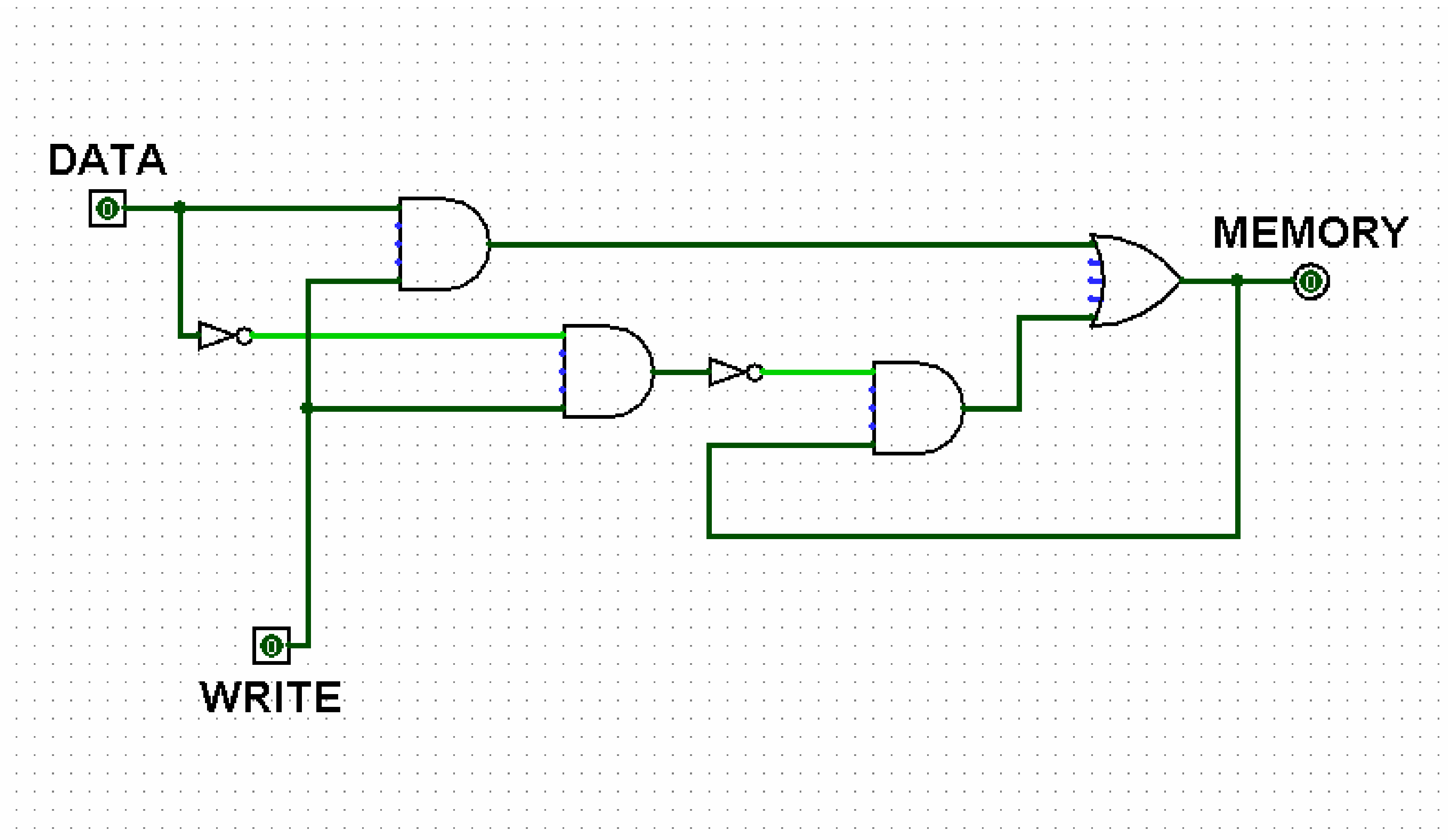
Today

- Brief review of last time.
- How computers manage memory.
- How computers multitask.

