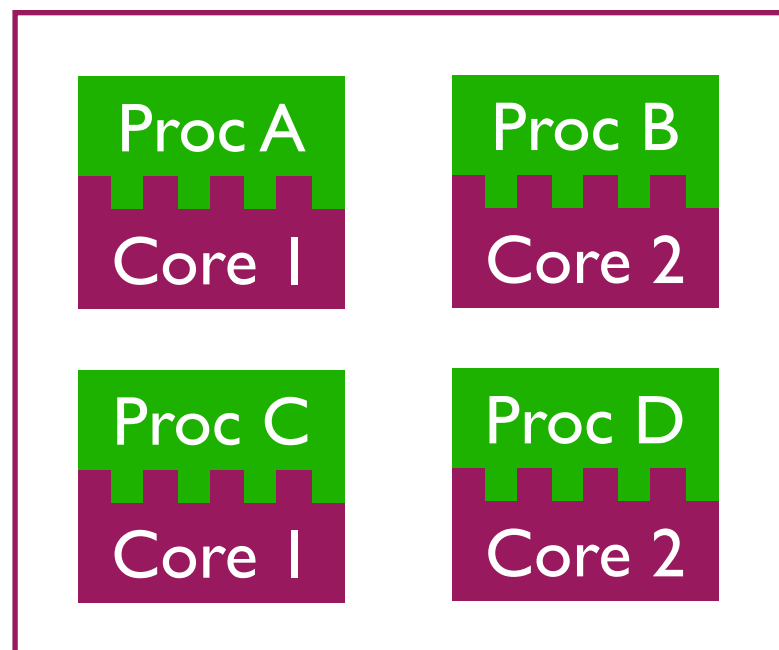
ignorant of
files/directories



Parallelism -- more later this semester...



running
processes



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

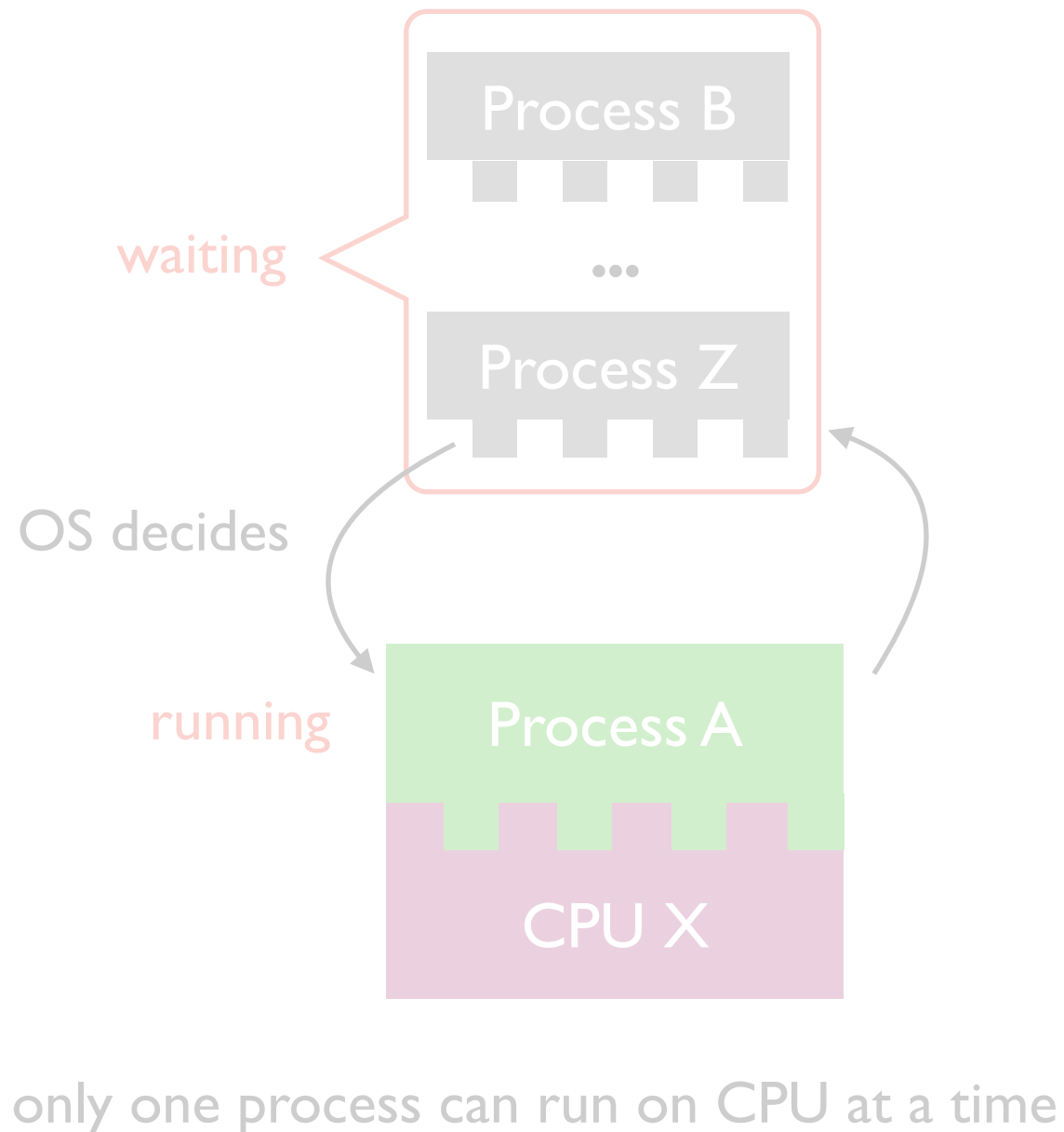
Later: *how can we write programs that run in parallel, going faster by using multiple cores?*

