[320] Welcome + Reproducibility I

Yiyin Shen

Who am I?

Yiyin Shen

- CS PhD student
- Email: yshen82@wisc.edu

Research Interest

- CS Education
- Large Language Models

Teaching Experience

- CS320 TA => Head TA => Instructor
- CS220, CS402 Guest Lectures

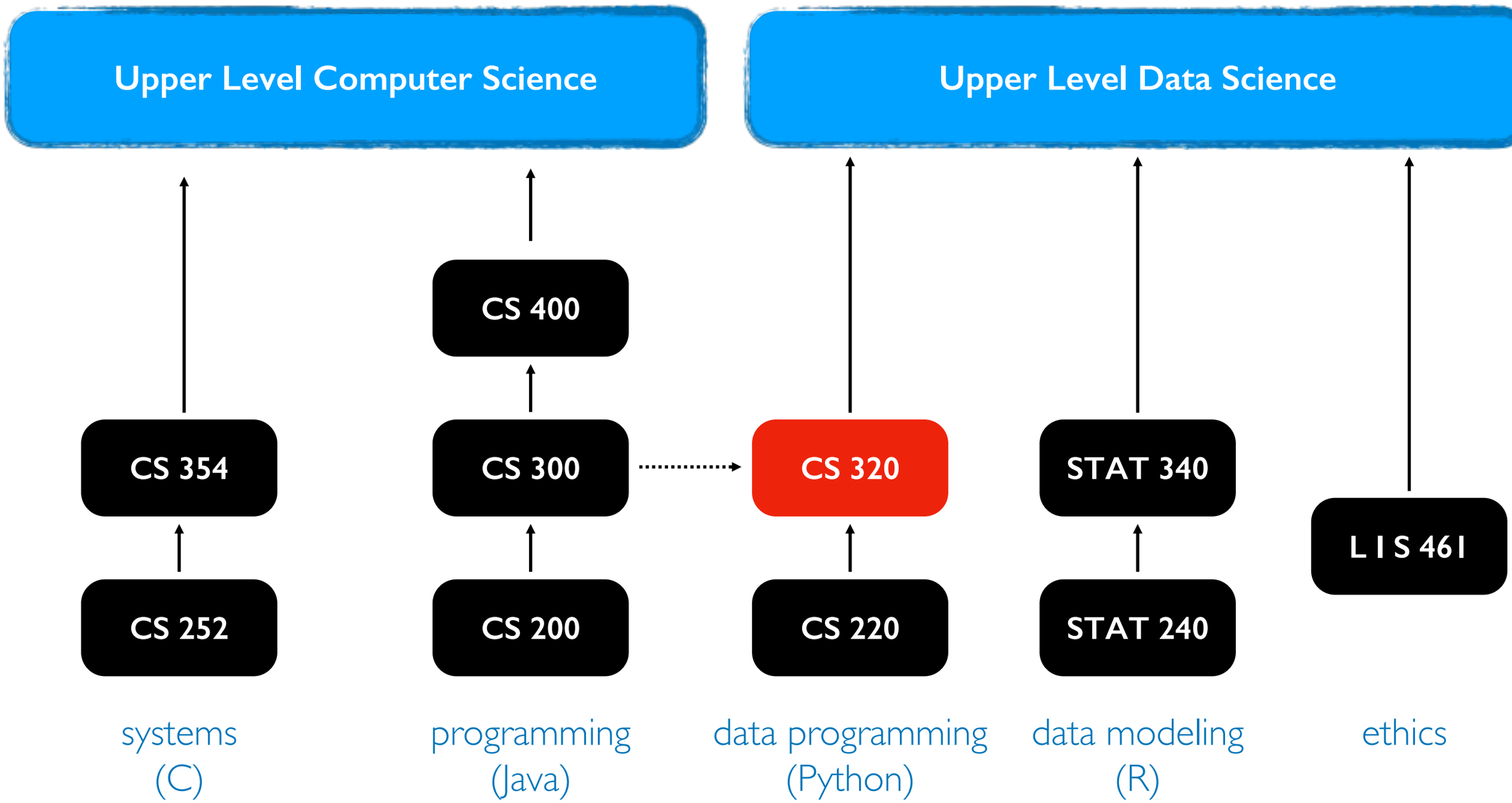
Who are You?

Year in school?
Major?

Please complete Quiz 1 (Student Information Survey):
(due Fri, Sep 8th):
Why?

- Help me get to know you
- Group formation

Related courses



P1 (Project 1) will help 300-to-320 students pickup Python.

Welcome to Data Science Programming II!

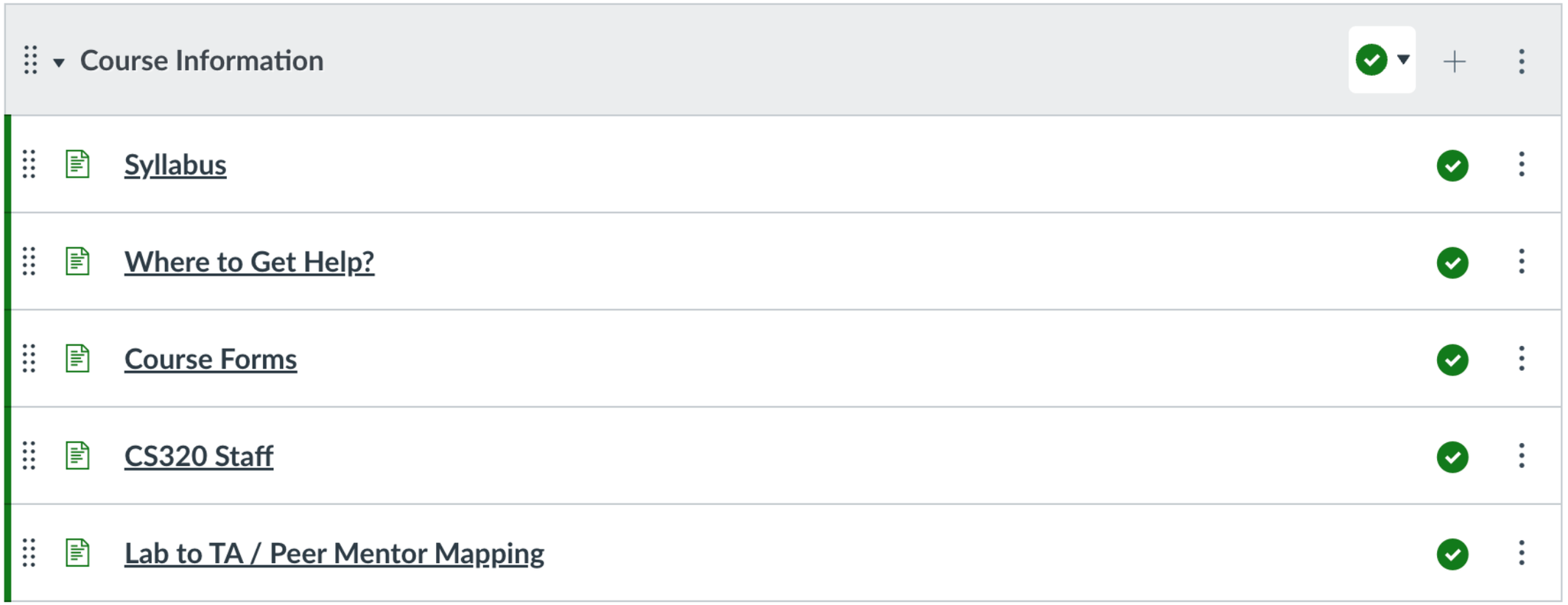
Builds on CS220. https://stat.wisc.edu/undergraduate-data-science-studies/

CS220	CS320
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	visualizations
tabular analysis	**simple machine learning**

CS220 content (for review): https://cs220.cs.wisc.edu/f22/schedule.html

Course Logistics

Canvas



Please read through the course info pages carefully!