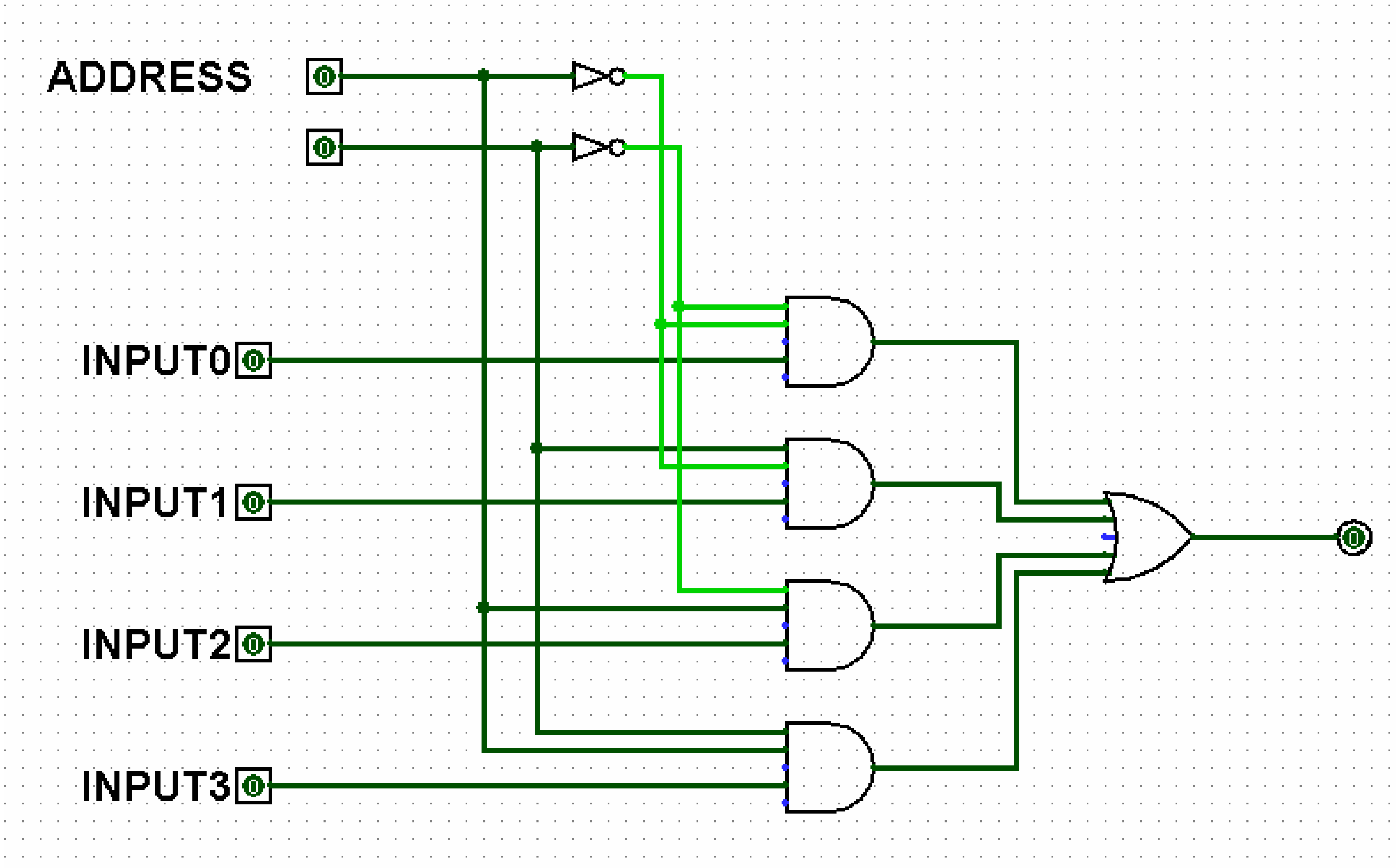
D Flip Flop



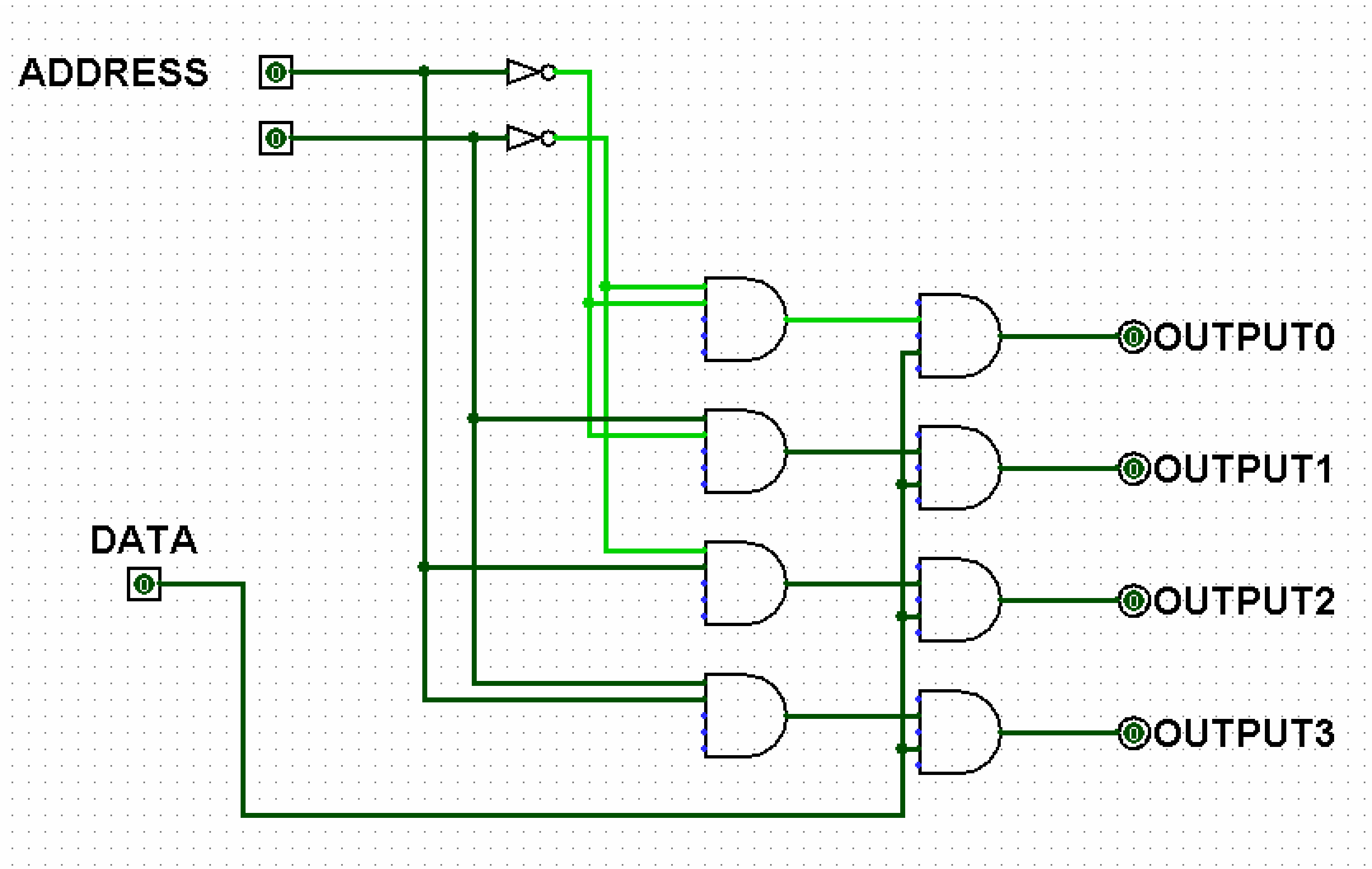
Try completing this for D F-F

DATA	WRITE	MEMORY (previous)	MEMORY
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