OS jobs: Allocate and Abstract Resources

[like CPU, hard drive, etc]

1

Allocation



2

Abstraction

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

convenient

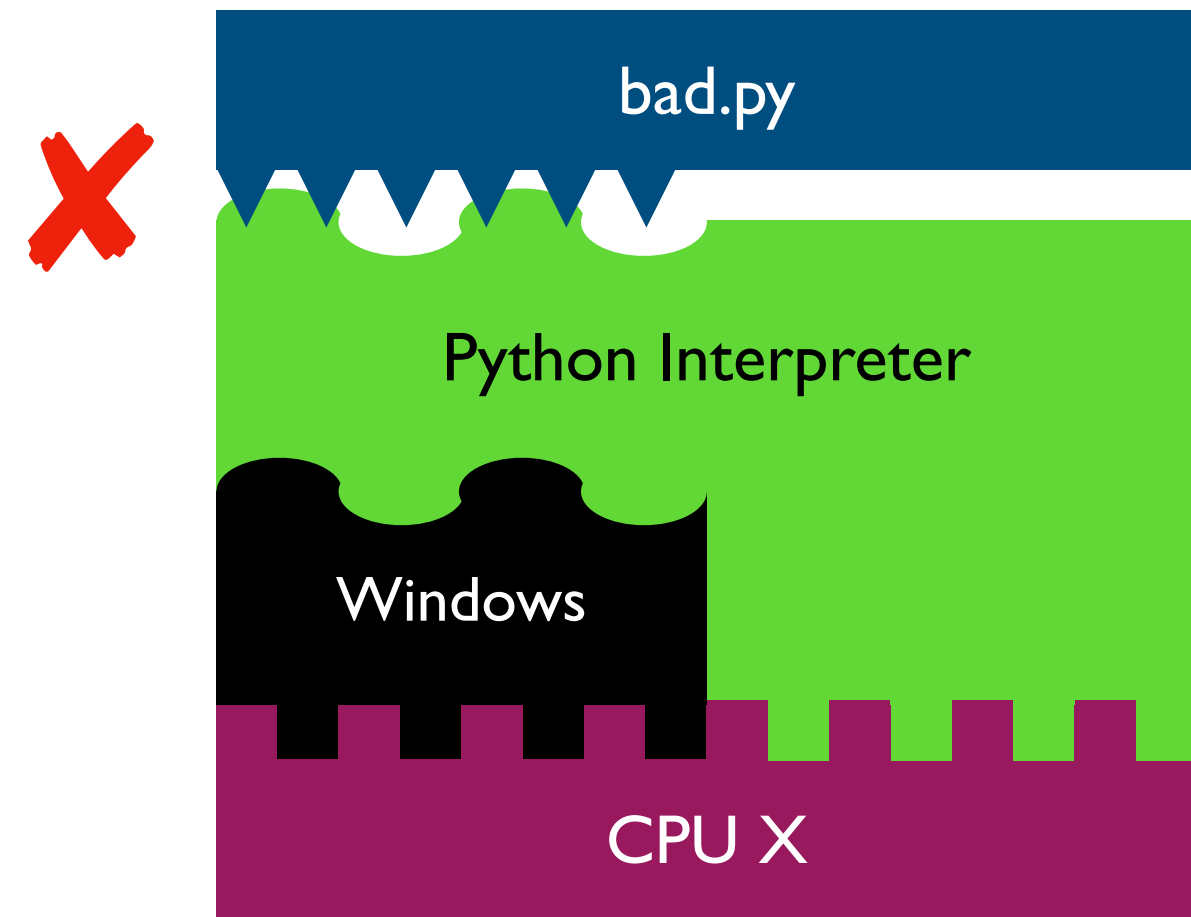
