[320] Welcome + First Lecture [reproducibility]

Department of Computer Sciences
University of Wisconsin-Madison

Introductions

Tyler Caraza-Harter

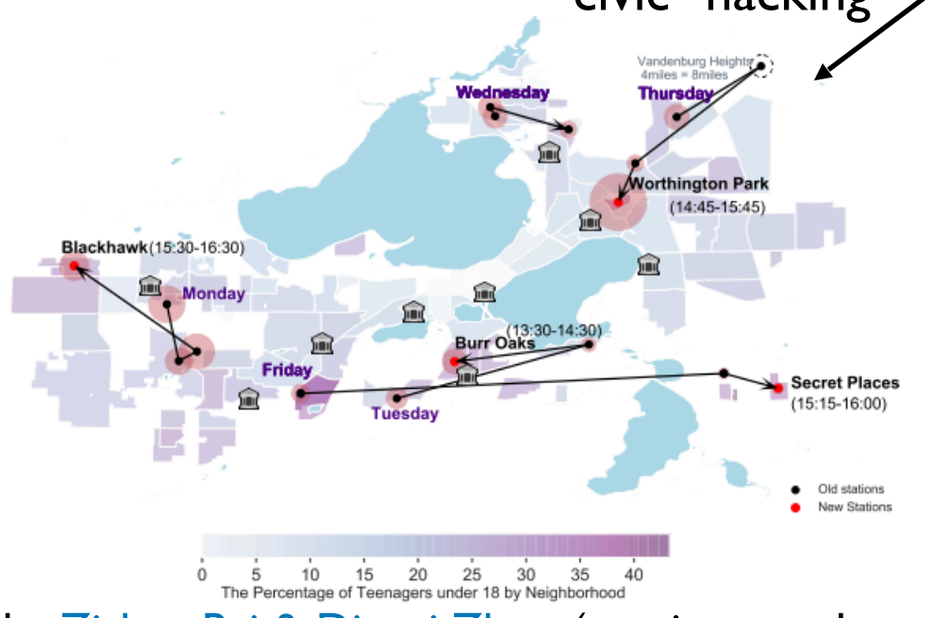
- Long time Badger
- Email: tharter@wisc.edu
- Just call me "Tyler" (he/him)

Industry experience

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

interests

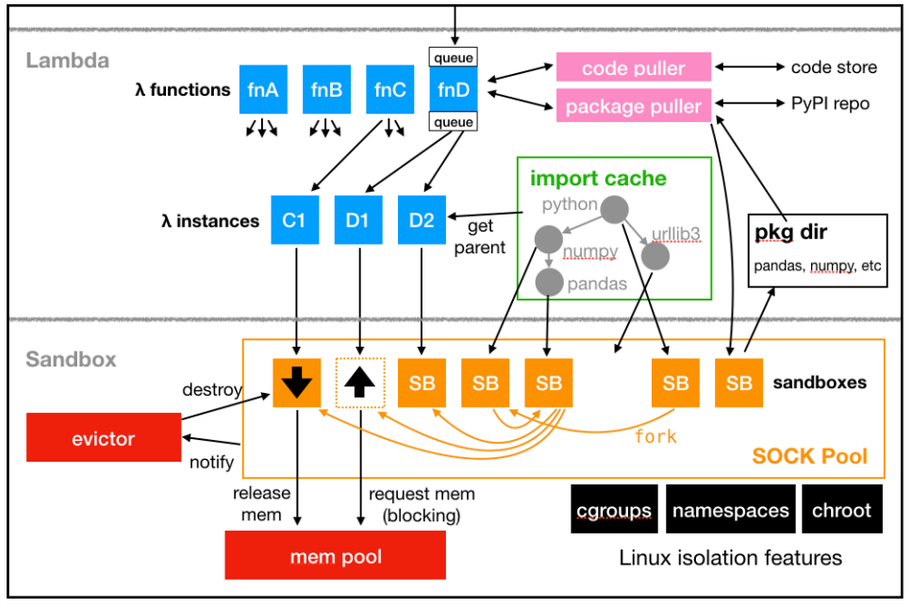
civic "hacking"



Plot by Zishan Bai & Dingyi Zhou (previous students)

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

OpenLambda



Introductions

Meenakshi (Meena) Syamkumar
- Email: ms@cs.wisc.edu
- Please call me "Meena"

Industry and Teaching experience
- Citrix, Cisco, and Microsoft
- CS300, CS220, CS367, guest lectures in CS640, CS740

Research
- Network measurements
- CS education

Introductions

Gurmail Singh
- Email: Gurmail.Singh@wisc.edu
- Please call me “Singh” (he/him/his)

Teaching experience
- BLM Girls College, Punjab, India
- Khalsa College, Punjab, India
- University of Regina, Saskatchewan, Canada

Research Interests
- Algebra and Artificial Intelligence

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?

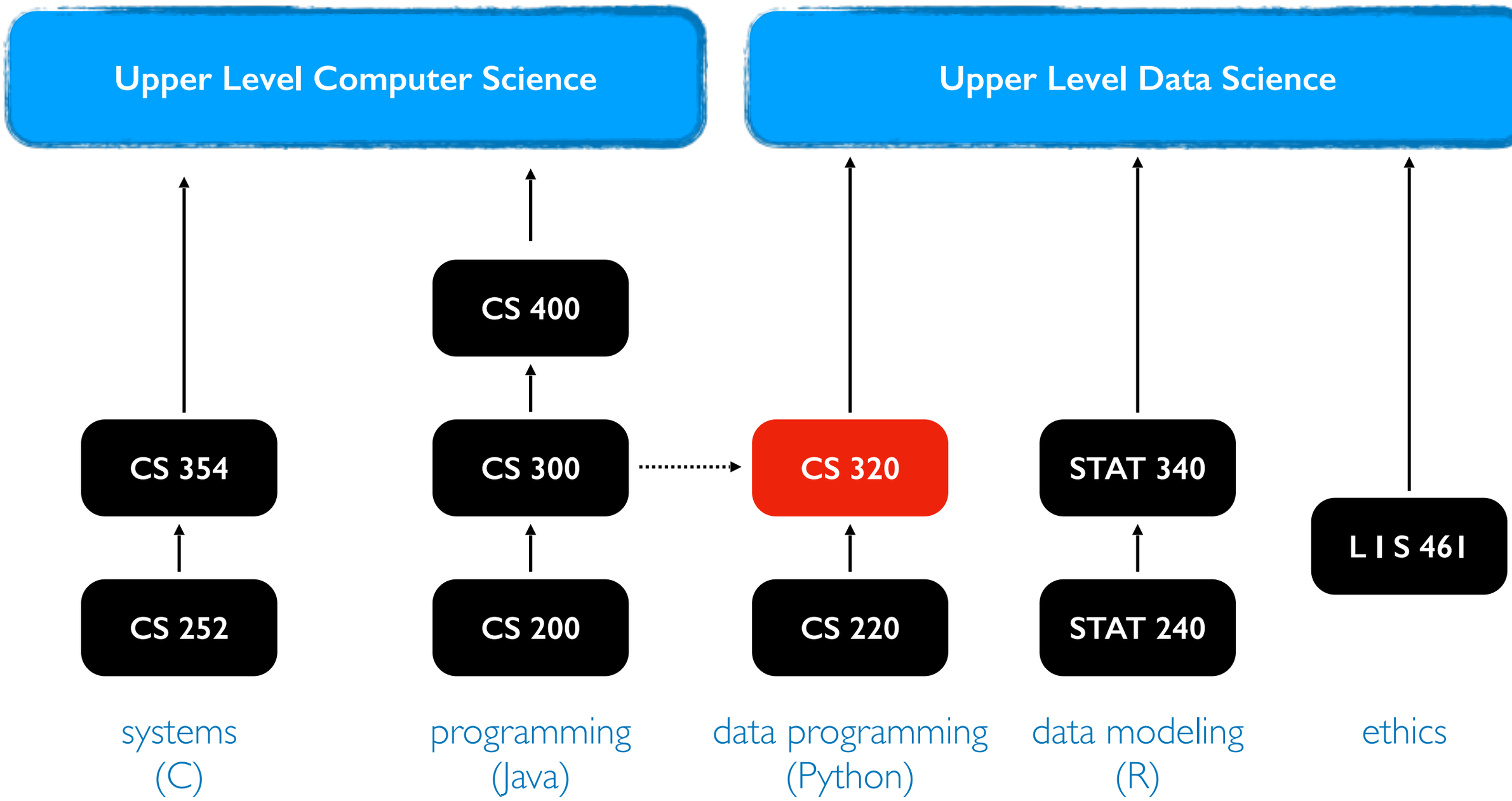
- CS 220/301? CS 200? CS 300? CS 354?