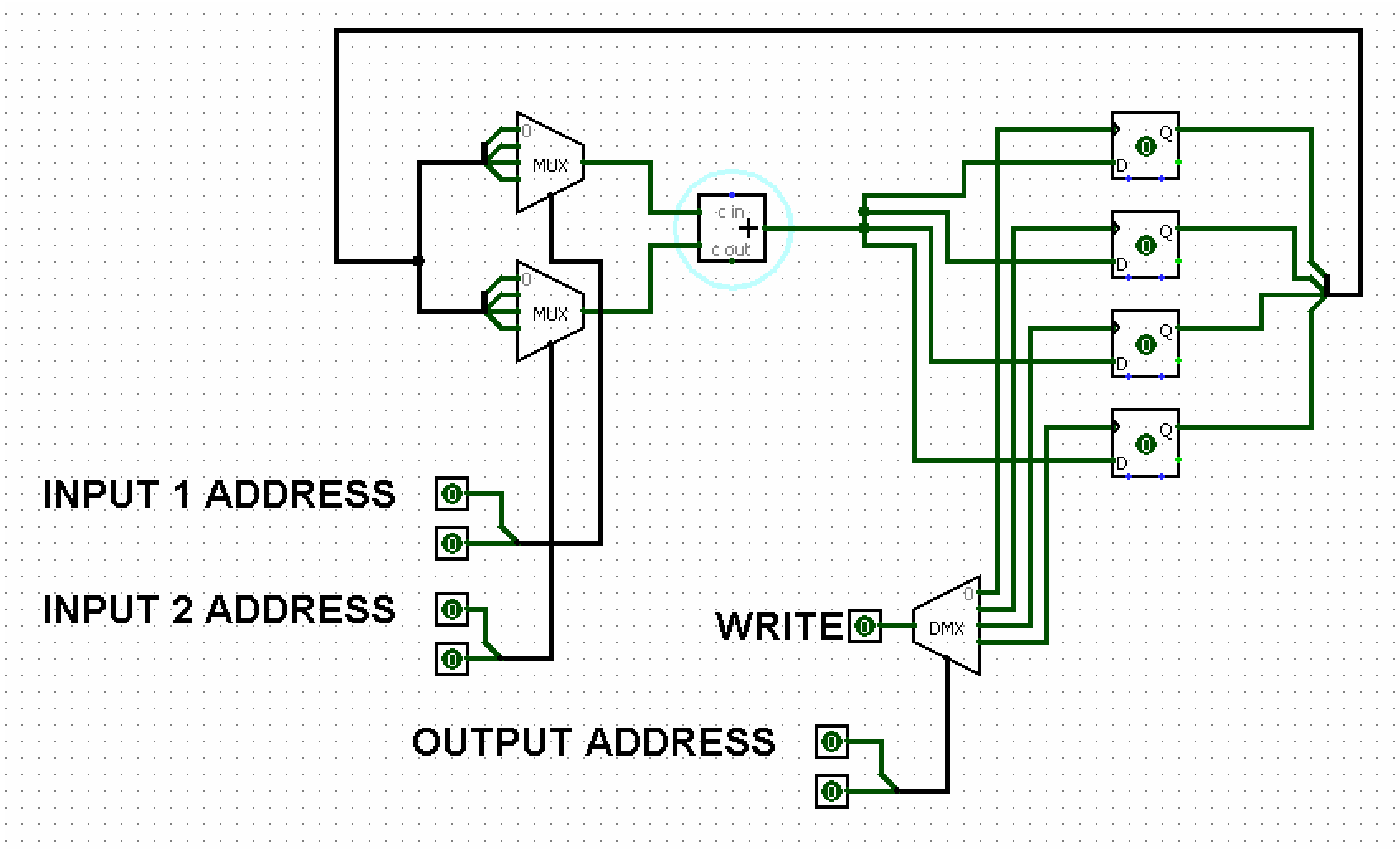
Multiplexer



Demultiplexer



Mini-CPU



MUX
MUX
c in
c out
INPUT 1 ADDRESS
INPUT 2 ADDRESS
WRITE
DMX
OUTPUT ADDRESS

What is a program?

- A program is a sequence of binary numbers -- *instructions*.
- <u>Each bit of each instruction corresponds to a control line in a programmable circuit (e.g. Pentium processor).</u>

Different CPUs have different machine languages

- Intel Pentium
- Power PC
- Palmpilot, etc.

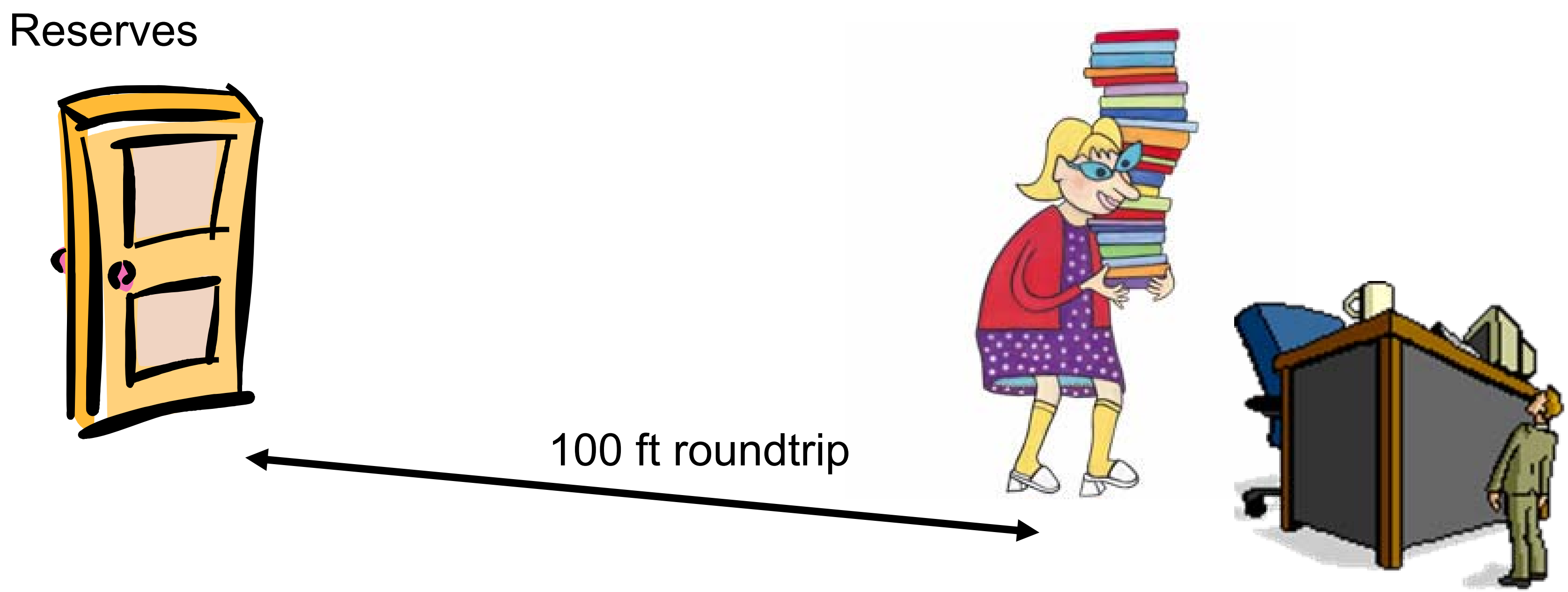
“Backwards Compatibility” – Pentium 4’s machine language extends Pentium 2’s machine language

Machine languages now allow complicated calculations (eg for multimedia, graphics) in a single instruction

How to streamline your life (lessons from computer architecture).