I'll also use Canvas for:

- Announcements
- Projects, labs, quizzes, exams
- Lecture materials (slides, readings, lecture recordings, in-class worksheets, etc.)
- Late day summaries
- Grades

Class Organization: People

Groups

- you'll be assigned to a group of 4-7 students
- groups will last the whole semester
- collaboration with group members are allowed (not required) on labs, quizzes, and group part of the projects
- collaboration with non-group members is not allowed

Communication

Drop-in Office Hours:

- Where to Get Help? Page on Canvas
- Queue: https://ohwl.herokuapp.com/ (will send out an announcement later about how to use this website)

Piazza

- Don't post >5 lines of project-related code (considered cheating)
- Private posts disabled

Course Forms on Canvas

- Exam Conflicts Forms, Project/Lab Grading Issue Form, Feedback Form, Thank You Form

Email (least preferred)

- Me yshen82@wisc.edu or Young yw@cs.wisc.edu
- Head TA: Jinlang jwang2775@wisc.edu
- Course Staff: https://canvas.wisc.edu/courses/374279/pages/cs320-staff?module_item_id=6393170

Course Rhythm

Mon	Tue	Wed	Thu	Fri
Lecture + In-class Quiz		Lecture + In-class Quiz		Lecture + In-class Quiz
Lab				
		Weekly Quiz Released		Weekly Quiz Due
See Project Release + Due Dates on Canvas				
				First 2 Exams

Scheduled Activities

Lectures (MWF) (5% overall)

- Bring your laptop to take notes on the provided template Jupyter notebook
- In-class quizzes graded by correctness (Google forms / TopHat)
- No in-class quizzes on section wrap-up days and in-class exam days
- 12 drops out of 38 lectures

Labs (M/T) (1% each, 7% overall)

- Work through lab activities with group members
- Staff will circulate around and answer questions
- Need to submit screenshots of lab work (code and/or running results) within five minutes after the lab section ends
- No need to complete everything, but need to show sufficient working progress
- 5 drops out of 14 labs

Graded Work: Quizzes & Exams

11 Weekly Canvas Quizzes – (1% each, 1 drop, 10% overall)

- cumulative, open book/notes
- no time limit, 3 attempts
- can take together AT THE SAME TIME with group members (no help from other human is allowed)

3 Exams – (10% each, 30% overall)

- individual, multi-choice, 50 minutes
- Canvas with HonorLock
- one-page two-sided note sheet
- Friday, Oct 13th, in-class
- Friday, Nov 10th, in-class
- Tue, Dec 19th, time TBD

Graded Work: Projects

6 Projects – (8% each, 48% overall)

- format: python notebook or module
- group part: you can optionally collaborate with group
- individual part: must be done individually (only receive help from 320 staff)
- regular deadlines on course website
- late days without penalty: overall 12 late days
- hard deadline: 5 days after the regular deadline – 3 days of late days without penalty + 2 days of late days with 10% deduction each day
- `tester.py` + TA manual grading
- clearing auto-grader on the submission portal (https://tyler.caraza-harter.com/yiyin/fa23/submission.html) is mandatory
- will go over how to submit projects after P1 is released

Letter Grades

- Your final grade is based on sum of all points earned
- Your grade does not depend on other students' grade
- Scores will NOT be rounded up at the end of the semester
- No major score changes at the end of the semester

Grade cut-offs

- 93% - 100%: A
- 88% - 92.99%: AB
- 80% - 87.99%: B
- 75% - 79.99%: BC
- 70% - 74.99%: C
- 60% - 69.99%: D

Time Commitment & Academic Conduct

Project commitment

- 10-14 hours per project is typical (2-4 hours can be done in labs)
- 20% of students sometimes spend 20+ hours on some projects
- recommendation: start early and be proactive

Typical Weekly Expectations

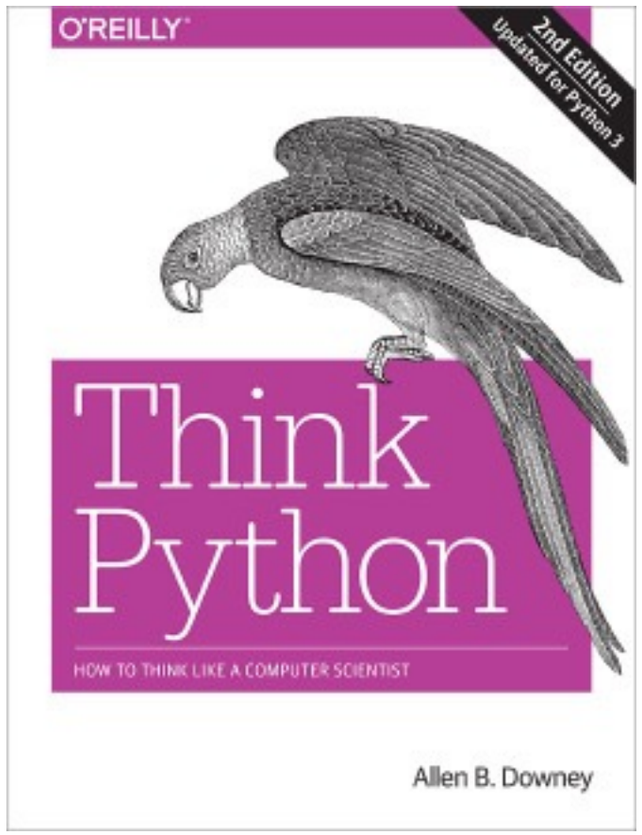
- 5 hours - lecture/lab
- 6 hours - project coding
- 2 hours - reading/quizzes/etc

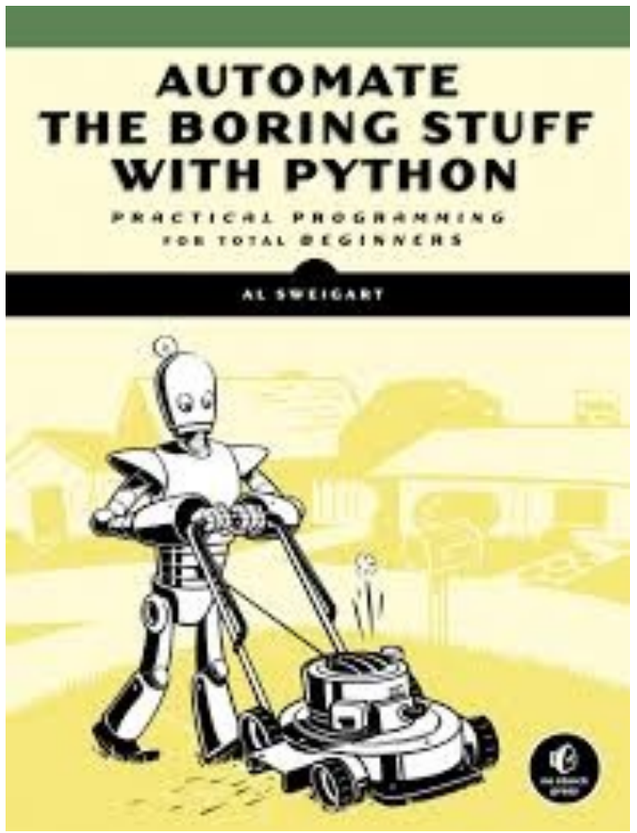
Please talk to me if you're feeling overwhelmed with 320 or your semester in general.

Academic Conduct

- Read syllabus to make sure you know what is and isn't acceptable.
- We will run plagiarism detection on project submissions.

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





I'll post links to other online articles and notes

Lectures don't assume any reading prior to class

Tips for 320 Success

1. Just show up
   in-class quizzes and labs, weekly quizzes, group work

2. Use office hours

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

Today's Lecture:

Reproducibility I

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**

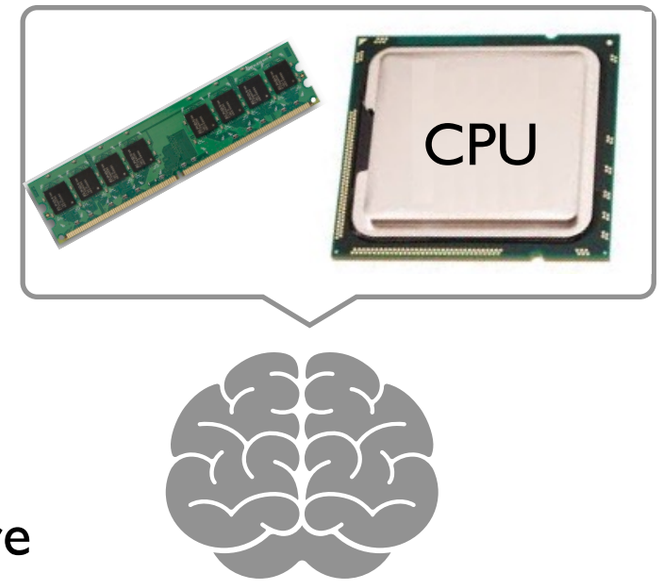
the ability to be reproduced or copied.
"the reproducibility of reconstructive surgery techniques"

- 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?*

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

Things to match:

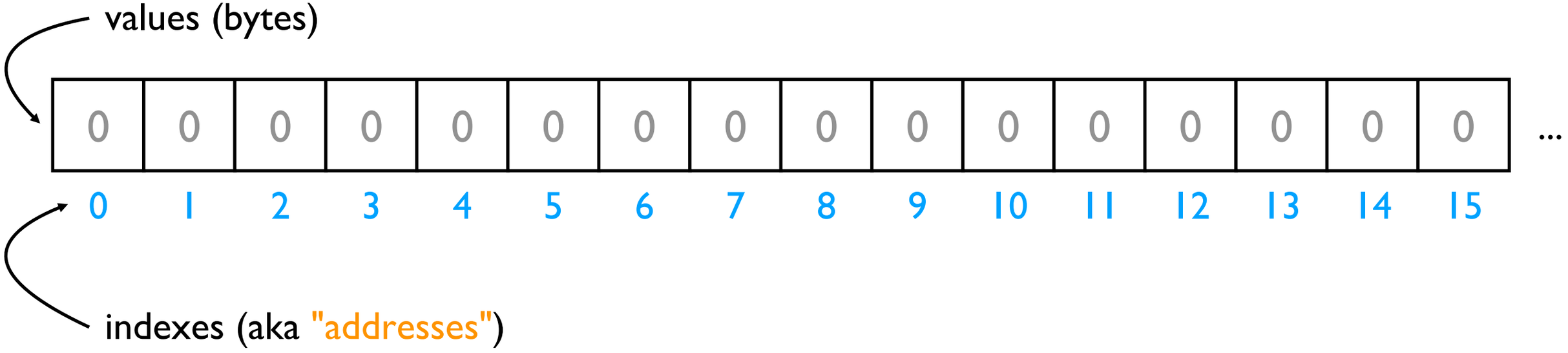


1. Hardware
2. Operating System ← next lecture
3. Dependencies ← next lecture

Hardware: Mental Model of Process Memory

Imagine...

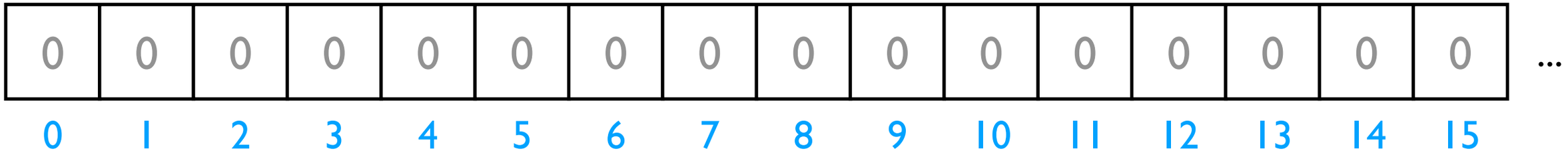
- one huge list, **per each** ~~running program~~ **process**, called **"address space"**
- every entry in the list is an integer between 0 and 255 (aka a "byte")



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

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

data



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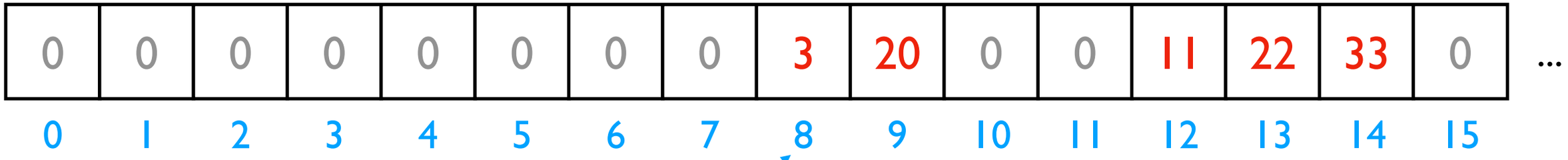

the [3,20] list starts at ~~index~~ address 8 in the giant list

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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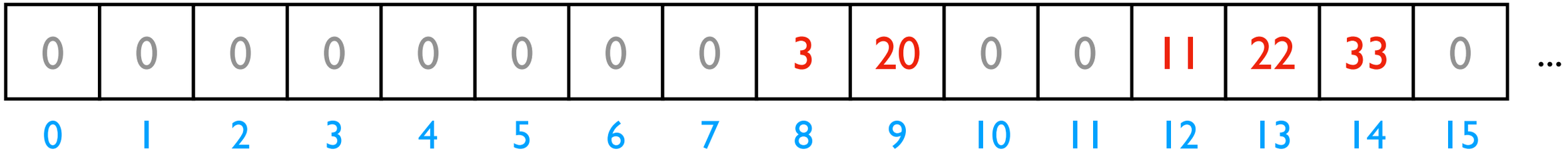

implications for performance...

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

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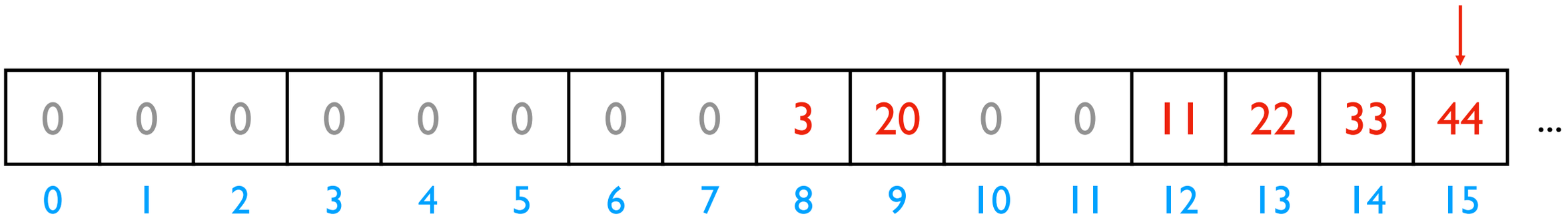

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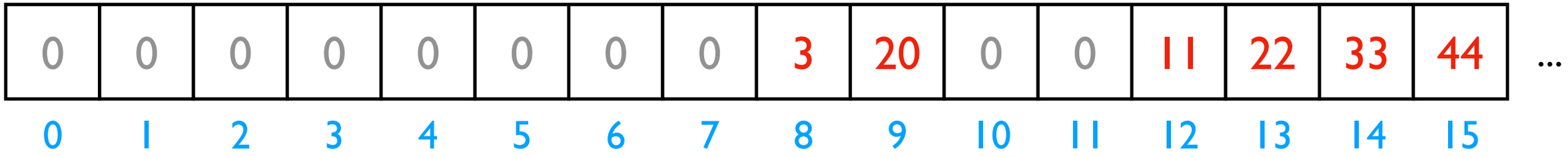

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# slow
L2.pop(0)
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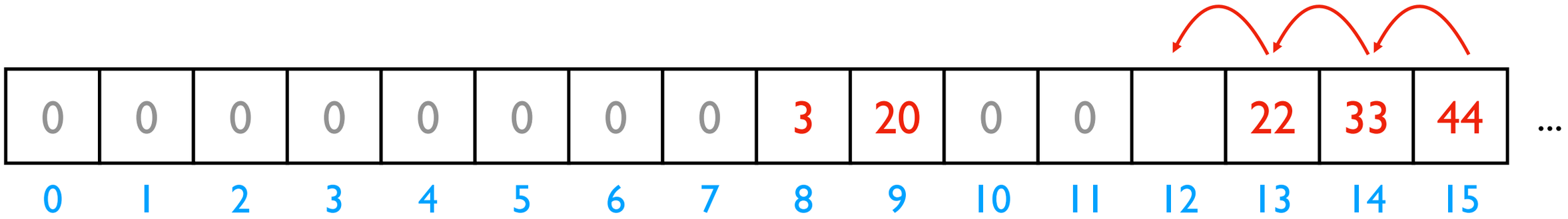

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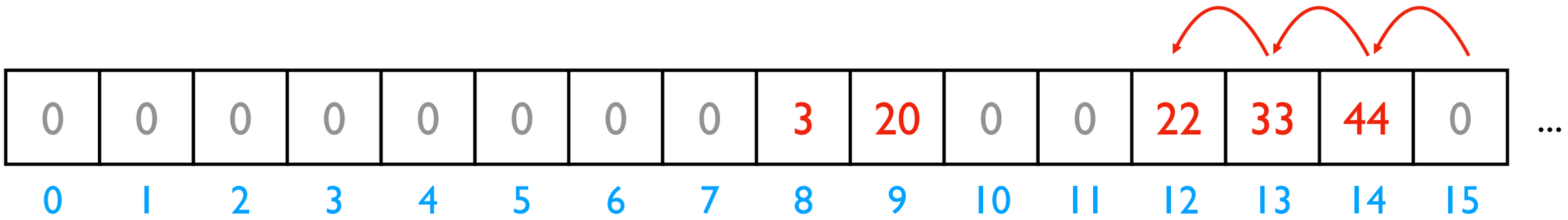