Please fill the Student Information Survey (Survey 1).

Why?

- Help me get to know you
- Get credit for completing it

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	animated visualizations
tabular analysis	**simple machine learning**

CS220 content (for review): https://cs220.cs.wisc.edu/f23/schedule.html

Course Logistics

Channels of Communication

- Course Website: https://cs320.cs.wisc.edu/fa24/schedule.html
    - Read the syllabus carefully and checkout other content on the course website
- Canvas: I will use Canvas for the following
    - General announcements
    - Quizzes/exams
    - Grade summaries
    - Online hours (Zoom links)
- Email: Students are supposed to check the their email regularly for possible emails from me.

Scheduled Activities

Lectures

- **2** times weekly; recommendation: bring your laptop
- Required for participation credit! Attendance recorded via TopHat quizzes (20% score drops) as mentioned in the syllabus
- will often be recorded + posted online (questions will be recorded -- feel free to save until after if you aren't comfortable being recorded)
- might not post if bad in-person attendance or technical issues, and recordings may be edited.

Lab

- Weekly on Tuesdays and Wednesdays, bring a laptop
- Work through lab exercises with group mates
- 320 staff will be available to answer questions
- Required for lab attendance credit! 3 score drops

Class organization: People

Teams

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

Staff

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

We all provide office hours.
For details, please read Get Help page on the course website.

Communication

Piazza

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

Forms

- https://cs320.cs.wisc.edu/fa24/surveys.html
- **Exam conflicts.** Grading Issues. Feedback form. Thank you form!

Email (least preferred)

- me: gurmail.Singh@wisc.du
- Course staff: https://canvas.wisc.edu/courses/427084/pages/cs320-staff
- Email is the least preferred form of communication. We will not provide debugging h
  email - please attend office hours for that.

Graded Work: Exams / Quizzes

Ten Online Quizzes - 1% each (10% overall)- 1 score drops

- cumulative, two attempts, no time limit
- score will be average of both attempts
- on Canvas, open book/notes
- can take together AT SAME TIME with team members (no other human help allowed)

Midterms - 10% each (20% overall)

- cumulative, individual, multi-choice, 40 minutes
- one-page two-sided note sheet allowed

Final - 10%

- cumulative, individual, multi-choice
- 2 hours (Probably less than the scheduled time will be used for the final exam)
- one-page two-sided note sheet allowed

Graded Work: Projects

8 Projects - 50% overall (for details, read the syllabus)

- **format**: notebook, module, or program
- regular deadlines are on course website
- late days: overall 12 late days
- hard deadline: 7 days after the regular deadline – maximum 3 late days; 5% score penalty per day after day 3
- still a `tester.py`, but more depends on TA evaluation
- clearing auto-grader on the submission portal is mandatory
- you may not be allowed to use any late days on the last project.
- ask for specific feedback (constructive)

Graded Work: Attendance + Surveys

Lab attendance - 5% overall

- 3 score drops:
- use these wisely – potential sickness, planned absences
- no other exceptions

Lecture attendance - 4% overall

- 20% score drops

Surveys - 1% overall

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 off 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

- 10-12 hours per project is typical
- 20% of students sometimes spend 20+ hours on some projects
- recommendation: start early and be proactive

Typical Weekly Expectations

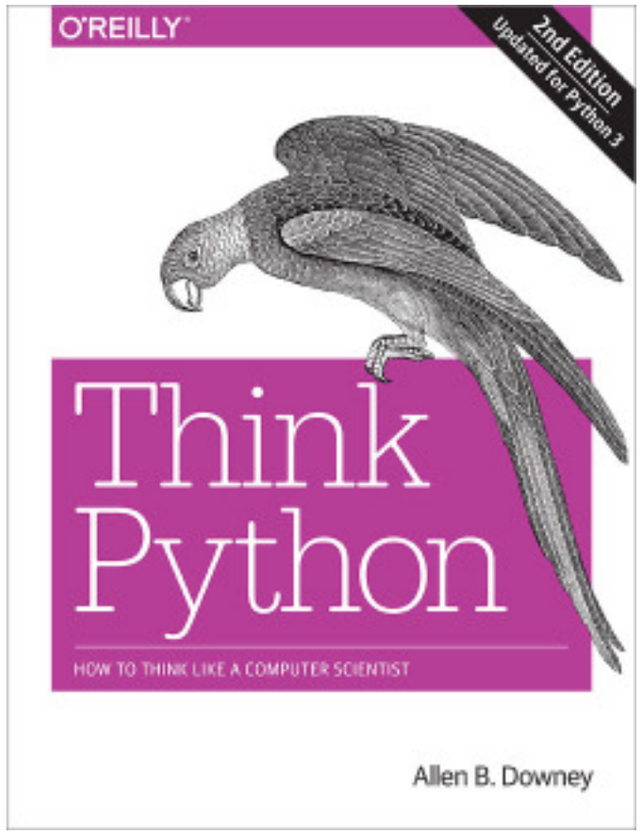
- 4 hours - lecture/lab
- 6 hours - project coding
- 2 hours - reading/quizzes/etc

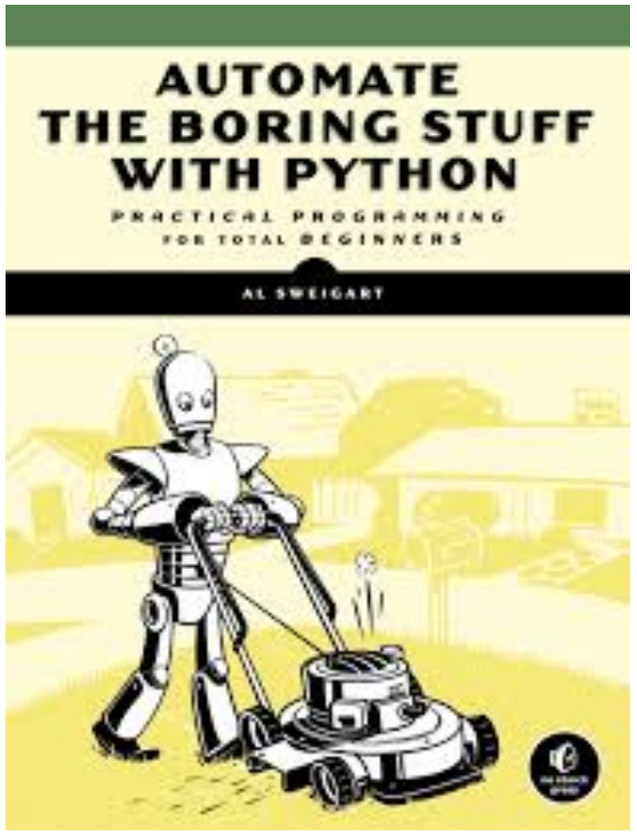
Please talk to me if you're feeling overwhelmed with 320 or your semester in general.

Academic Conduct

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

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





I may 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!
   - ➡ Get 100% on participation, don't miss quizzes, submit group work

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

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)o͞osəˈbilədē/

noun

noun: **reproducibility**

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

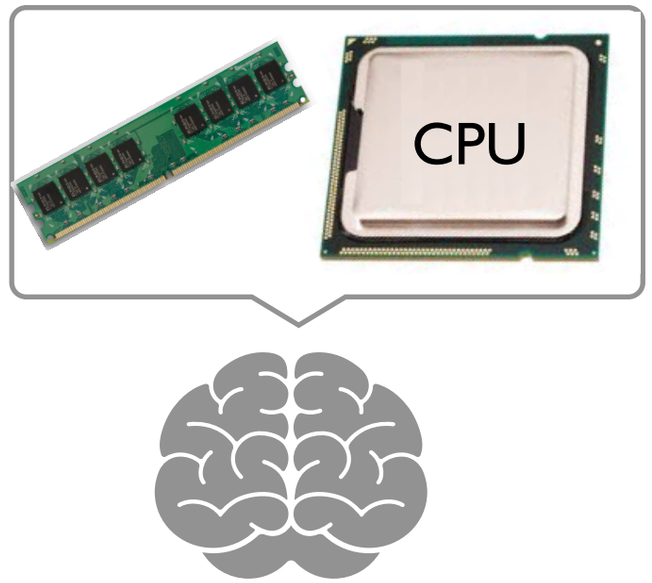
- the extent to which consistent results are obtained when an experiment is repeated.
  "the experiments were conducted numerous times to test the reproducibility of the results"