COS 116
4/3/2006
Instructor: Umar Syed

The Tired Librarian

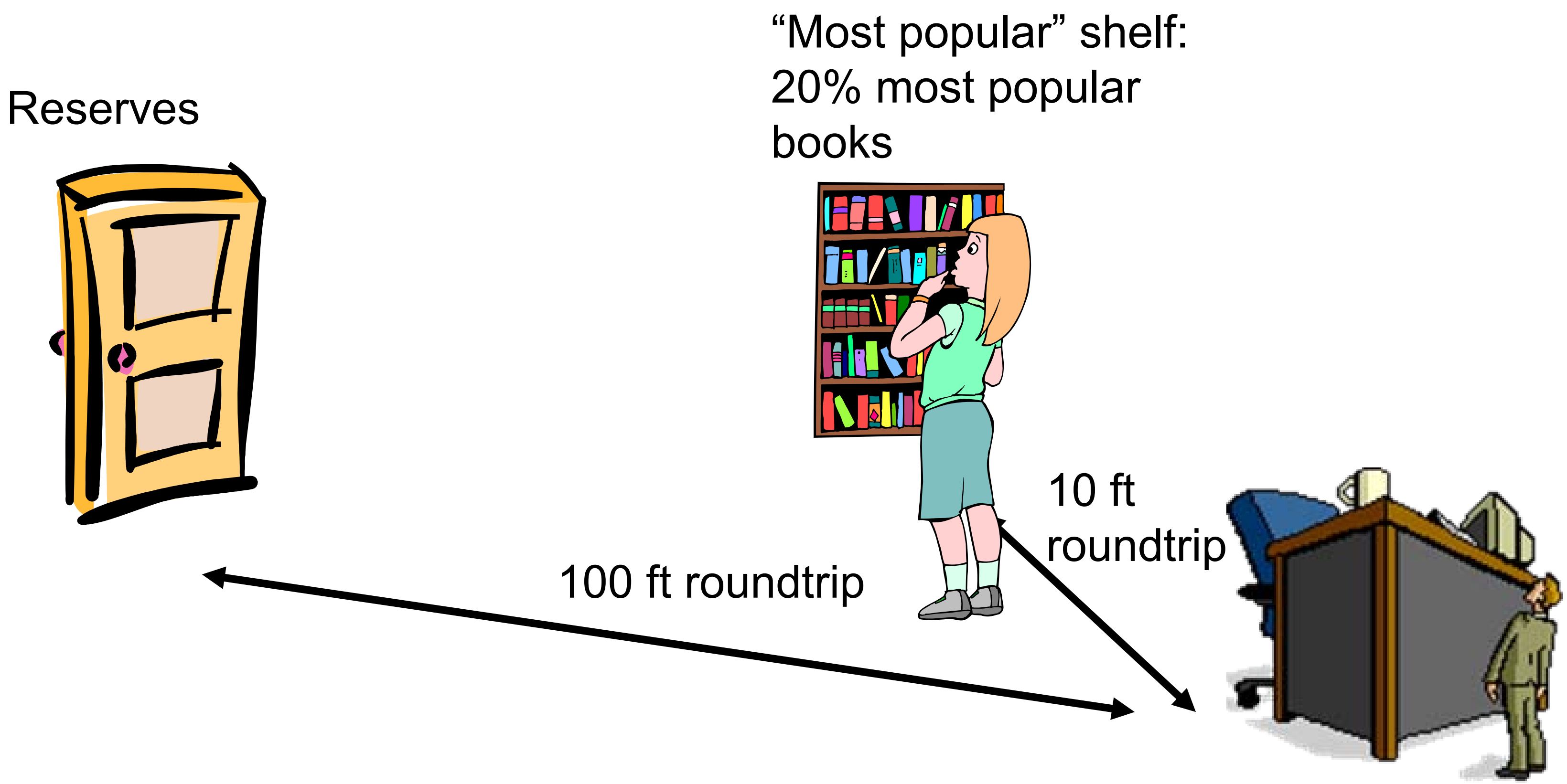


- 1000 checkouts/returns per day
- Distance covered = 1000 x 100ft = 100,000 ft ~ 20 miles
- Please help!!!

80-20 “Rule”