We'll think more rigorously about performance in CS 320 (big-O notation)

```
# fast
L2.append(44)

# slow
L2.pop(0)
```

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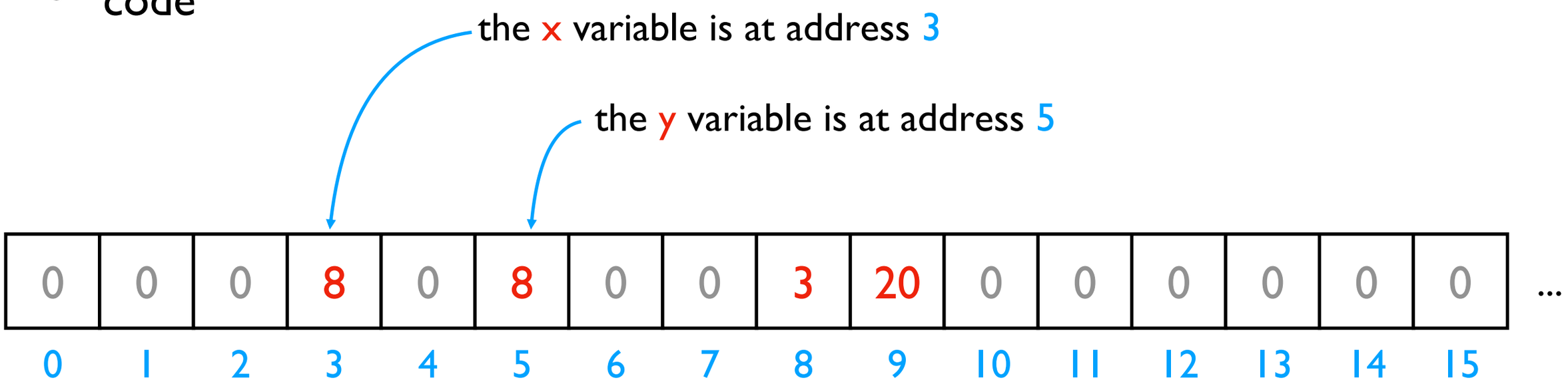

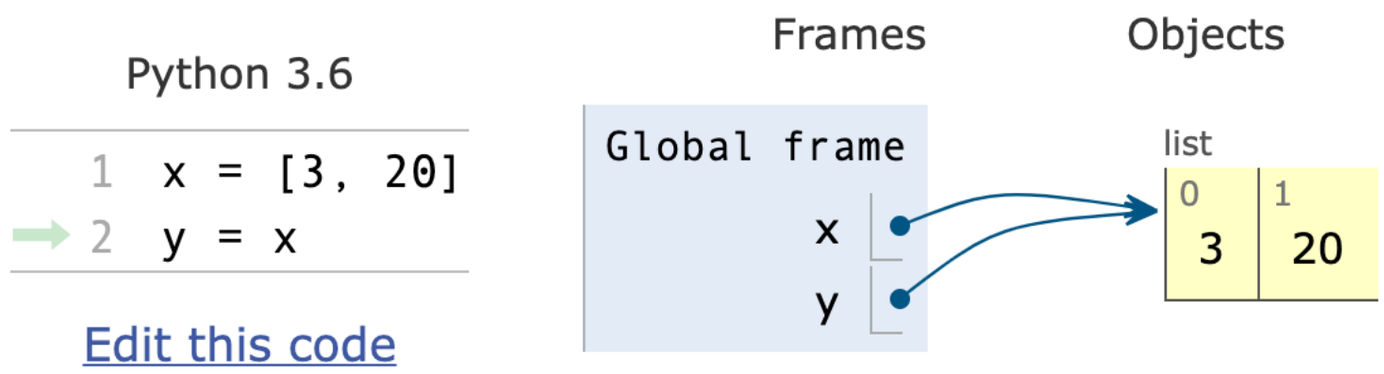

PythonTutor's visualization

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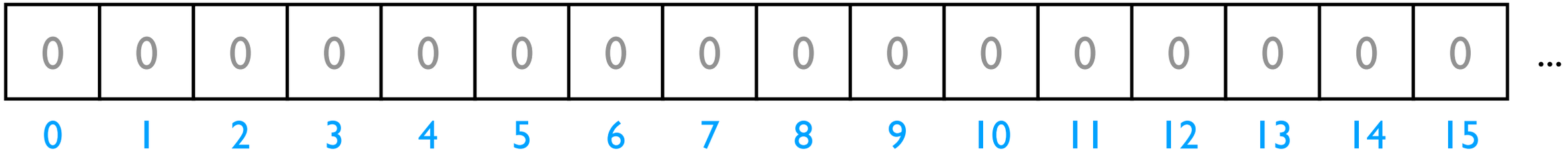
discuss: how?



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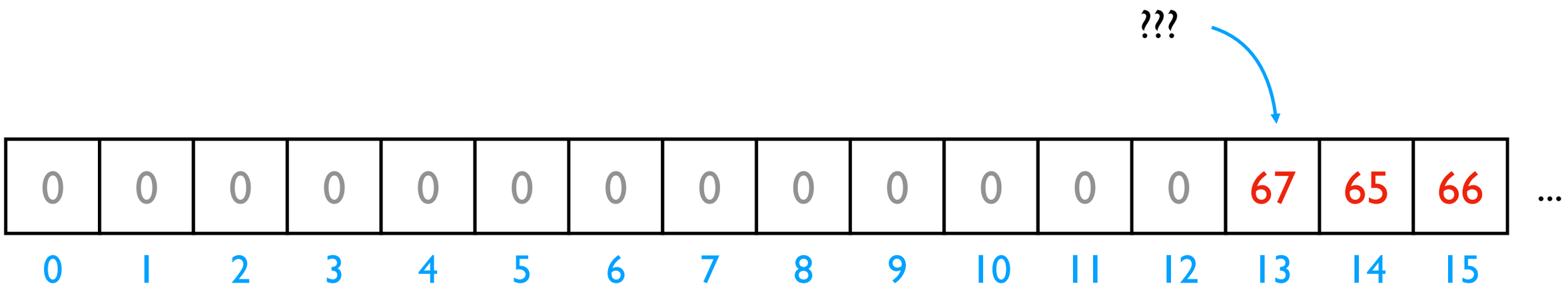

encoding:

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

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

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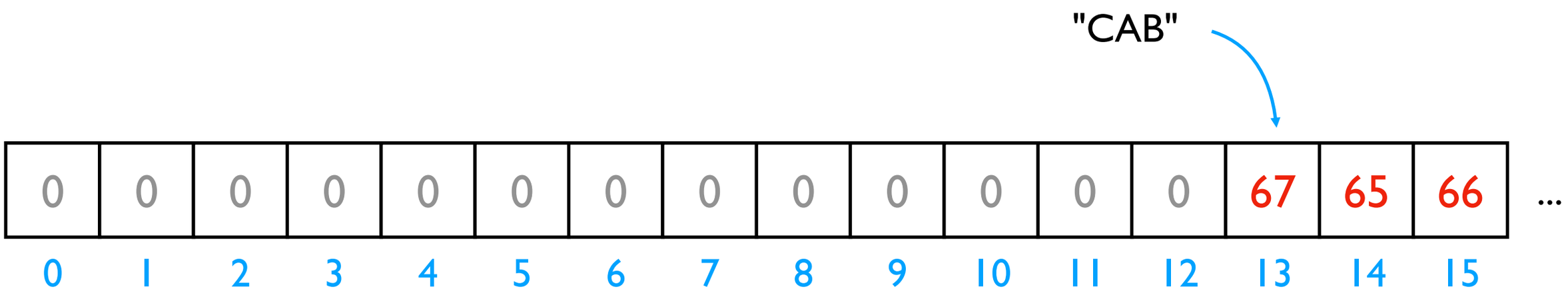