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:

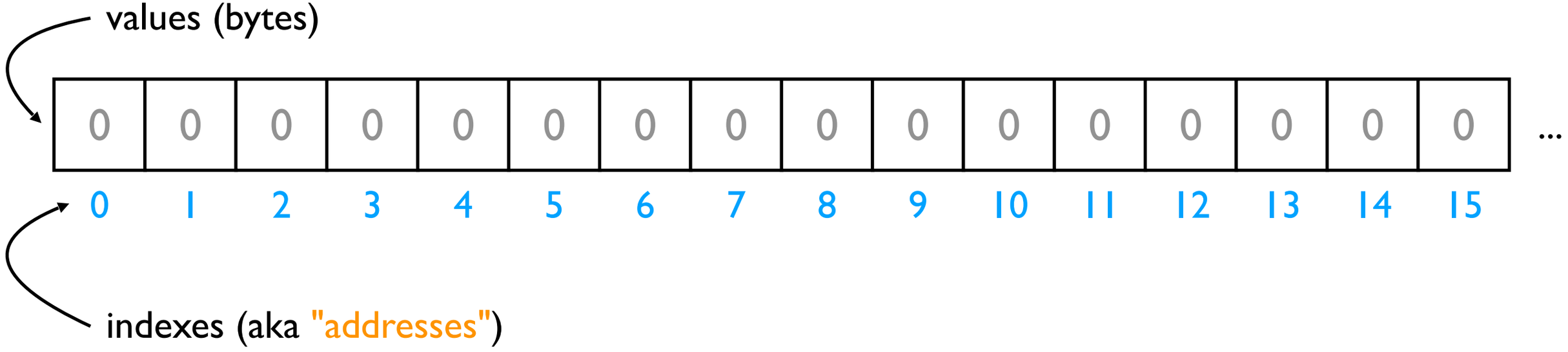
1. Hardware
2. Operating System
3. Dependencies



Hardware: Mental Model of Process Memory

Imagine...

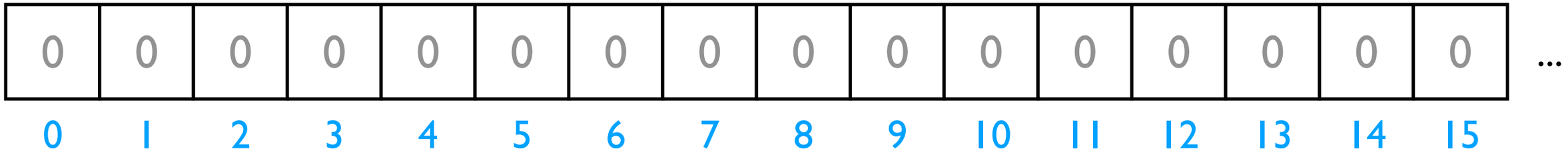
- one huge list, **per each** ~~running program~~ **process**, called **"address space"**
- every entry in the list is an integer between 0 and 255 (aka a "byte")



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

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

data



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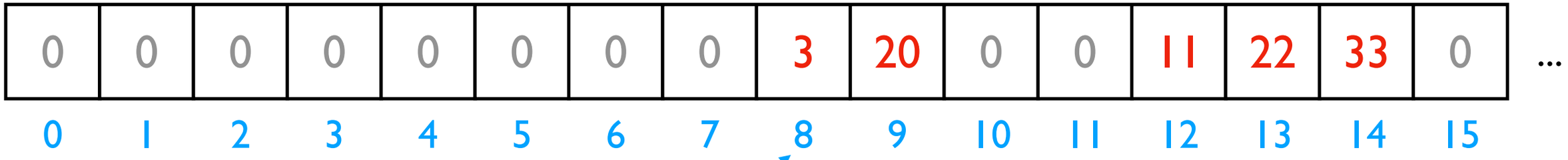

the [3,20] list starts at ~~index~~ address 8 in the giant list

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

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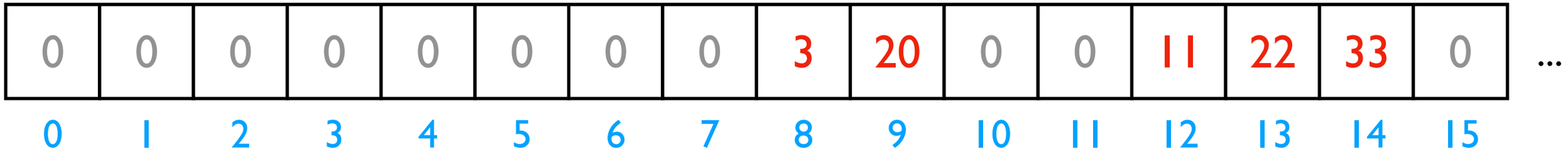

implications for performance...

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

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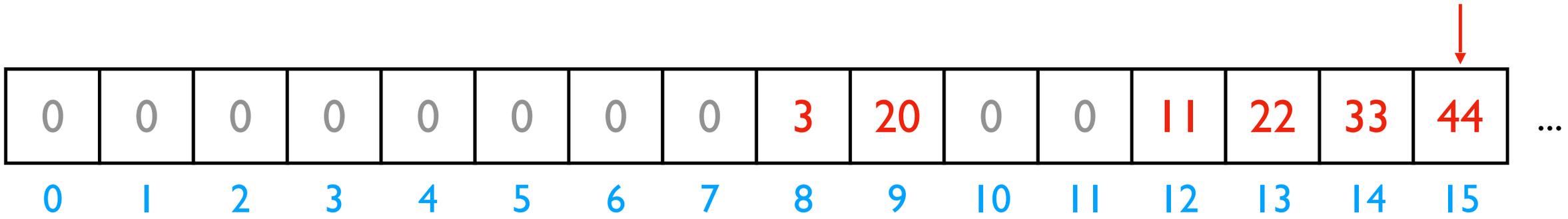

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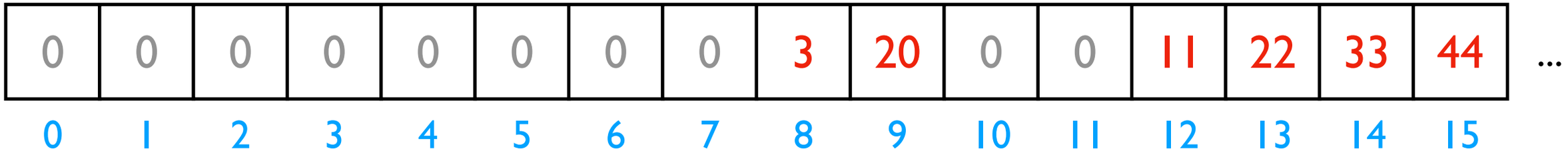

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# fast
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L2.pop(0)
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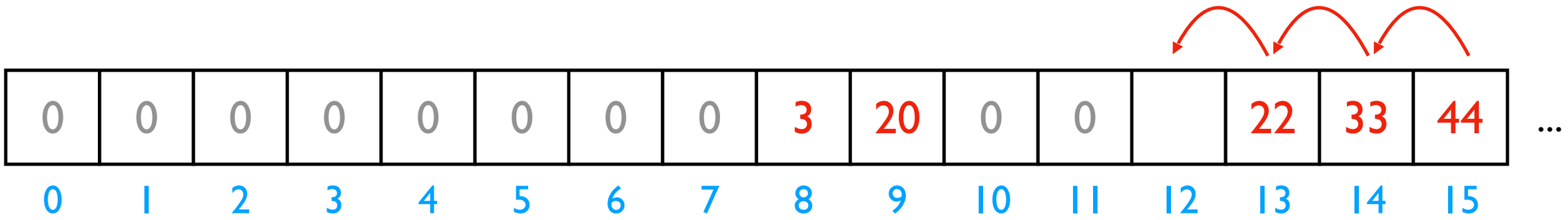

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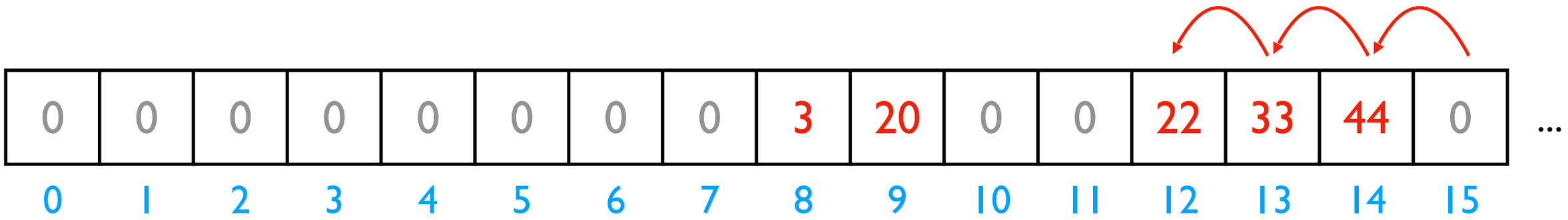