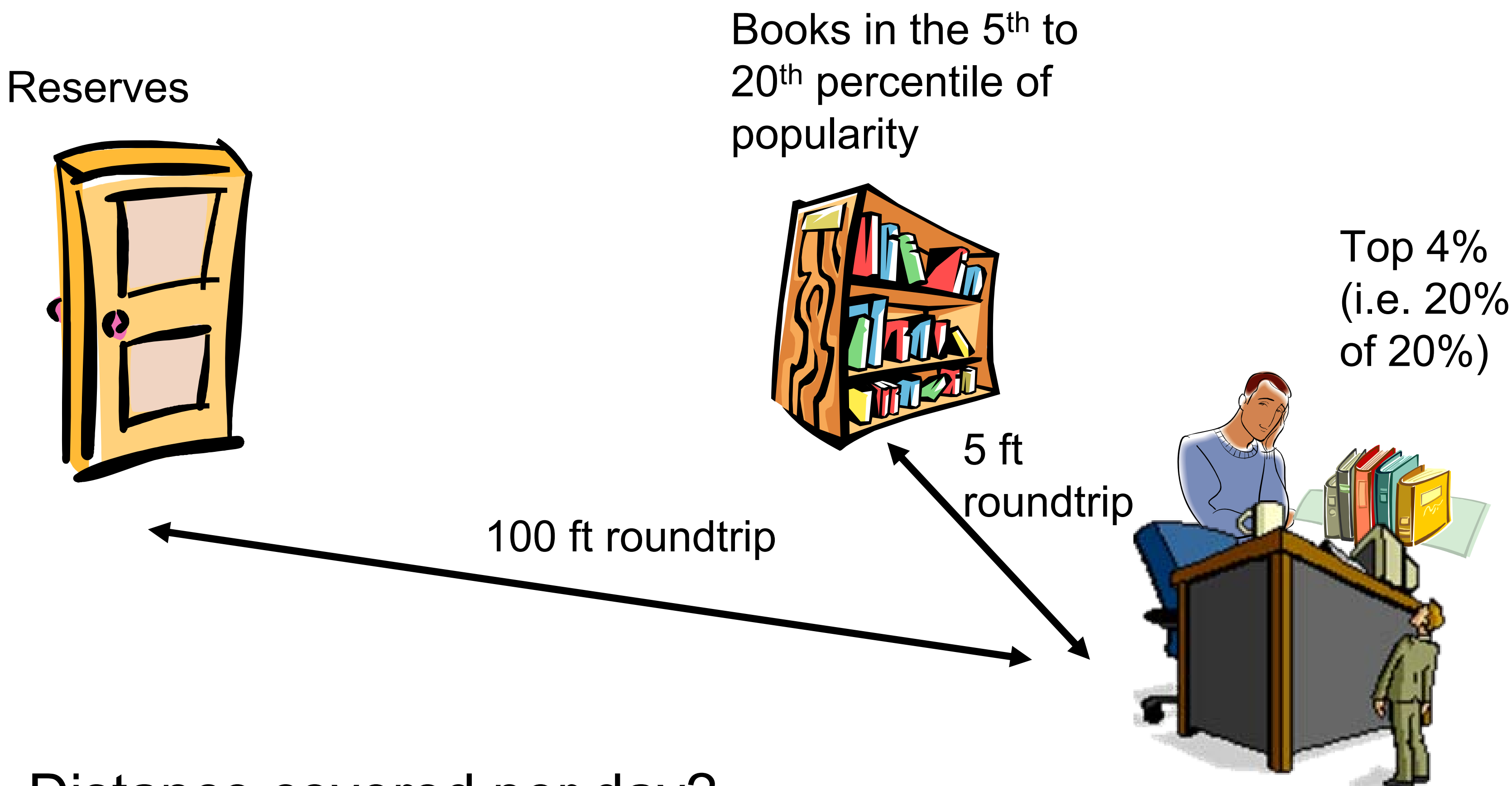
- Pareto [1906]: 20% of the people own 80% of the wealth
- Juran [1930’s]: 20% of the organization does 80% of the work

Better Arrangement



- Distance covered per day?
- (80% x 1000 x 10 ft) + (20% x 1000 x 100 ft) = 28,000 ft

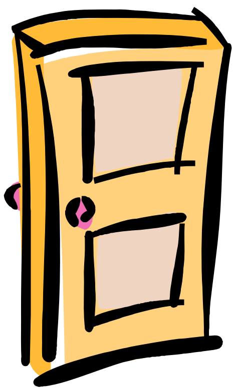
Even better arrangement



- Distance covered per day?
- (80% x 80% x 1000 x 0 ft) + (20% x 80% x 1000 x 10 ft) + (20% x 1000 x 100 ft) = 21,600 ft

Computer ~~Librarian~~ arrangement

Reserves
Disk



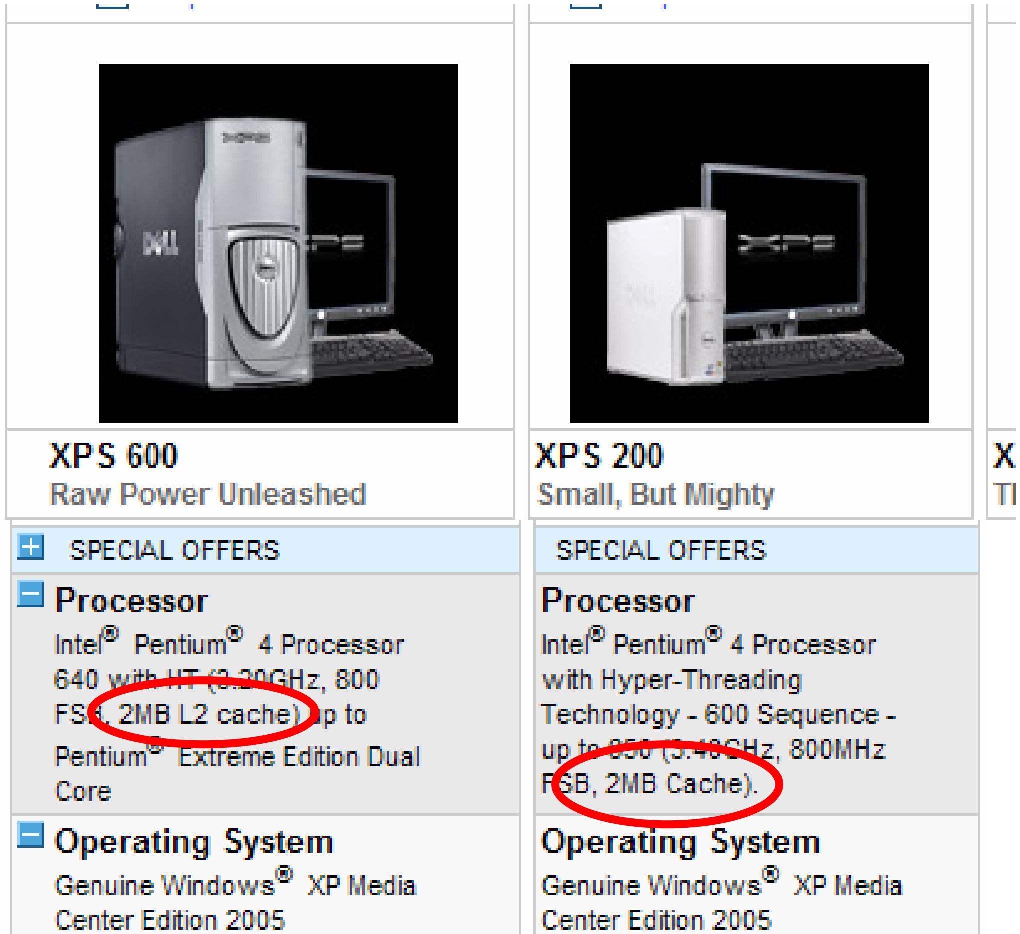
Books in the 5th to 20th percentile of popularity
Memory

CPU

Top 4%
Cache

Often, today's computers have even more levels of caching

New and improved



Class Discussion

- Is problem solved?

