Welcome!

Partner finding

Searching for a study buddy or partner? Looking to meet a new friend? Are you taking CS, INFO, or ORIE classes?

If so, the CIS Partner Finding Social is for you! This is the PERFECT opportunity to find a partner and meet other students in your classes!

September 1
4-6 pm
Upson 142

Common systems challenges

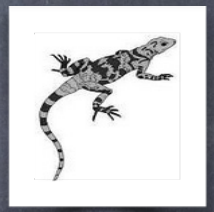
- Emergent properties
- Propagation of effects
- Incommensurate scaling
- Trade-offs

Propagation of effects: fighting malaria

- WHO sprayed villages in N. Borneo with DDT

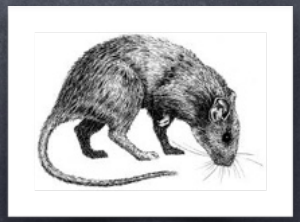
- Wiped out mosquitos, but...

- Roaches collected DDT in tissue



- Lizard ate roaches, and became slower
- Easy target for cats

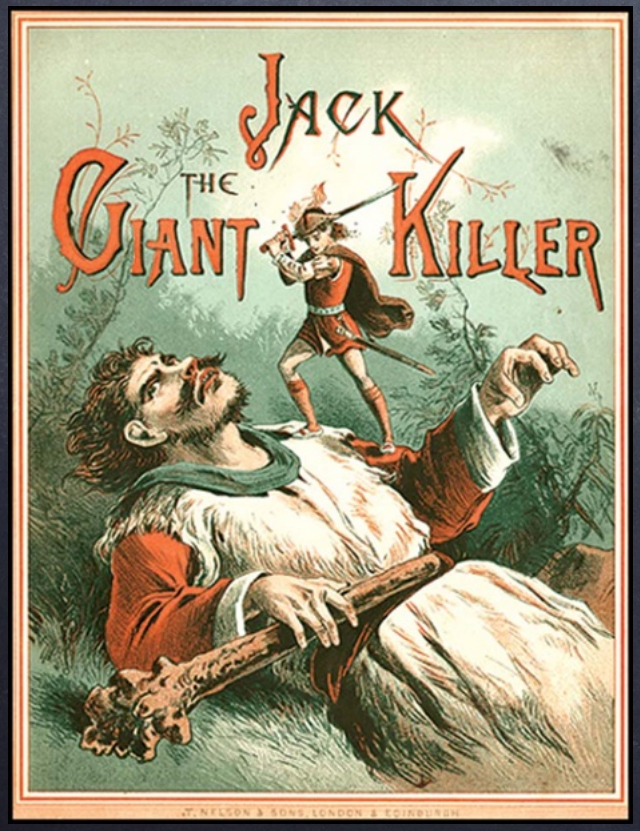
- DDT caused cats to die



- Forest rats moved into villages
- Rats carried the bacillus of the plague!

Incommensurate scaling

As the system increases in size or speed, not all components can manage the scale, and things break down



10x higher than Jack!

but also 10x wider and thicker!

About 1000x Jack's weight — but the cross section of the Giant's bones was only 100x Jack's

A human thigh bone breaks at about 10x human weight

The giant would have broken his thighs every time he was taking a step!