Operating System

inconvenient

ignorant of
files/directories



Harder to reproduce on different OS...

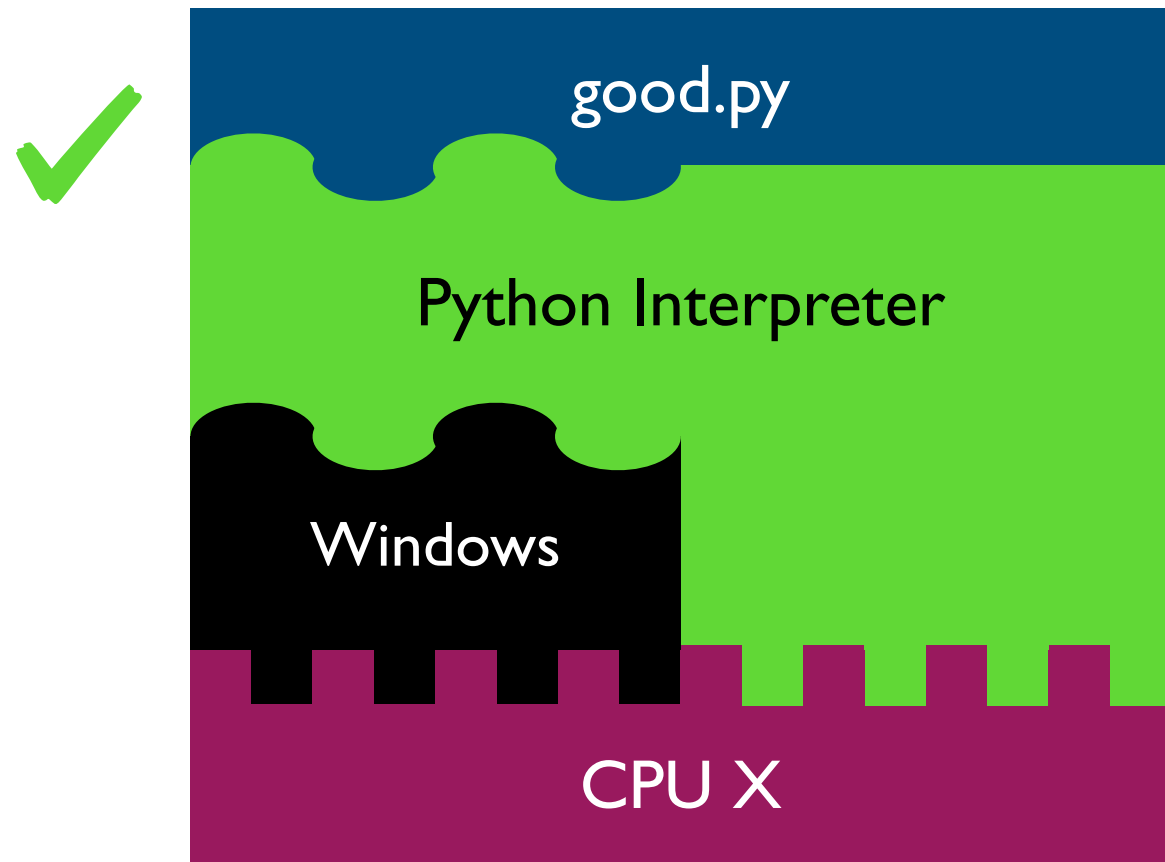


```
f = open("/data/file.txt")  
...
```