We'll think more rigorously about performance in CS 320 (big-O notation)

```
# fast
L2.append(44)

# slow
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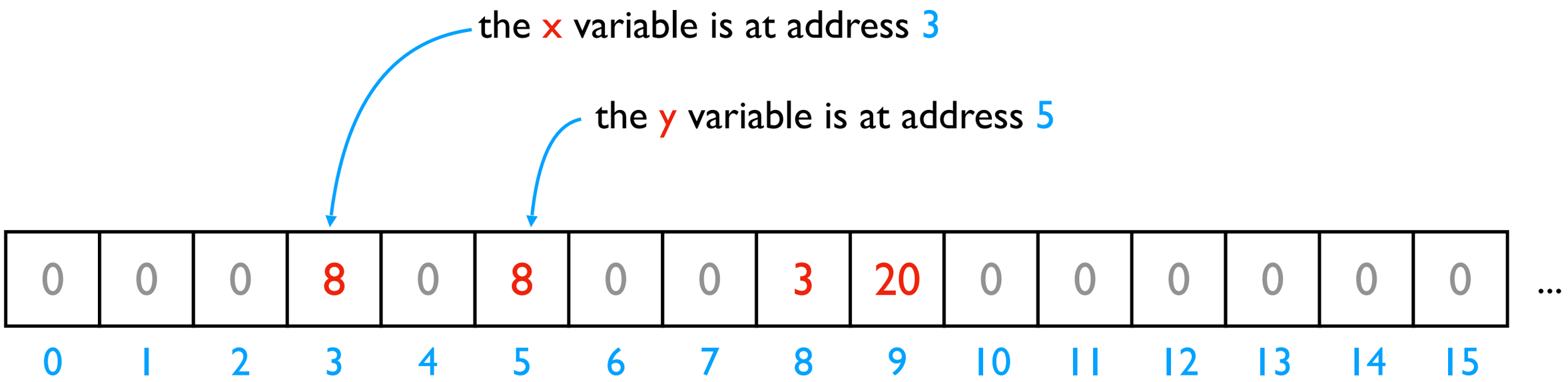

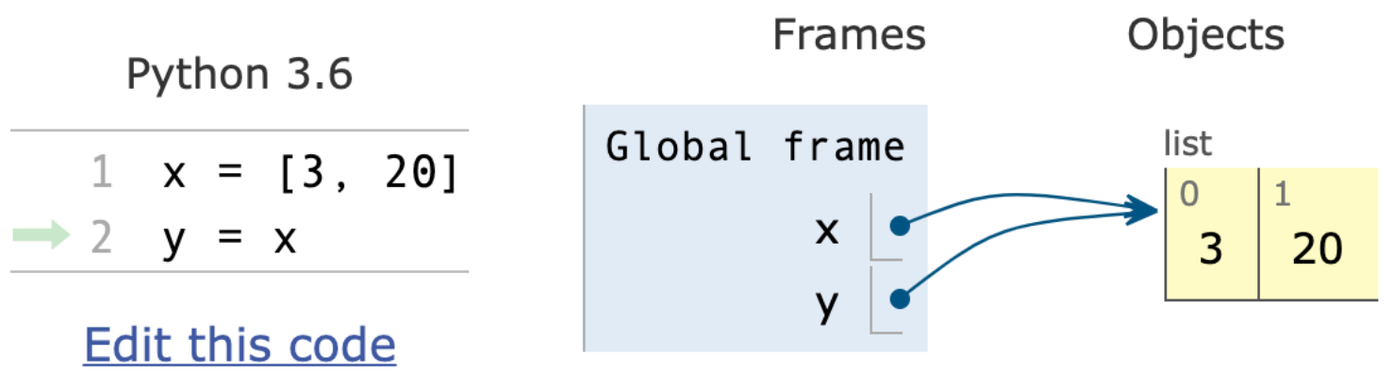

PythonTutor's visualization

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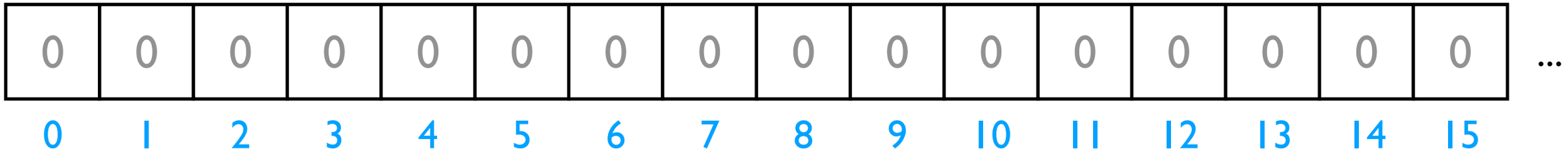
discuss: how?



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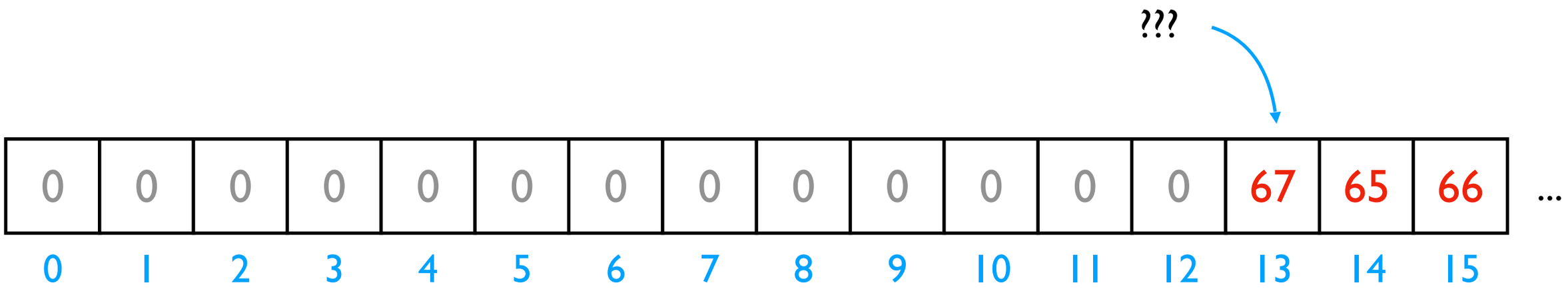

encoding:

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

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

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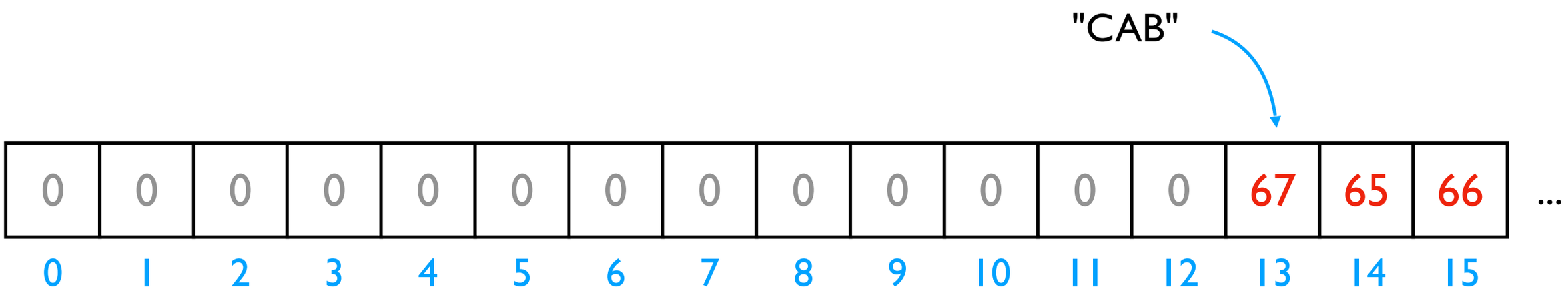

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```
i = 0
while ????:
    i += 2
    # what line next?
```

operator

operands

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	

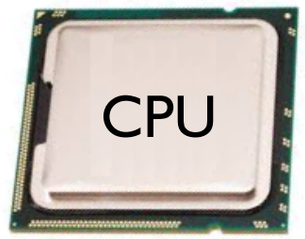
Instruction Set

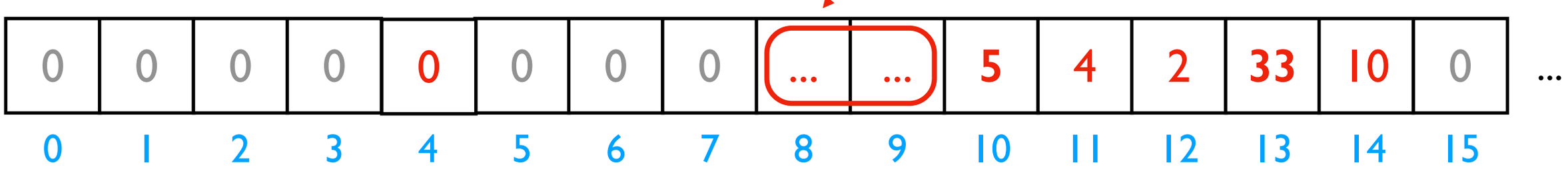
code	operation
5	ADD
8	SUB
33	JUMP
...	...