noted in "On being the right size"
J.B.S. Haldane

Inevitable Trade-offs

Speed vs power in processors

Bandwidth vs computation in compression

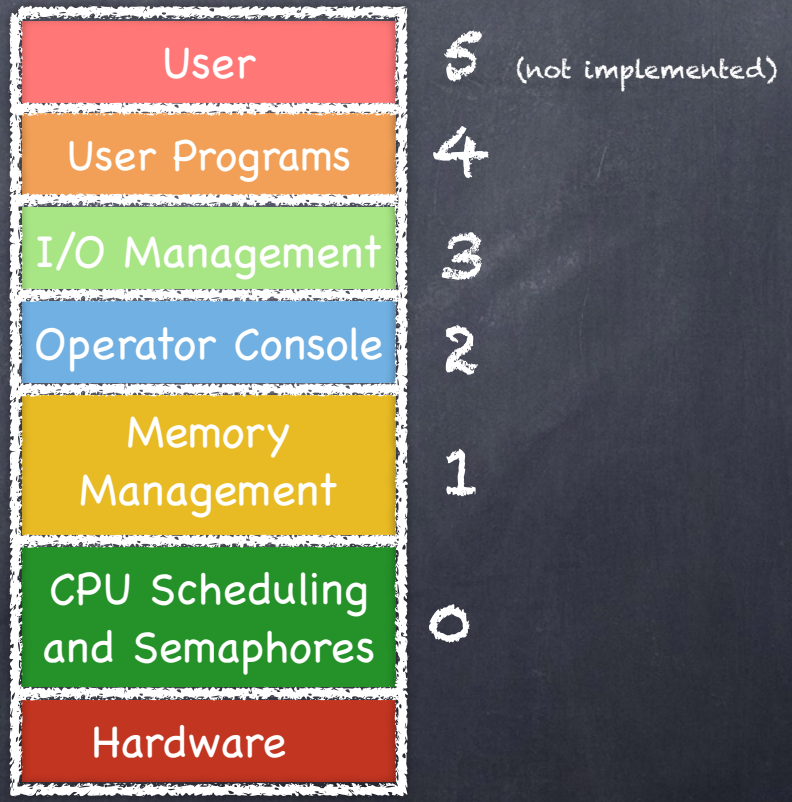
A pawn vs better position in chess

Space vs time almost everywhere

...

How to Manage Complexity

- Modularity
  - Good modularity minimizes connections between components
- Abstraction
  - Separate interface from internals; separate specification from implementation
- Hierarchy/Layering
  - Constrain interactions so they are easier to understand

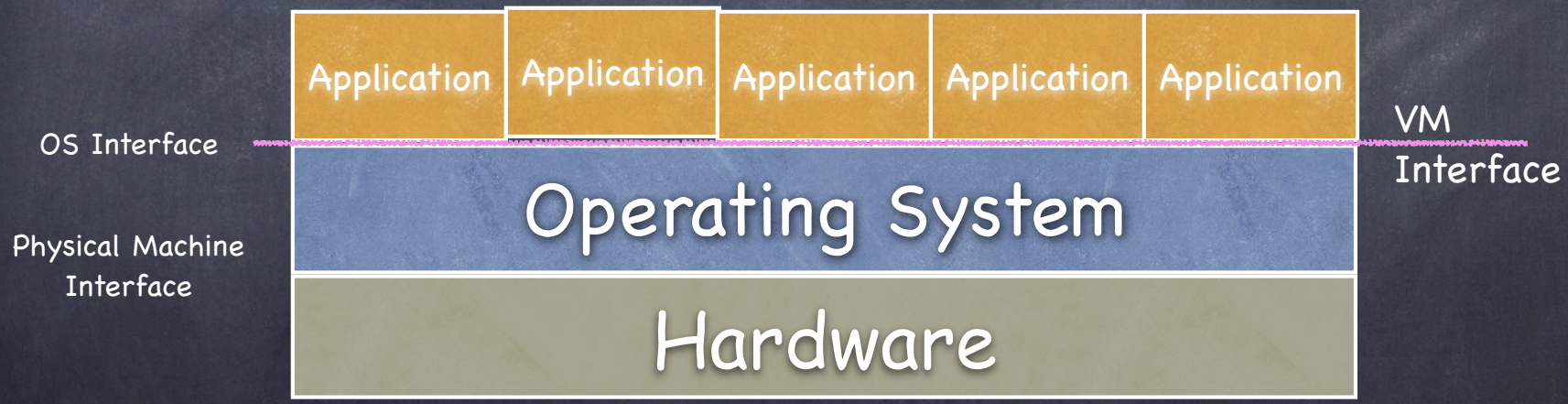


THE Operating system

EWD 196, 1965

What is an OS?

- An Operating System implements a virtual machine whose interface is more convenient* that the raw hardware interface



* easier to use, simpler to code, more reliable, more secure...

Fine. But what is an OS?

A collection of software components that run directly on and manage the hardware and provide services to the user and to application programs

OS wears many hats

- Referee

  - Manages shared resources: CPU, memory, disks, networks, displays, cameras…

- Illusionist

  - Clean, easy-to-use abstractions of physical resources
  - Look! Infinite memory! Your own private processor!

- Glue

  - Offers a set of common services (e.g., UI routines)

OS as Referee

Resource allocation

- Multiple concurrent tasks... who gets how much?