How to predict the most popular memory locations?

It’s not easy, because:

- Popularity is dynamic.
- Difficult to predict what a program will do in the future.
  - Remember the halting problem!
- Not a lot of time to make predictions.

Computer programs typically exhibit…

- Temporal locality
  - "If a memory location is accessed now, it will be accessed again in the near future."
- Spatial locality
  - "If a memory location is accessed now, nearby locations will be accessed in the near future."

Temporal and spatial locality?

```
sum ← 0
for i = 1 to n
{
  sum ← sum + A[i]
}
avg ← sum / n
```

Simple rules for managing the cache

- When accessing a memory location:
  - Bring that location into the cache.
  - Bring nearby locations into the cache.
- When the cache gets full:
  - Remove the memory location that was *Least Recently Used*.

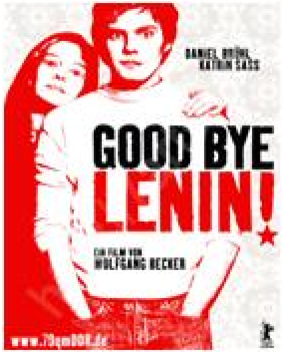
Delay vs. cost of various memories

	Cost: $ / GB	Delay: CPU cycles/byte
Hard drive	< 1	> 100,000
RAM	200	50-100
Cache	80,000	1

Moral

- Performance:
  - Speed is close to that of fastest memory (cache)
  - Overall capacity is that of largest memory (disk)

Virtual Memory



Recall: Compilation

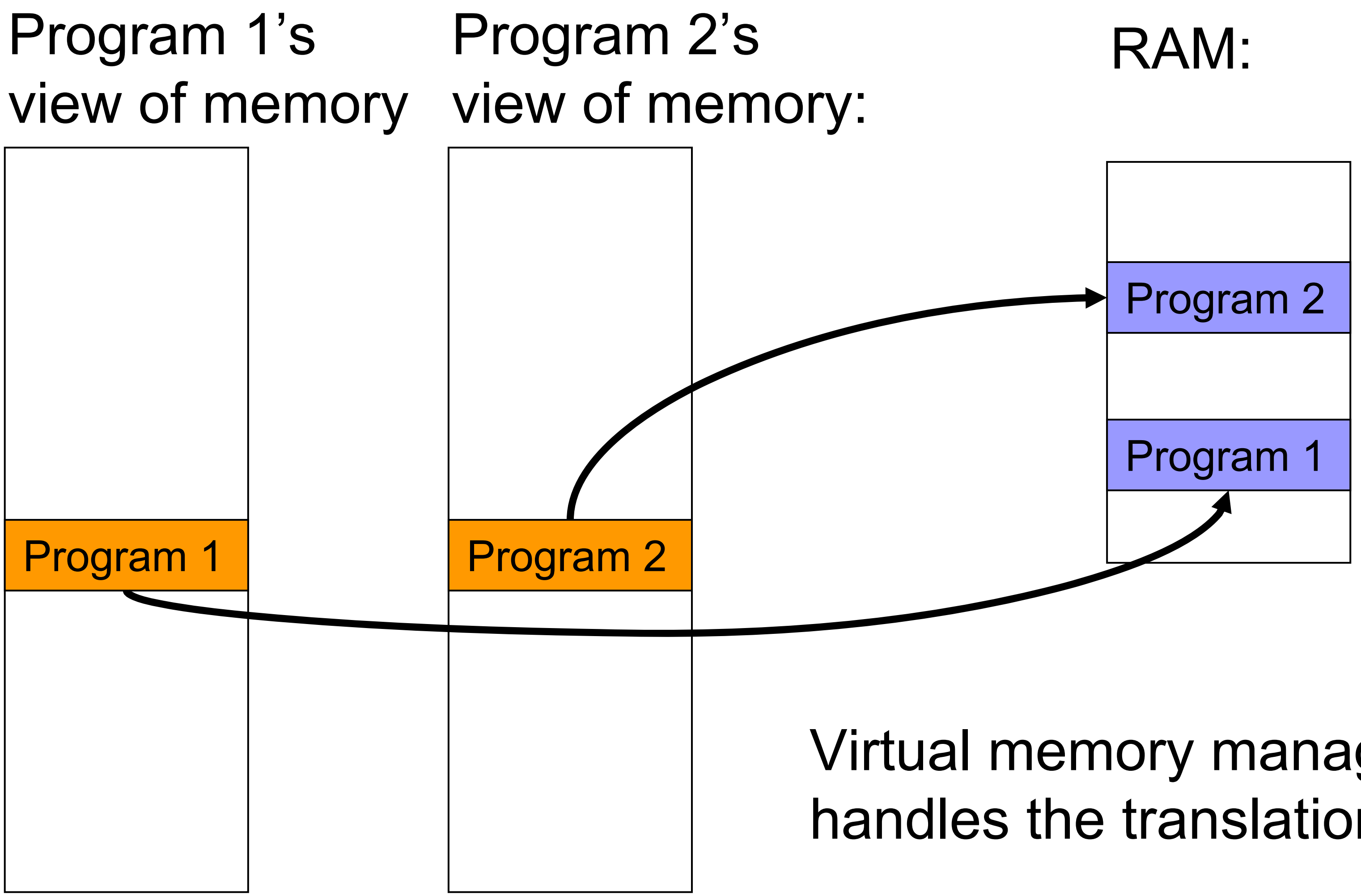
X ← Y + Z ↕ **ADD 10 11 12** ↕ 100 1010 1011 1100	1. Human writes this. 2. "Add contents of Location 11 and 12, and store result in Location 10" ▪ X in Location 10 ▪ Y in Location 11 ▪ Z in Location 12 3. Convert to binary

Question:

- What if two programs choose the same memory locations???