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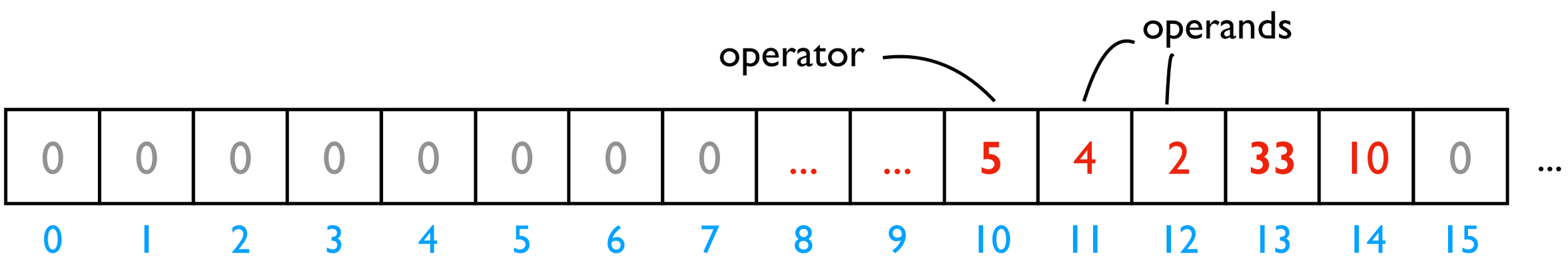
```
i = 0
while ????:
    i += 2
    # what line next?
```



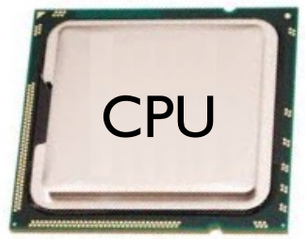
Instruction Set

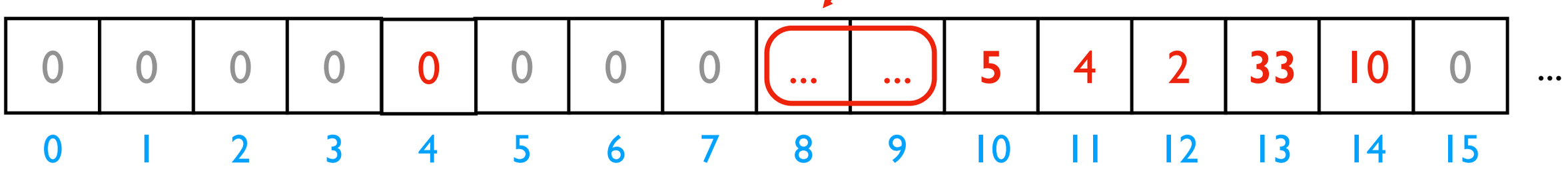
code	operation
5	ADD
8	SUB
33	JUMP
...	...