Isolation

- A faulty app should not disrupt other apps or OS

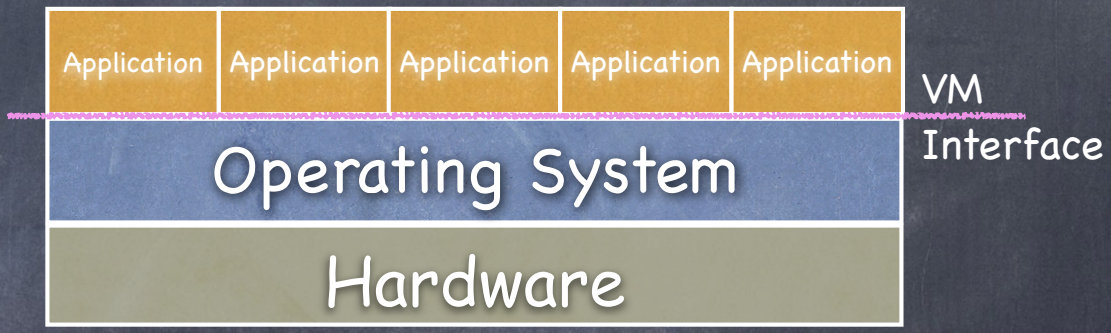
Communication/Coordination

- Apps need to coordinate and share state

OS as Illusionist

Appearance of resources not physically present

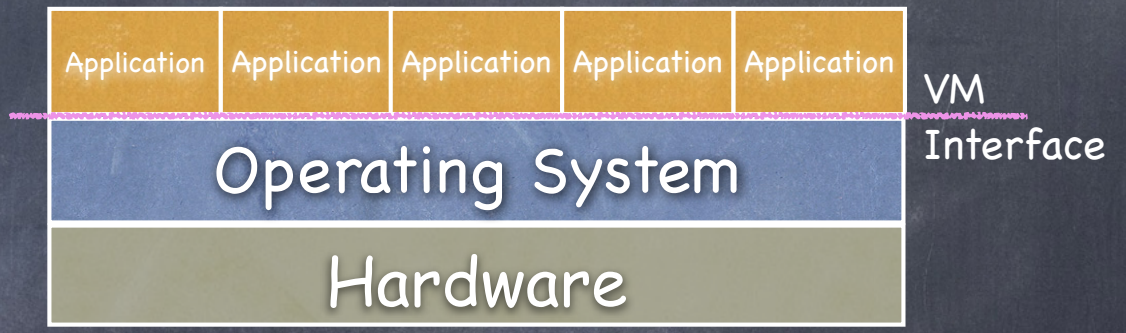
- Virtualization
  - Processor, memory, screen space, disk, network

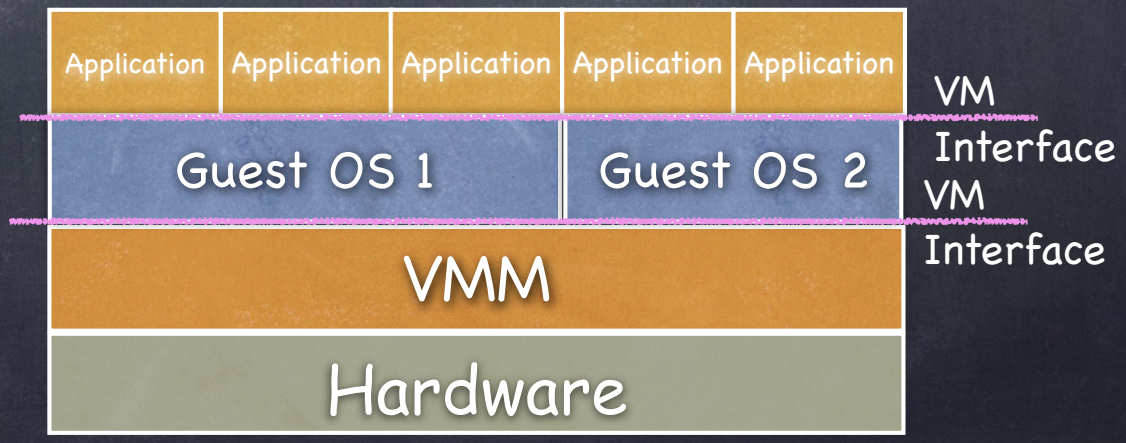


OS as Illusionist

Appearance of resources not physically present

- Virtualization
  - Processor, memory, screen space, disk, network
  - The entire computer
    - Fooling the OS itself!
    - Eases debugging, portability, isolation