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
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...	...

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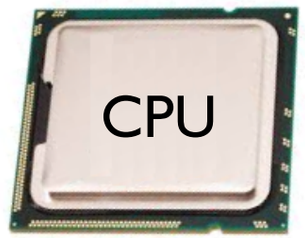
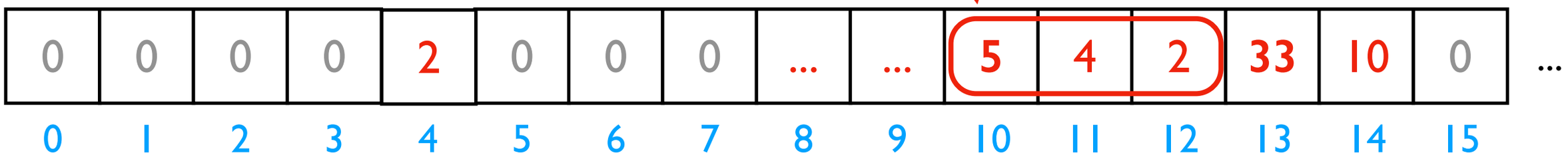


add 2 to variable



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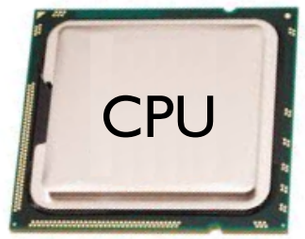
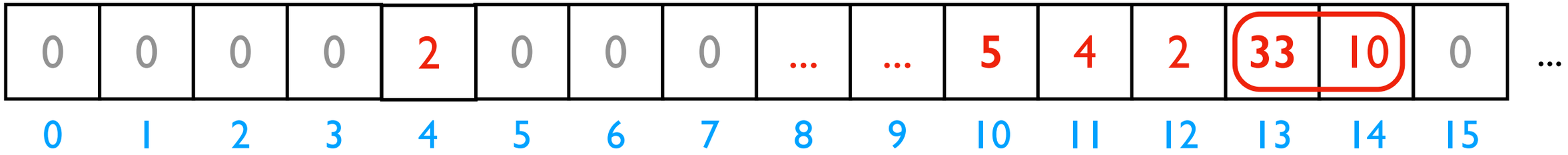


go back to top of loop



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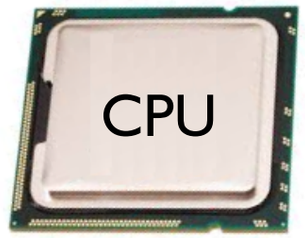

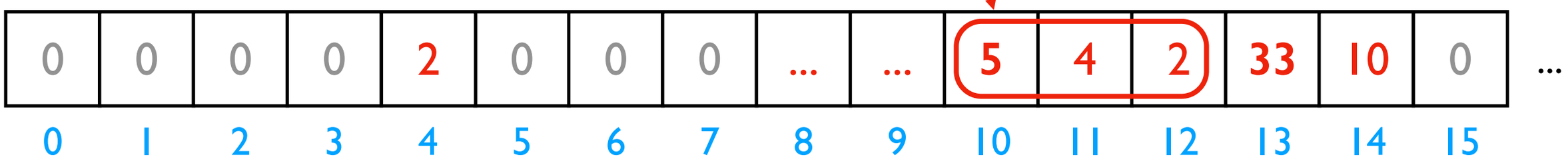

Instruction Set

code	operation
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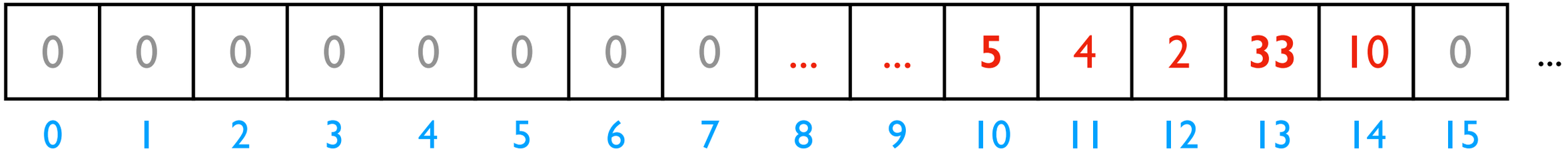
8	SUB
33	JUMP
...	...

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

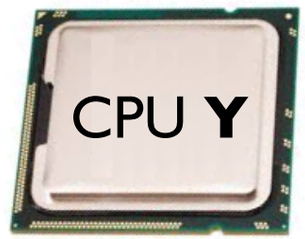
code	operation
5	ADD
8	SUB
33	JUMP
...	...

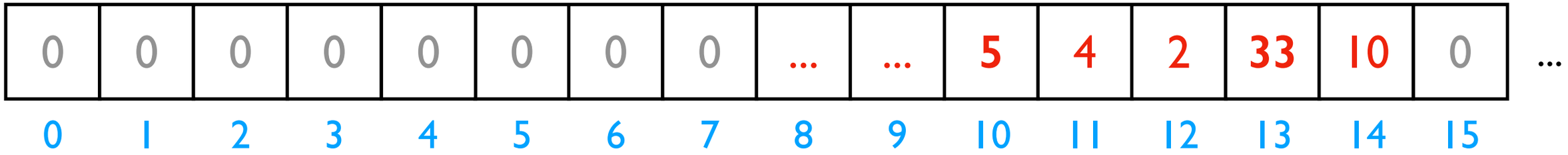
Instruction Set for CPU Y

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

Hardware: Mental Model of CPU

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





Instruction Set for CPU X

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

Instruction Set for CPU Y

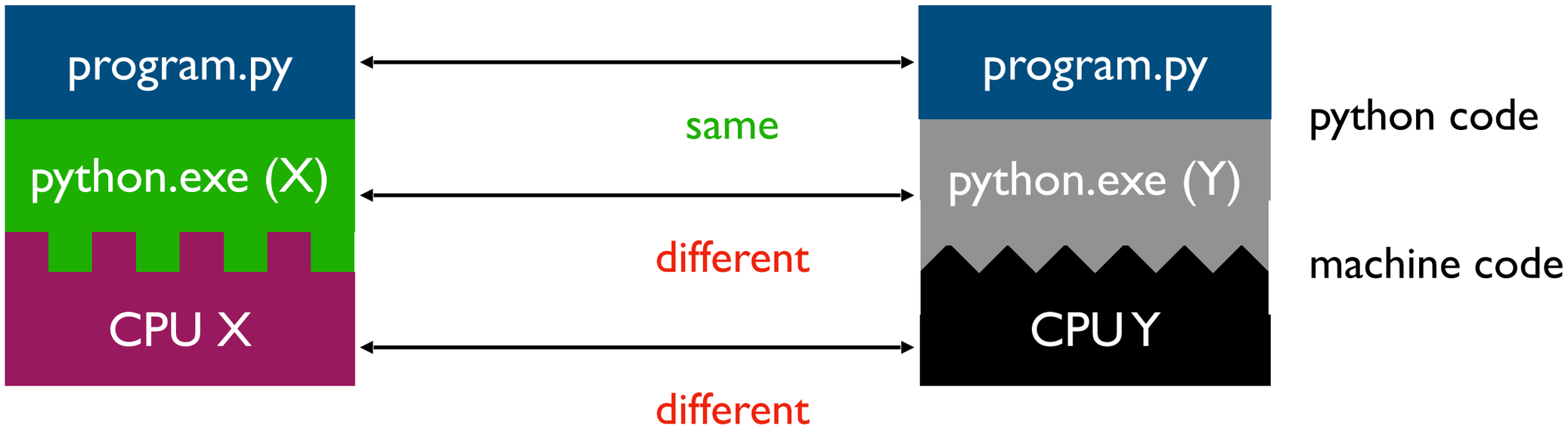
code	operation
5	SUB
8	ADD
33	undefined
...	...