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
2
3
```

line that just executed

next line to execute

Instruction Set

code	operation
5	ADD
8	SUB
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...	...

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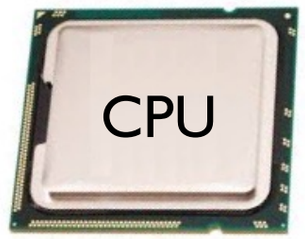
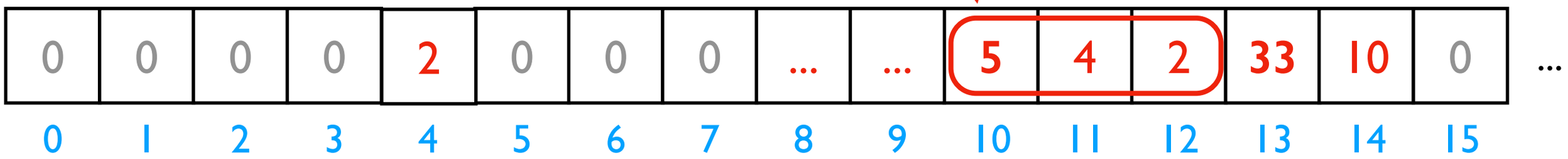


add 2 to variable



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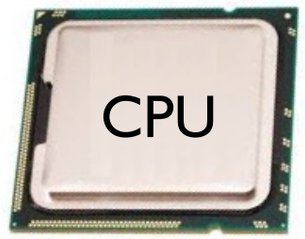
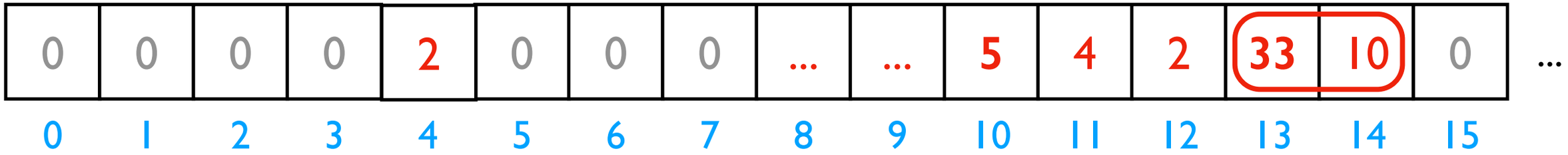


go back to top of loop



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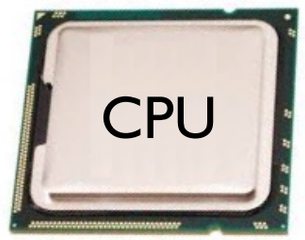
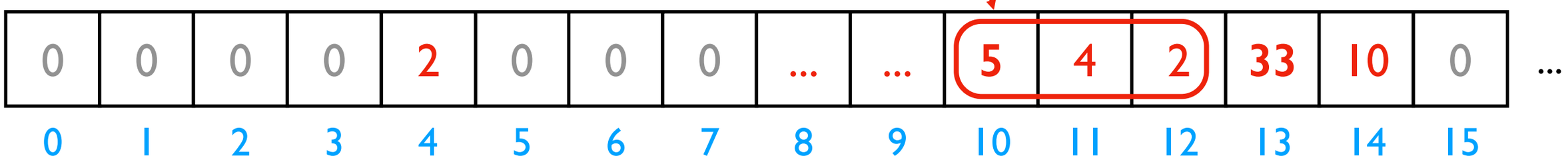


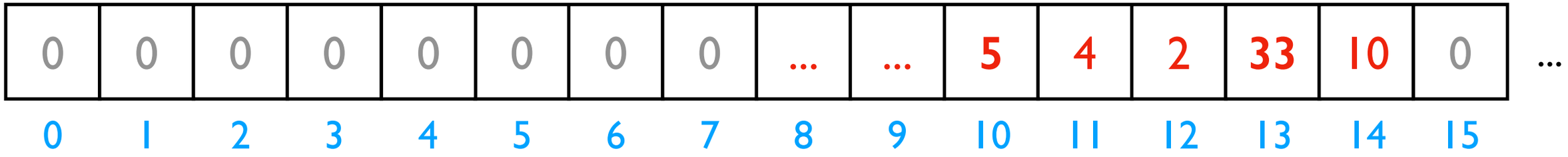


Instruction Set

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?



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!

0	0	0	0	0	0	0	0	...	...	**5**	**4**	**2**	**33**	**10**	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

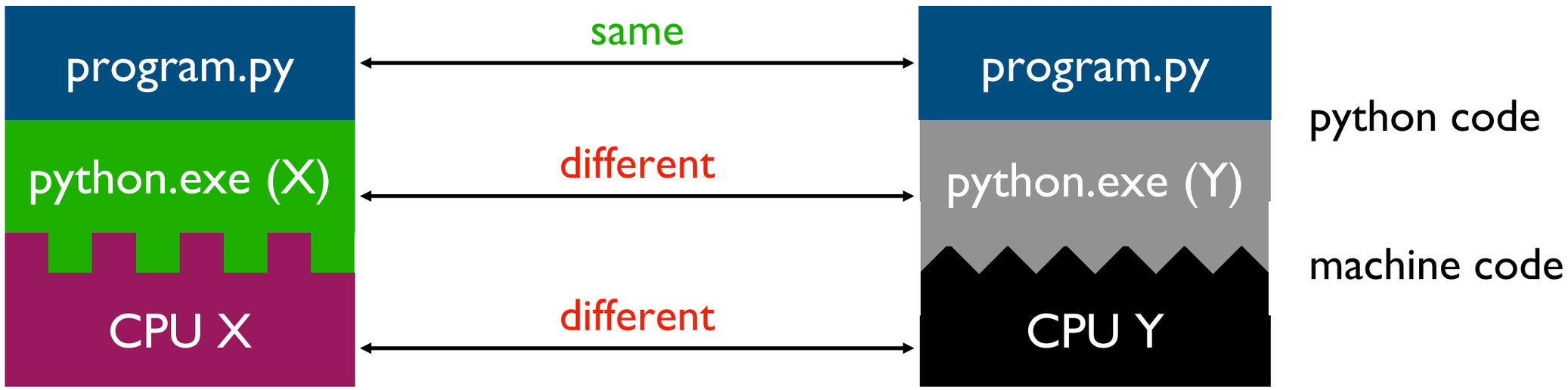
code	operation
5	SUB
8	ADD
33	undefined
...	...

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?

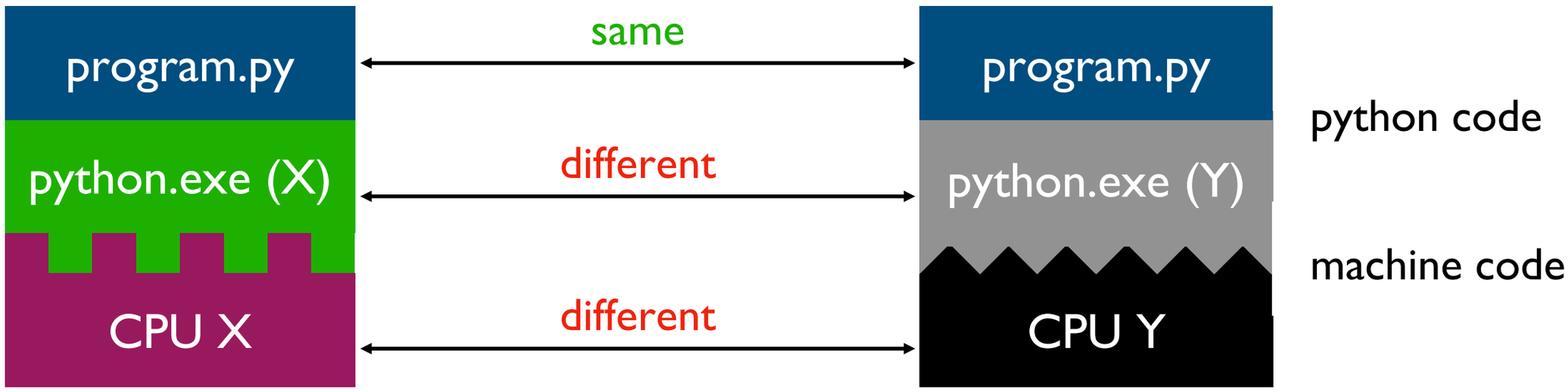
Interpreters



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



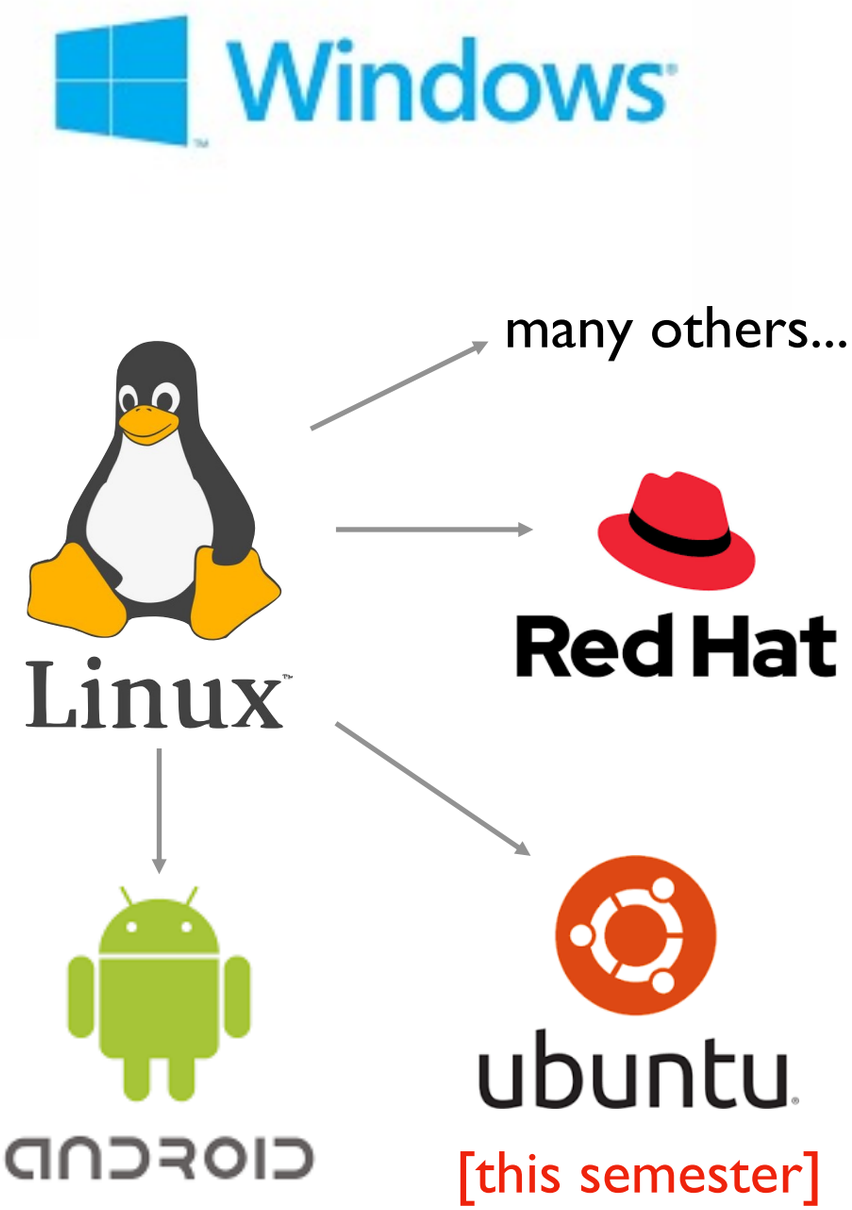
Interpreters (such as python.exe) make it easier to run the same code on different machines

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:

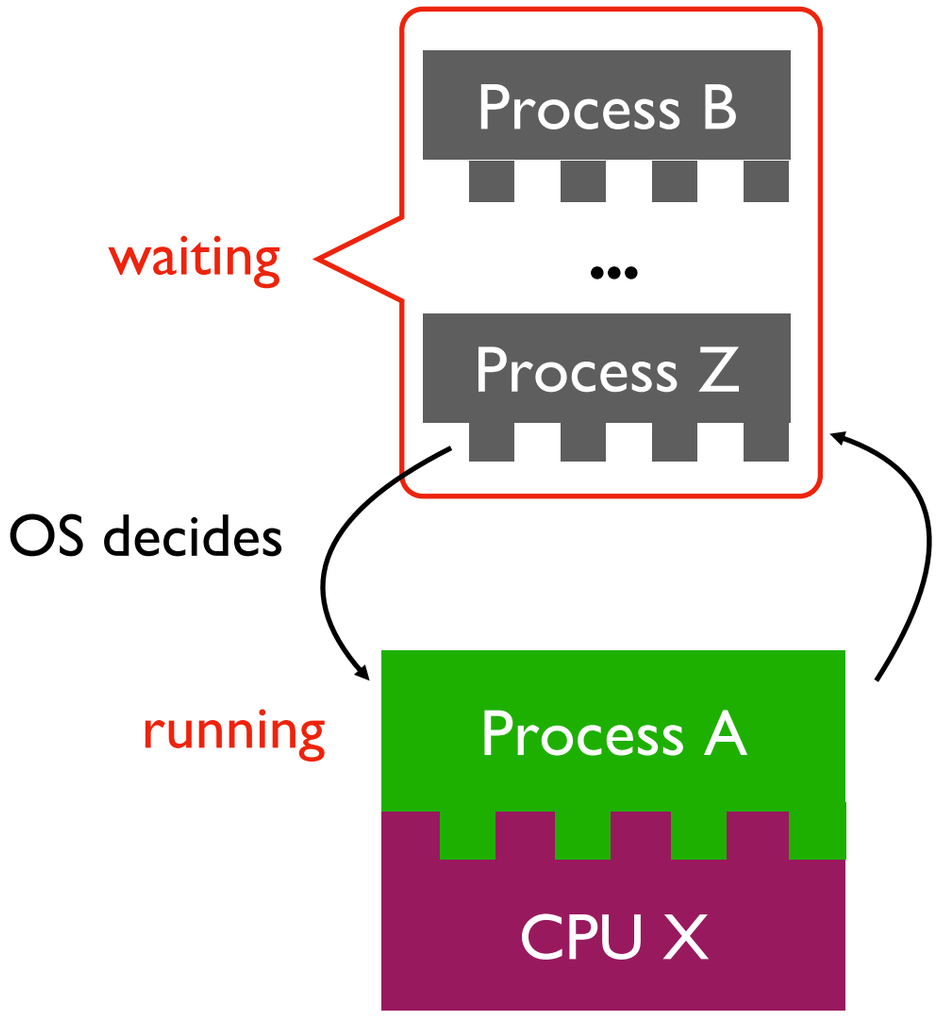
1. Hardware
2. Operating System
3. Dependencies



OS jobs: Allocate and Abstract Resources

[like CPU, hard drive, etc]

1 Allocation



only one process can run on CPU at a time
(or a few things if the CPU has multiple "cores")

2 Abstraction

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

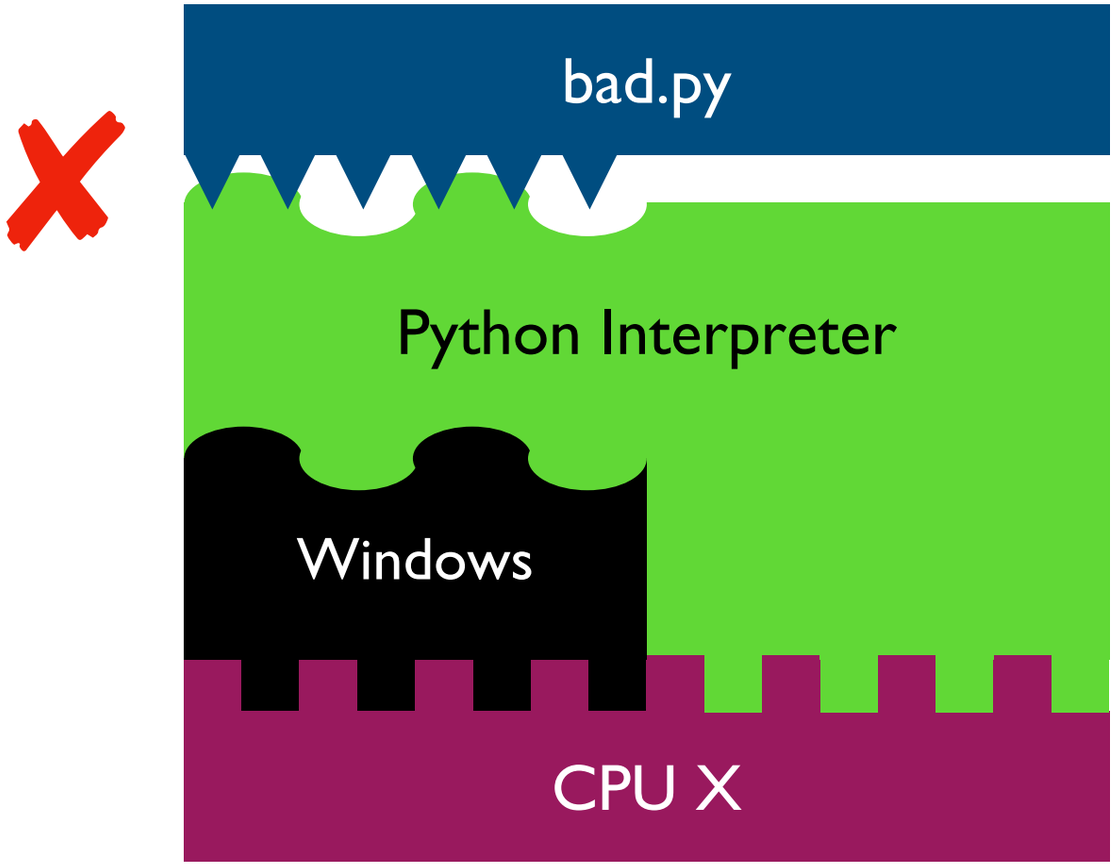
convenient

Operating System

inconvenient

ignorant of files/directories

Harder to reproduce on different OS...

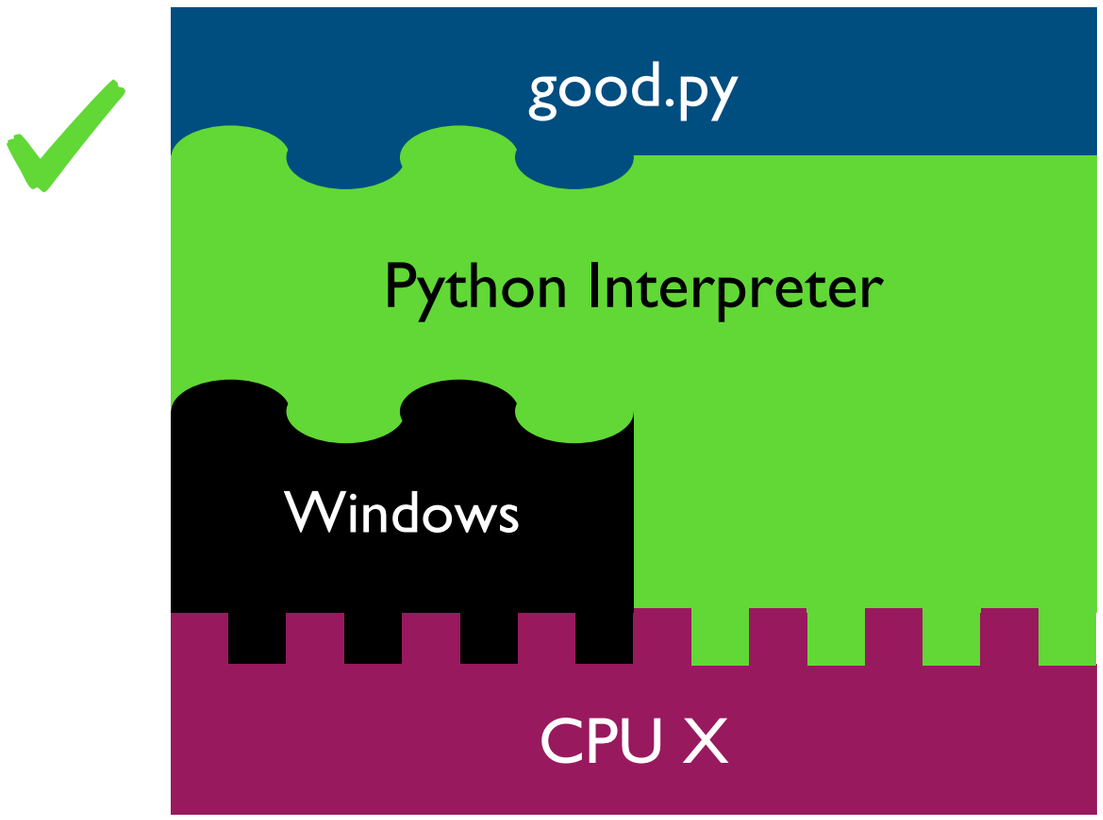