OS as Illusionist

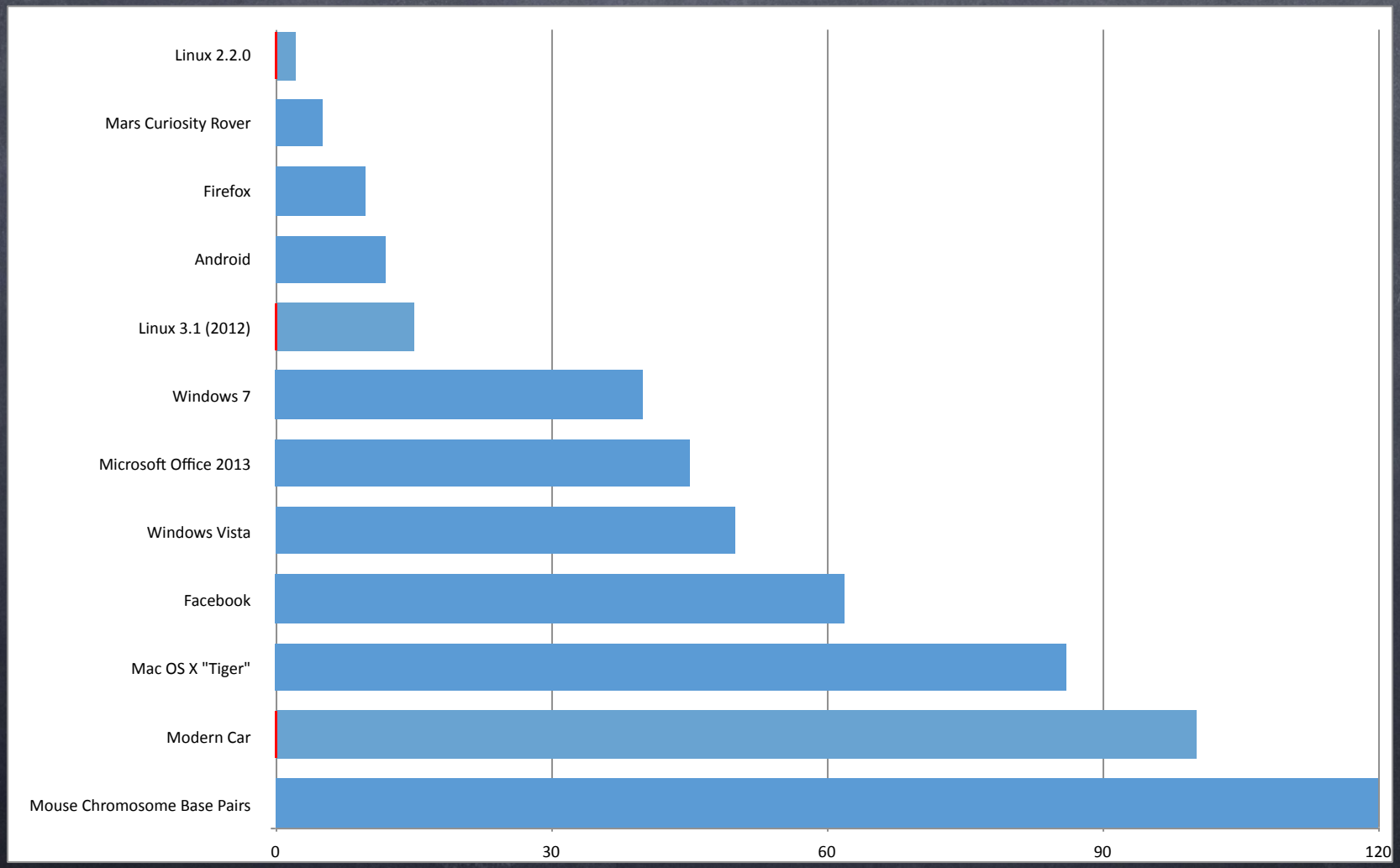
Appearance of resources not physically present