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?

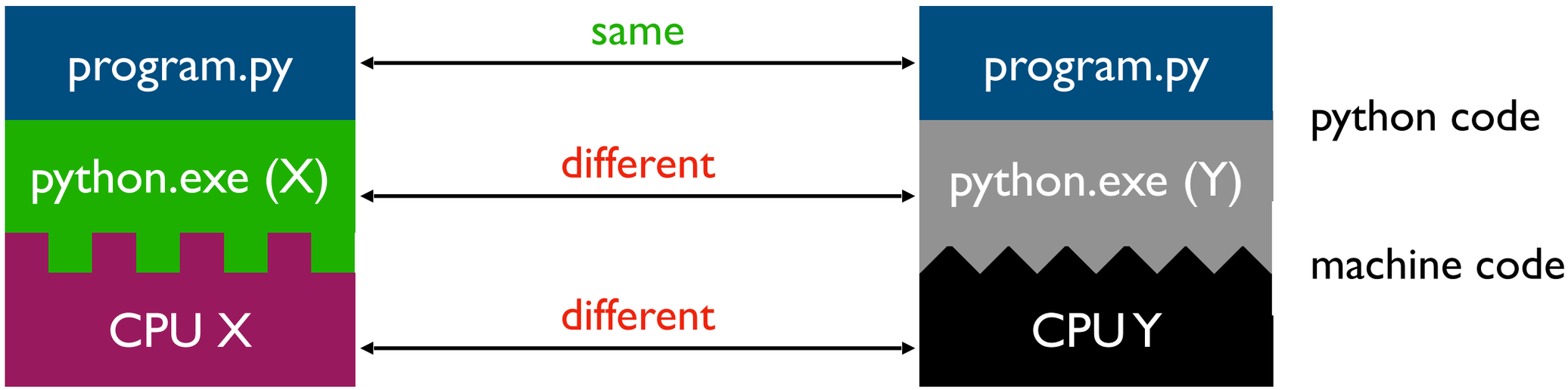
Interpreters



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



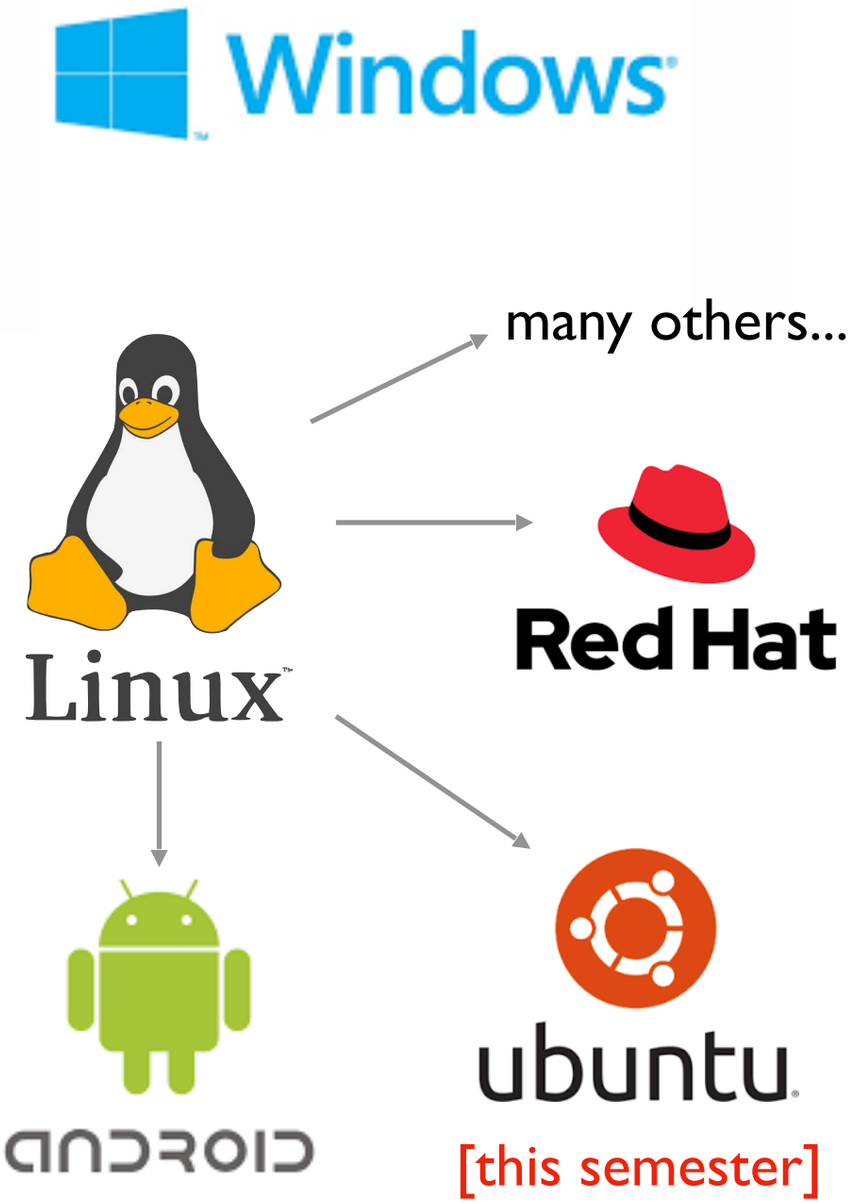
Interpreters (such as python.exe) make it easier to run the same code on different machines

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:

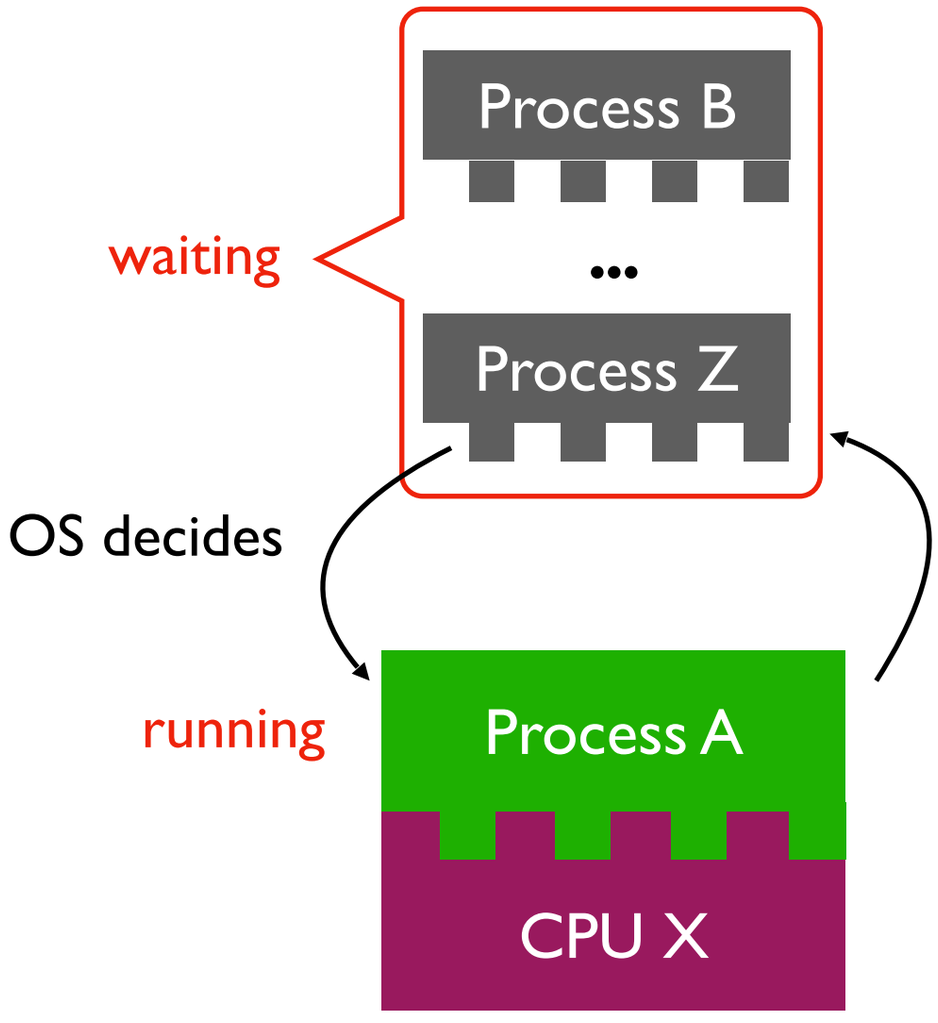
1. Hardware
2. Operating System
3. Dependencies