```
f = open("/data/file.txt")
...
```

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...

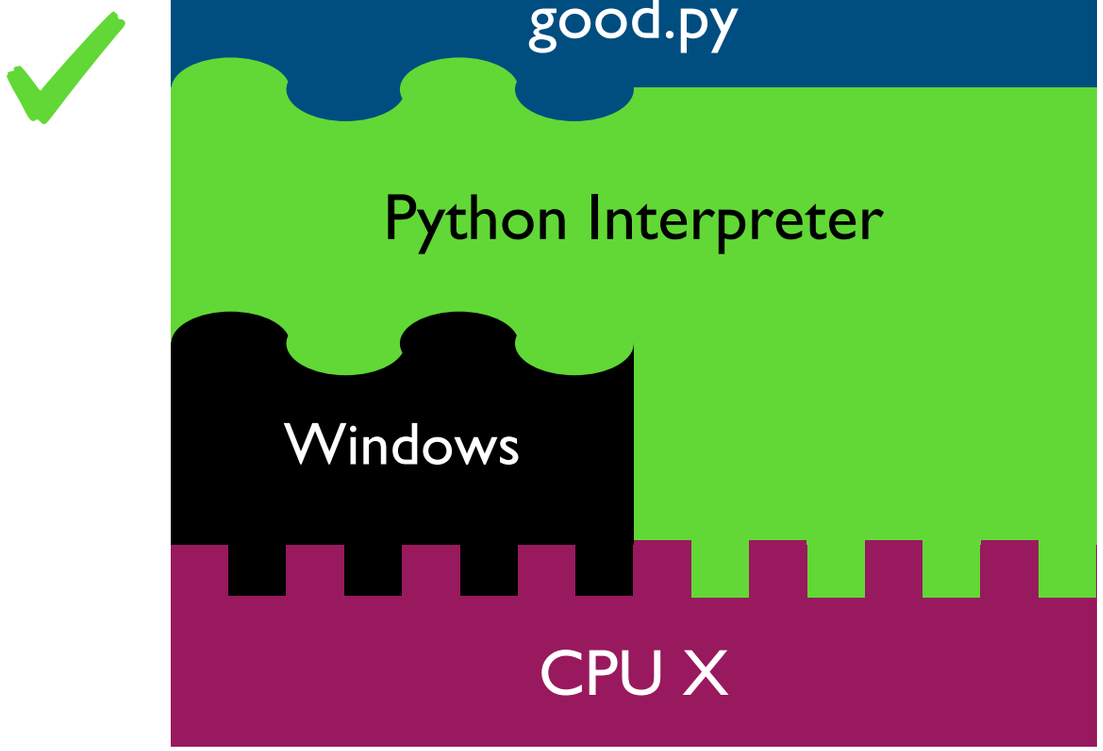