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...

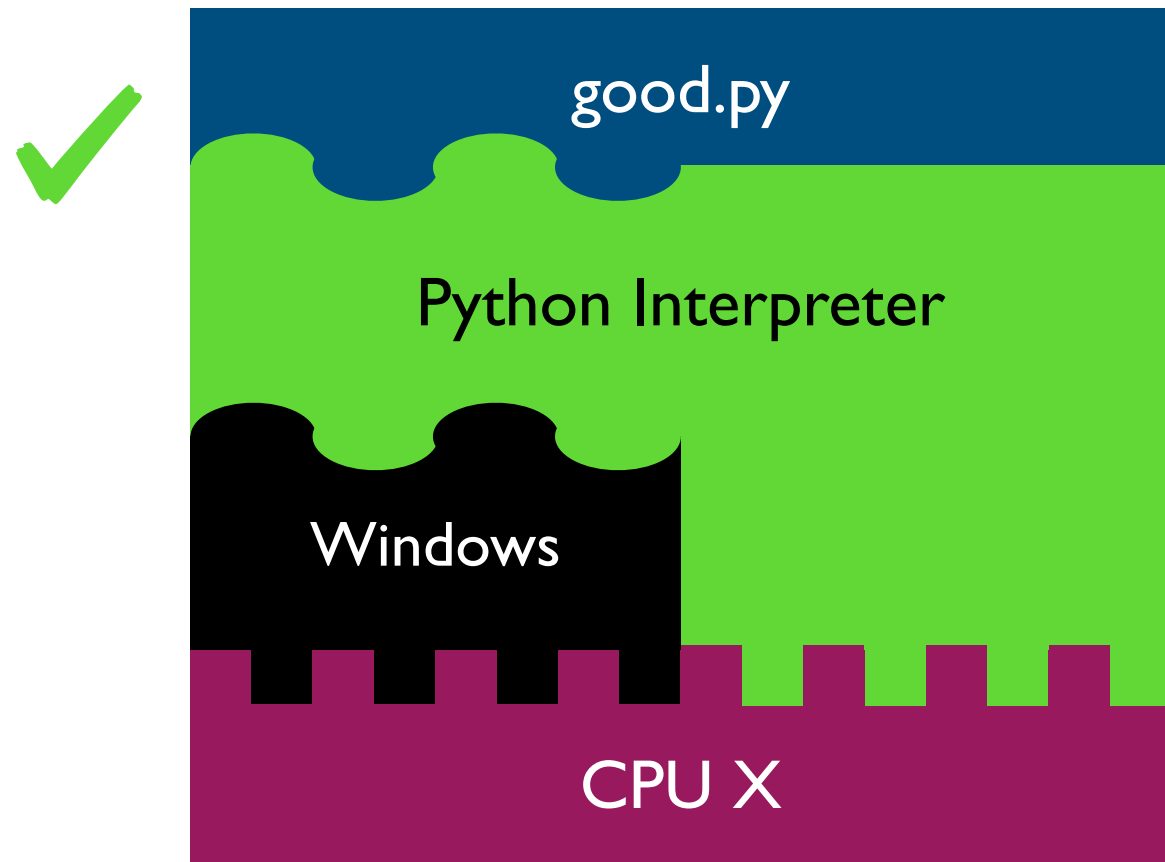


```
f = open("c:\data\file.txt")  
...
```

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!