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()
```

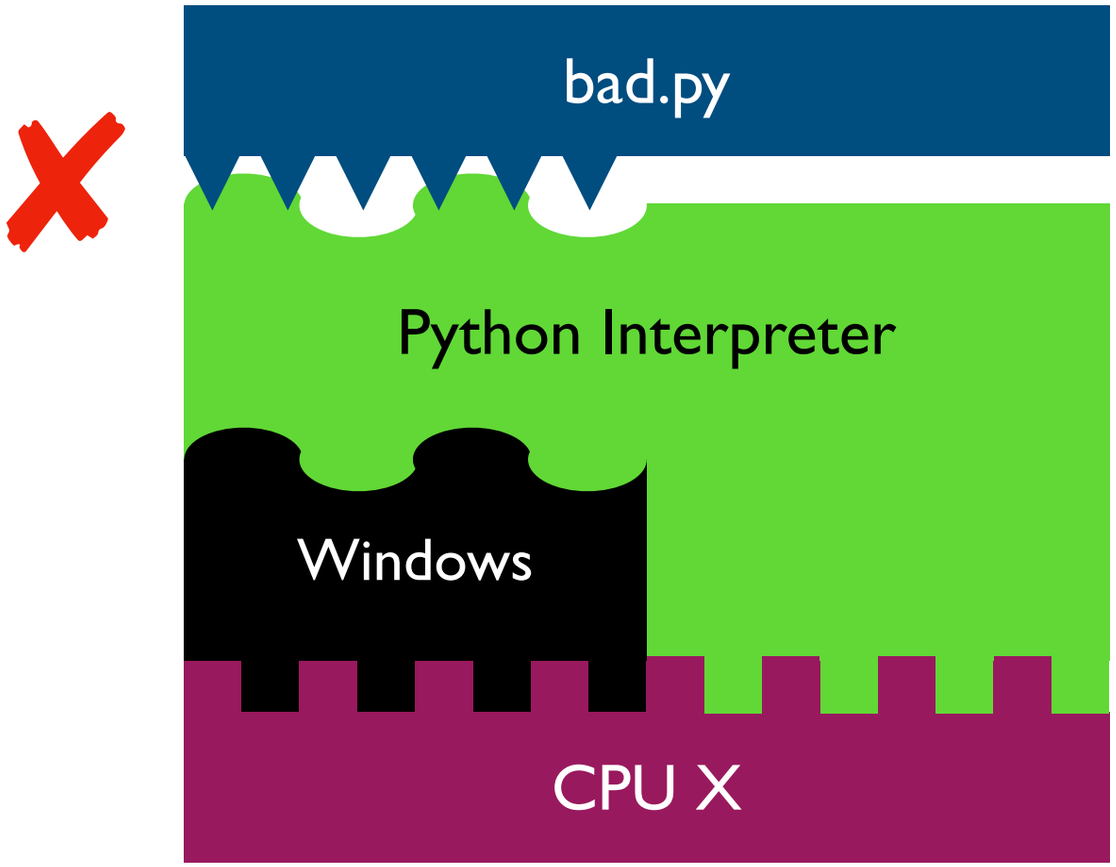
convenient

Operating System

inconvenient

ignorant of files/directories

Harder to reproduce on different OS...

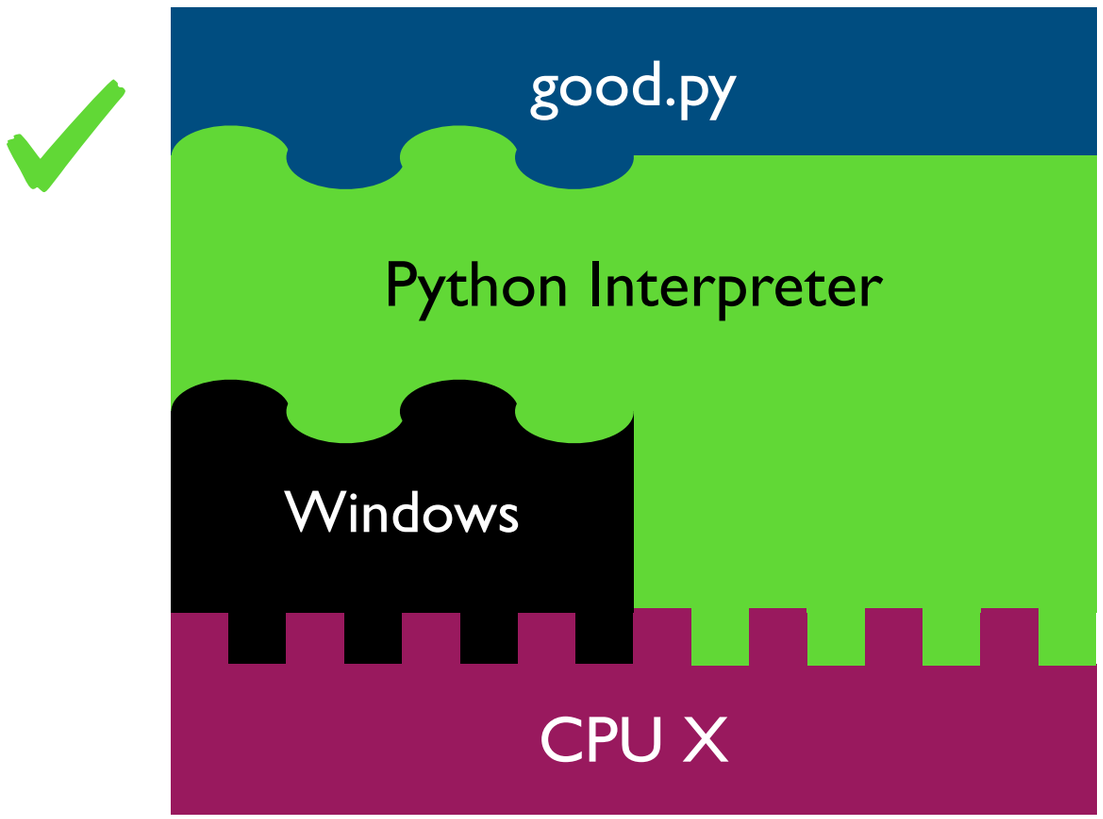



```
f = open("/data/file.txt")
...
```

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...

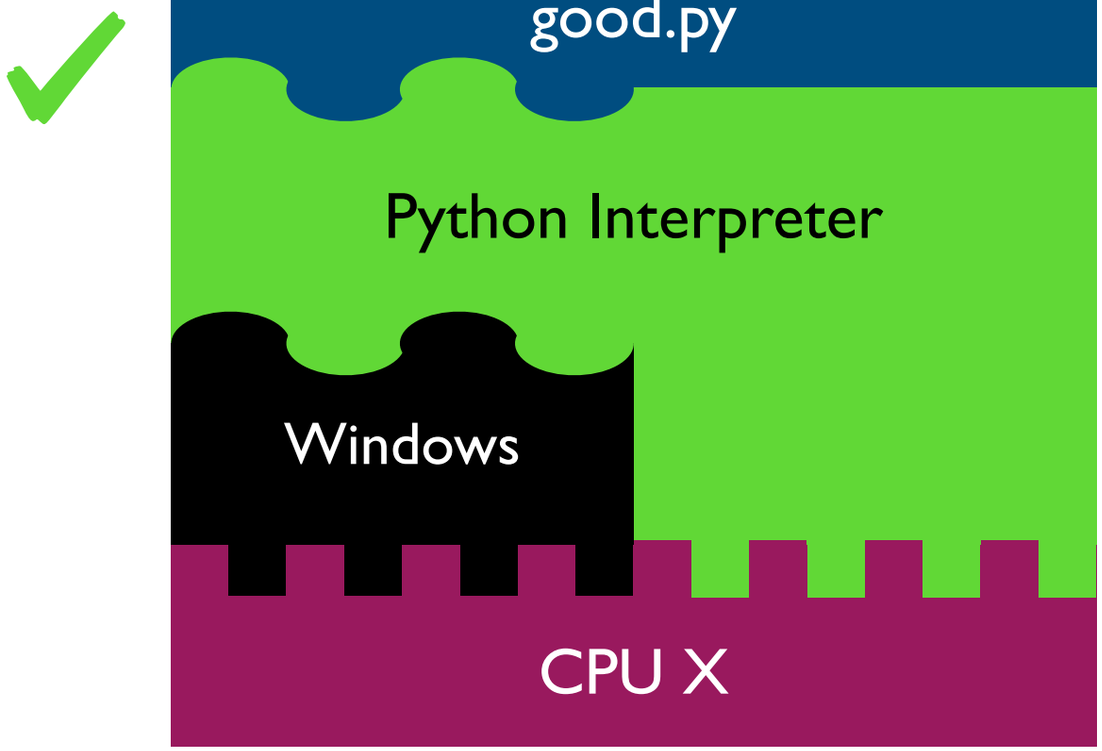