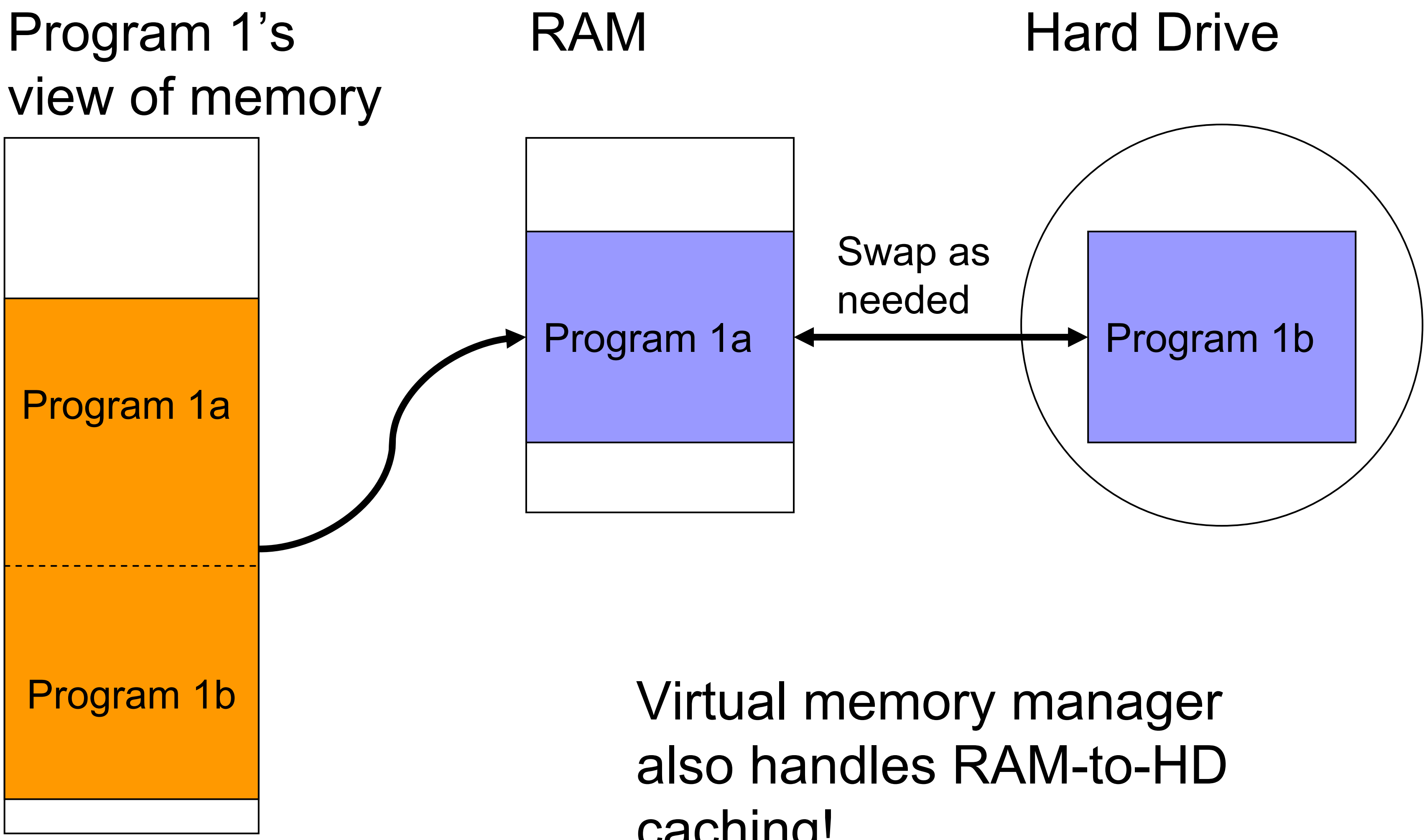
Program 1	Program 2
X ← Y + Z ↕ **ADD 10 11 12** ↕ 100 1010 1011 1100	**A ← B + C** ↕ **ADD 10 11 12** ↕ 100 1010 1011 1100

Virtual Memory



Virtual memory manager handles the translation.

Virtual Memory



Virtual memory manager also handles RAM-to-HD caching!

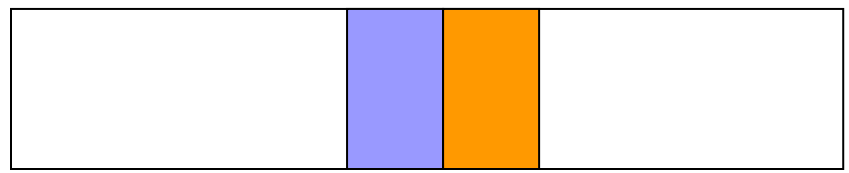
Virtual Memory

- Program’s view:

Lec15.ppt P ≠ NP.ppt

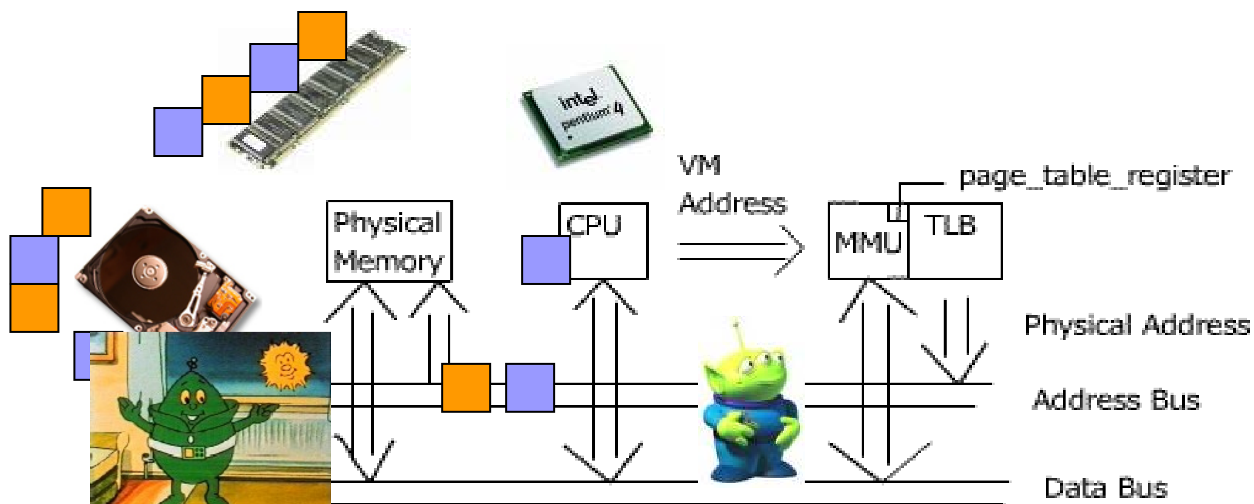
Powerpoint

Memory:



Address 0 Address 2^{64} - 1

- Underlying truth:



Multitasking

- “The Multitasking Generation”

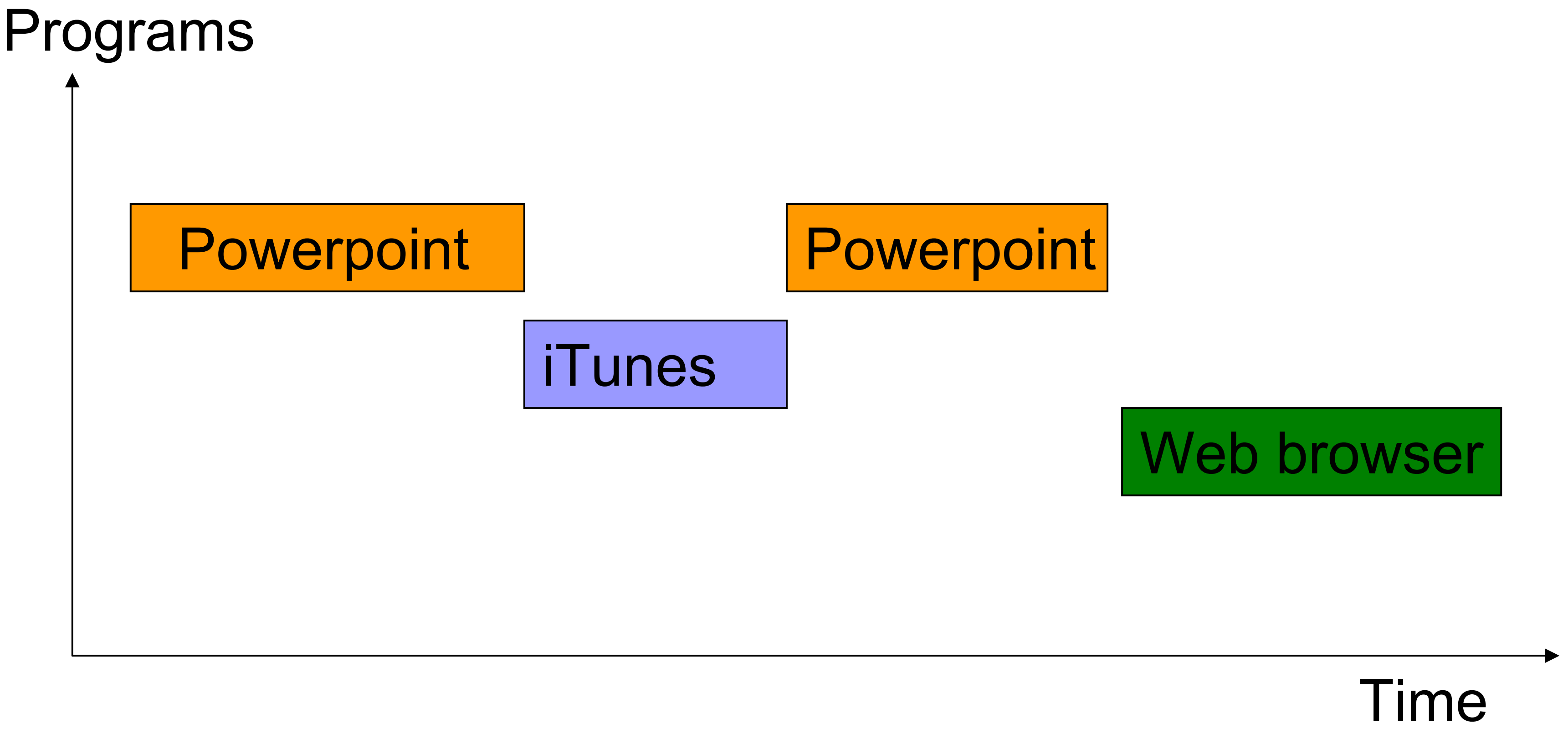
An Evening's Tasks for a Gen-M'er

- Homework
- Listen to music
- Instant Messaging
- Call Mom (goes to bed by 11 PM!)
- Answer phone
- Read a bit more of Joyce's *Ulysses*
- Watch the Daily Show

- How do you do it all?

How does a CPU multitask?

- Answer: It doesn't!

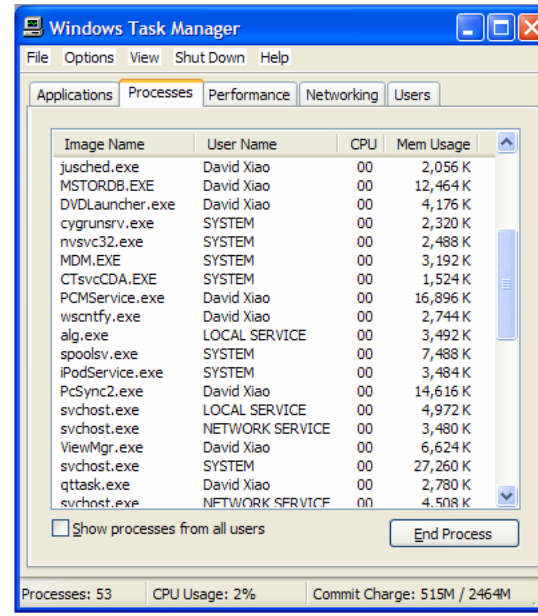


Scheduler’s objectives

- Fairness
- Timeliness
- Critical tasks processed promptly
- Low overhead

Class Discussion: How can one achieve these (often conflicting) goals?

Tasks done by my PC last night



- Word processing
- Play CD
- Download news updates
- Download email
- Run clock
- Hidden tasks: handle network traffic, manage disk and RAM traffic, scheduler, etc.

Managed by “Operating System”
(WinXP, Linux, MacOS, etc.)

- Bonus reading (in the "Extras" section): Proof of the halting problem, written in Dr. Seuss rhyme.
- Please pick up your graded lab reports.