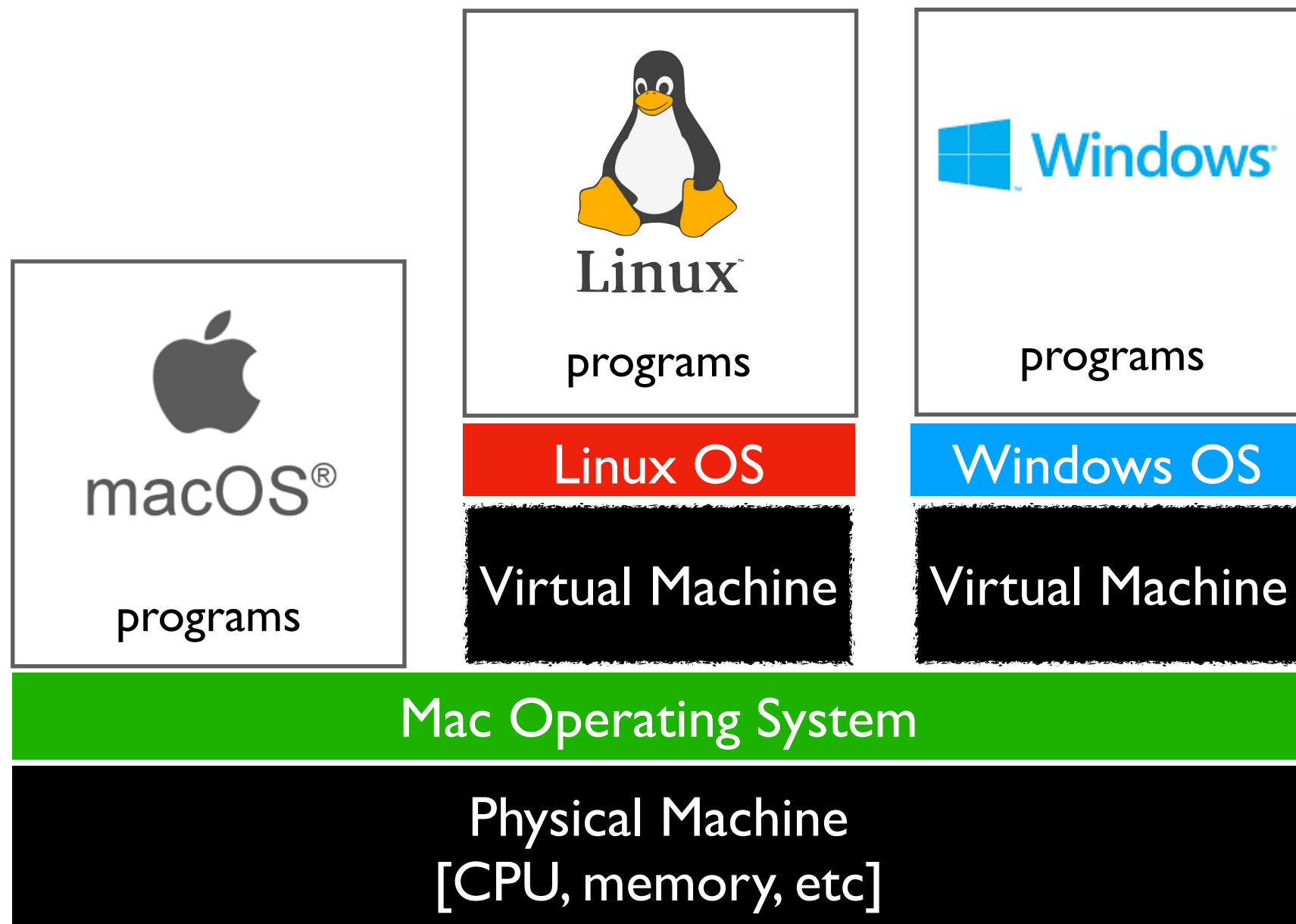
tradeoffs?