```
f = open("c:\data\file.txt")
...
```

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?

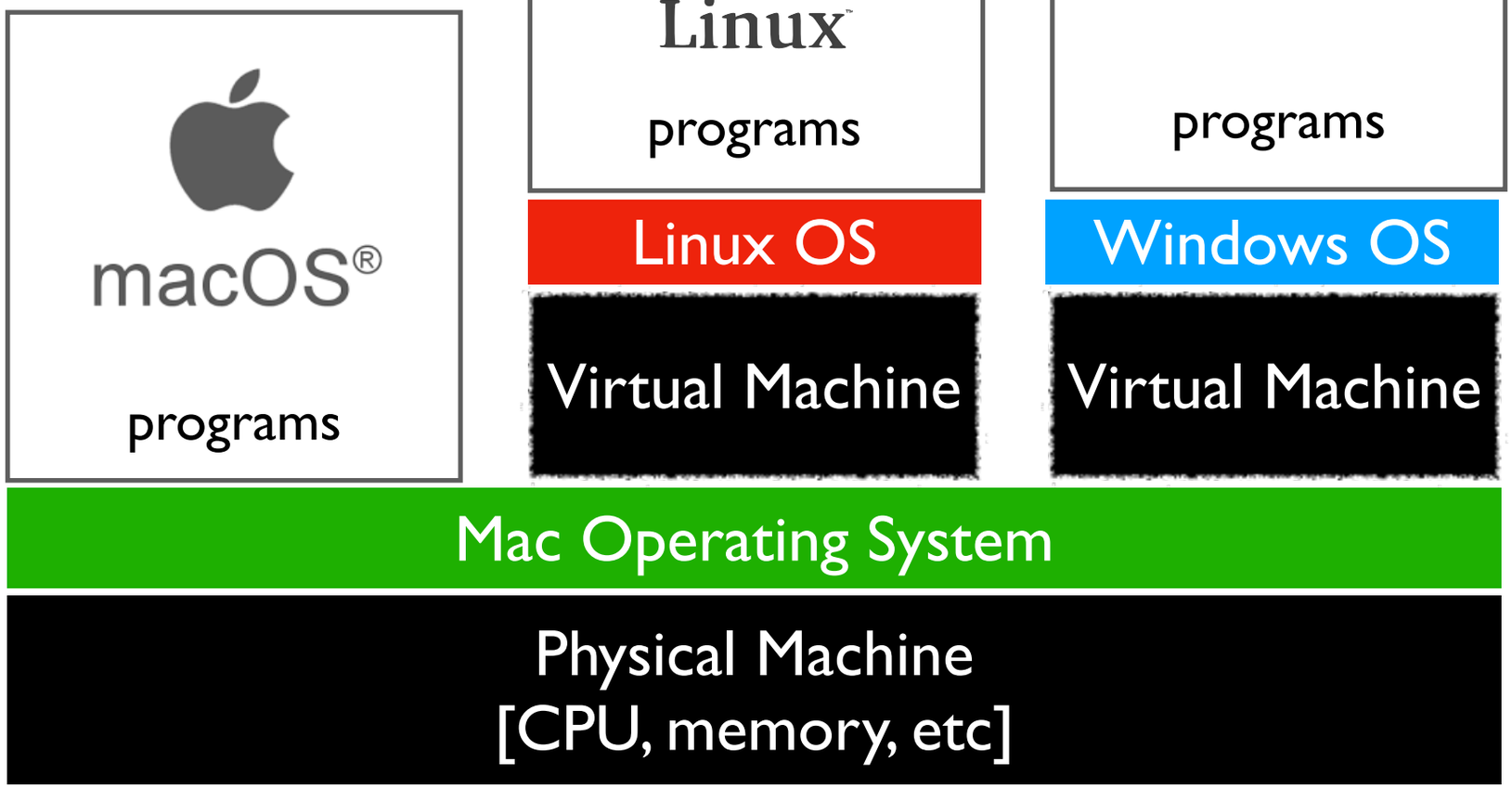
The Python interpreter mostly lets you
[Python Programmer] ignore the CPU you run on.

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

VMs (Virtual Machines)

popular virtual machine software

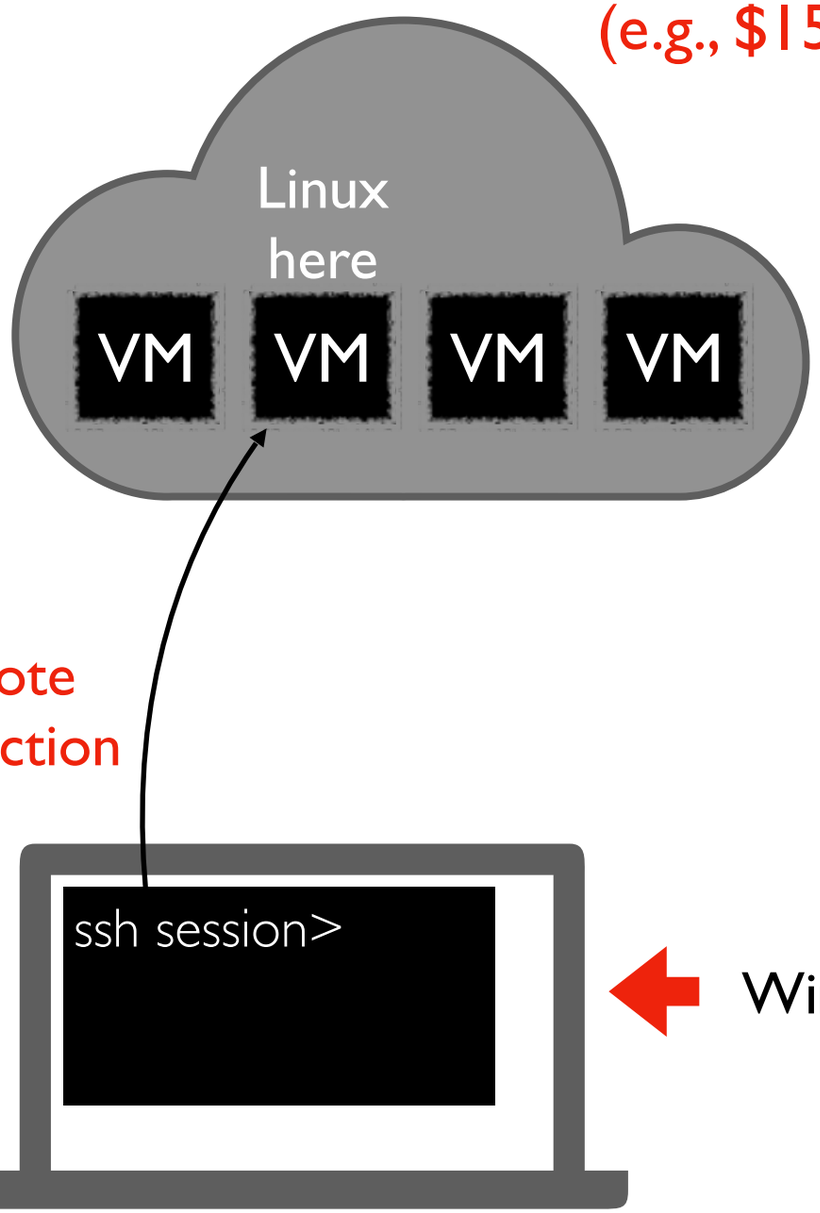
Microsoft Hyper-V



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

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

popular cloud providers

amazon web services™

Microsoft Azure

Google Cloud Platform

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

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