```
f = open("c:\data\file.txt")
...
```

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?

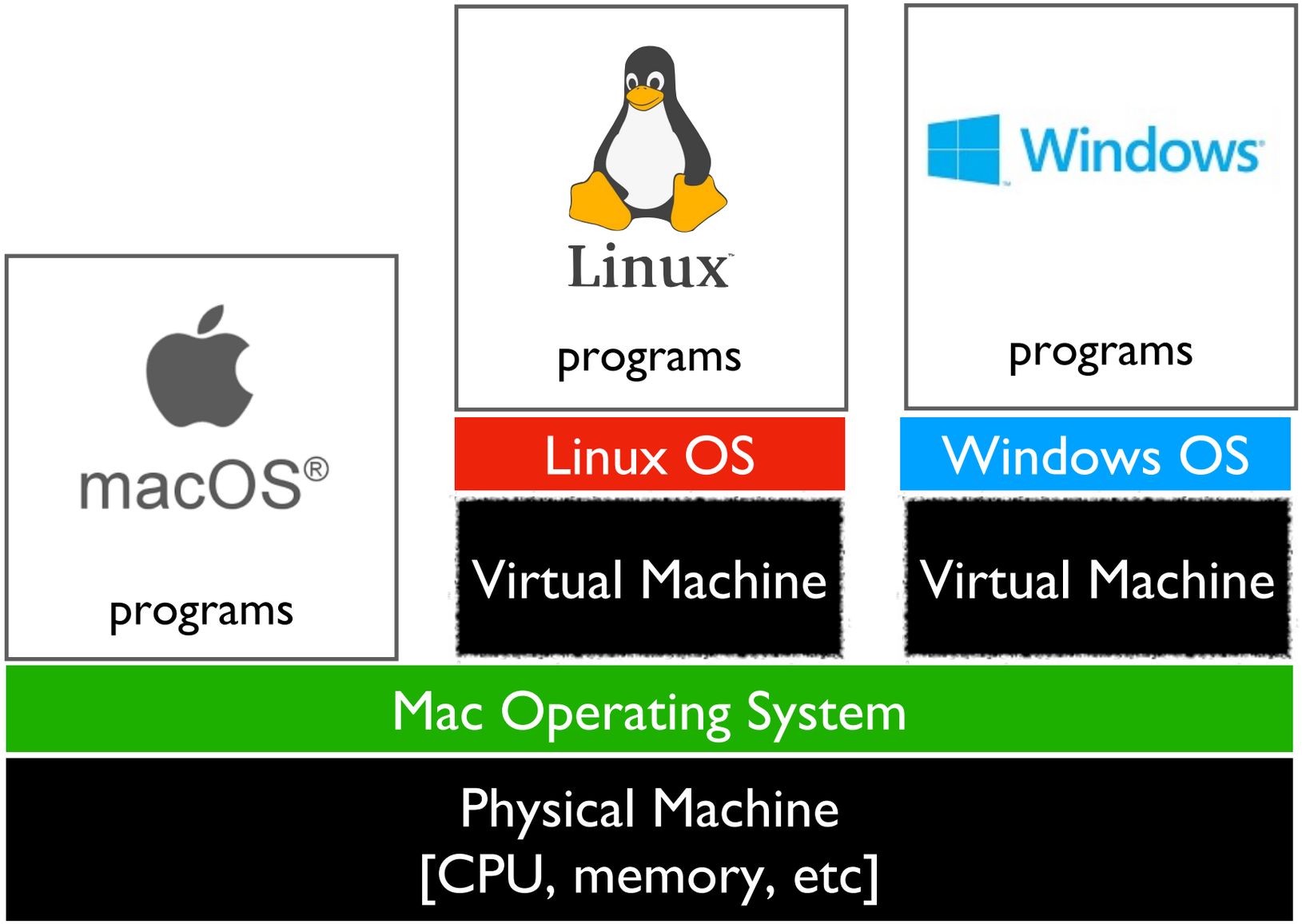
The Python interpreter mostly lets you
[Python Programmer] ignore the CPU you run on.

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

VMs (Virtual Machines)

popular virtual machine software

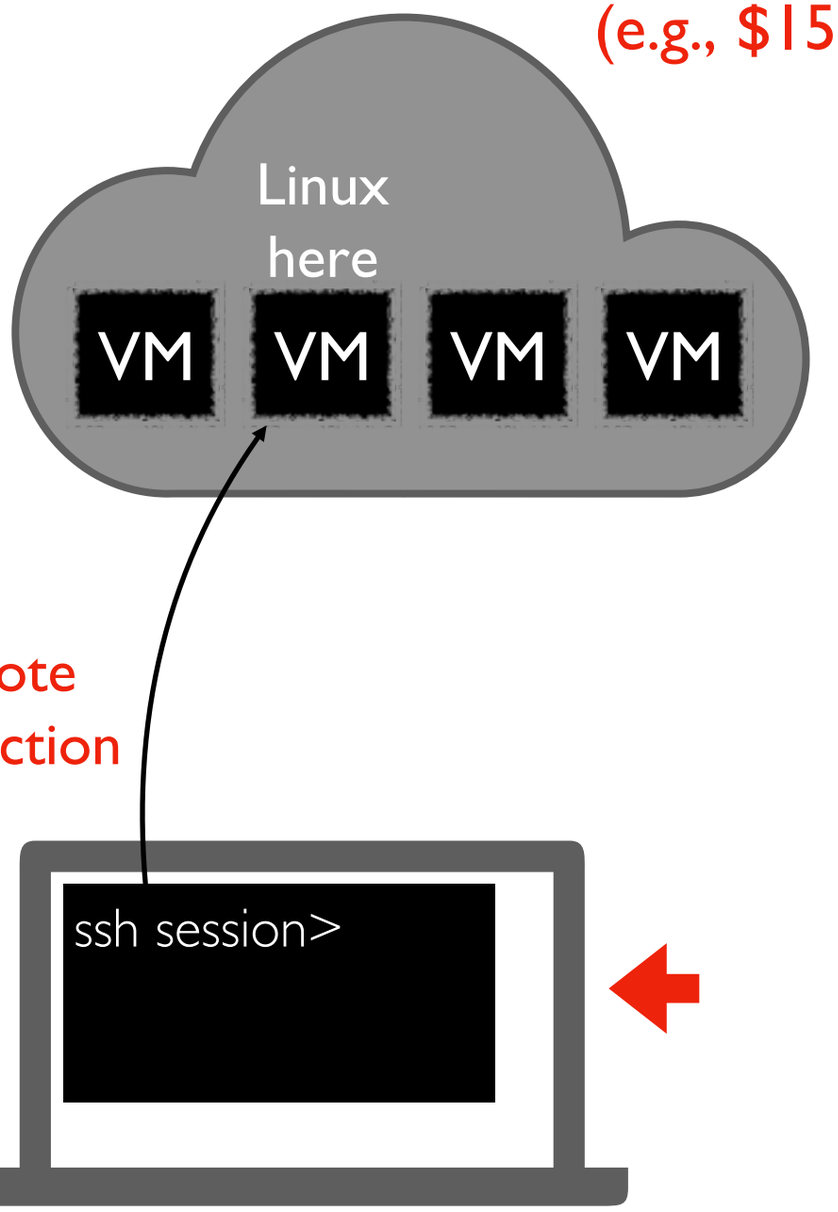
Microsoft Hyper-V



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

Google Cloud Platform

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

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

address space: 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 run 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