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



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

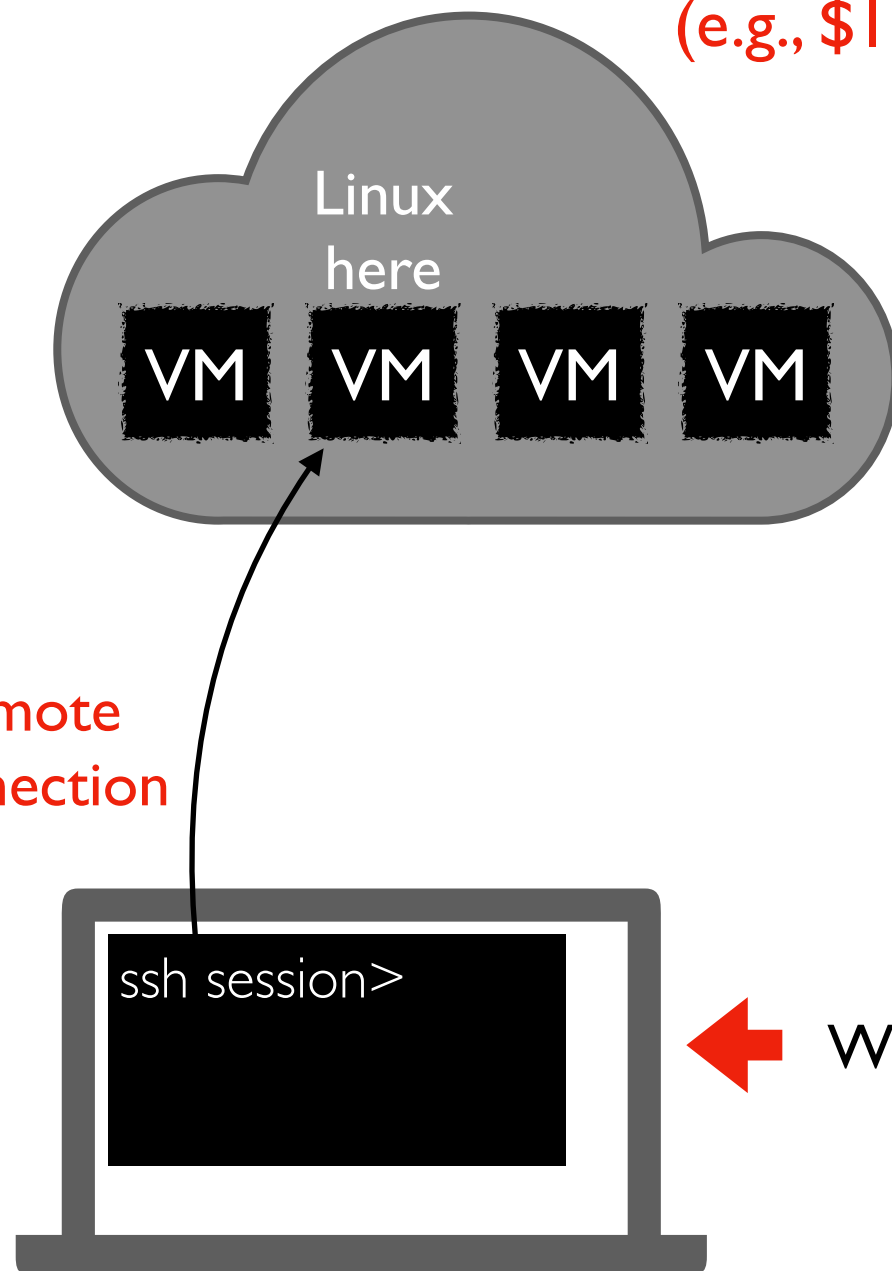
cloud providers let you rent VMs
in the cloud on hourly basis
(e.g., \$15 / month)

popular cloud providers



Google Cloud Platform

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



Windows, Mac, whatever

`ssh user@best-linux.cs.wisc.edu` ← run in PowerShell/
bash to access CS lab

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

Remember to "Reflect"! <https://tyler.caraza-harter.com/cs320/f21/surveys.html>

what is something you learned? What is something you didn't understand? What is a question you had?