- Atomic operations
  - HW guarantees atomicity at the word level…
    - What happens during concurrent updates to complex data structures?
    - What is a computer crashes while writing a file block?
  - At the hardware level, packets are lost
    - Reliable communication channels

OS as Glue

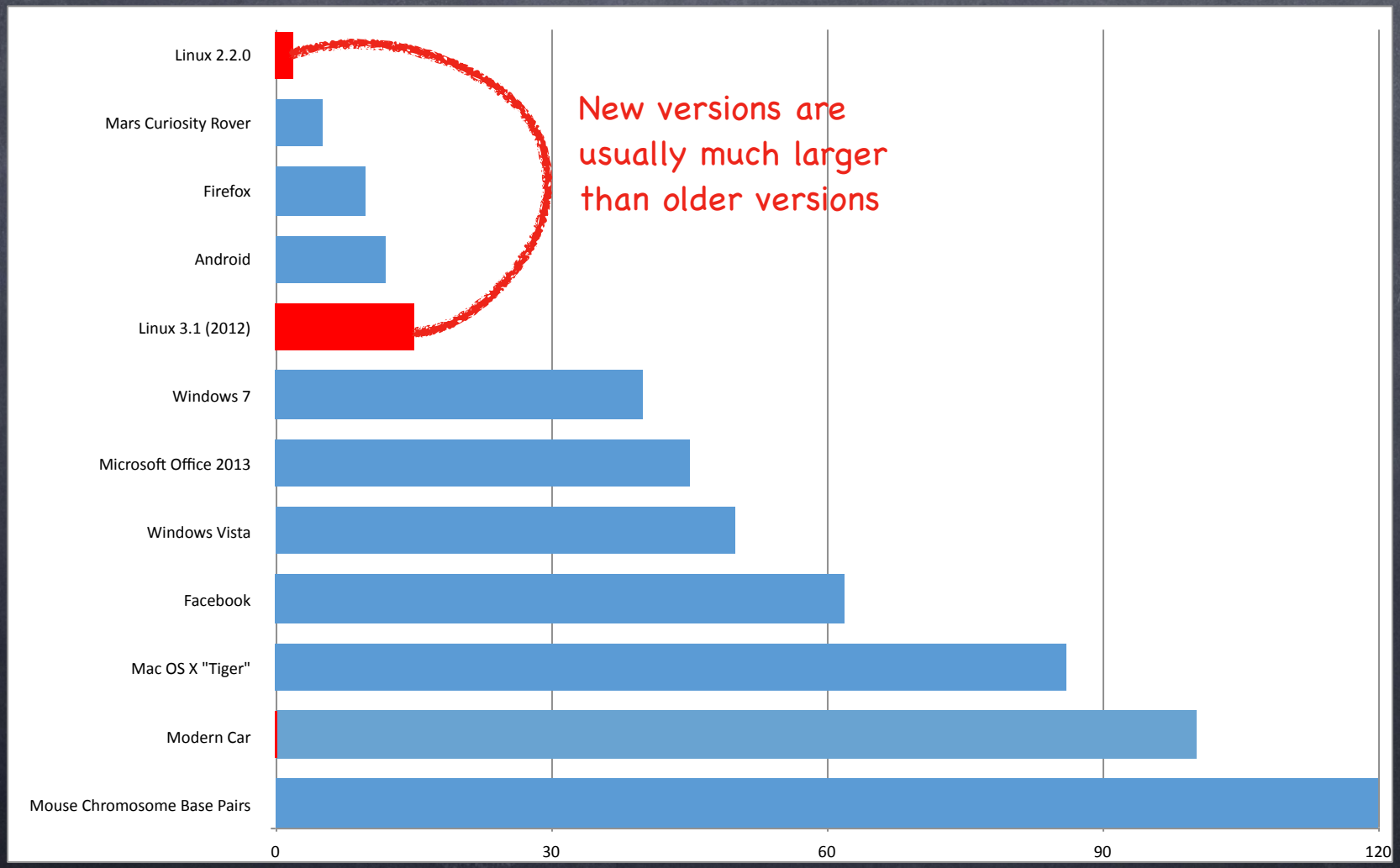
- Offers standard services to simplify app design and facilitate sharing
  - Send/Receive byte streams
  - Read/Write files
  - Pass messages
  - Share memory
  - UI
- Decouples HW and app development

We need all the help we can get…



Millions of lines of code

We need all the help we can get…



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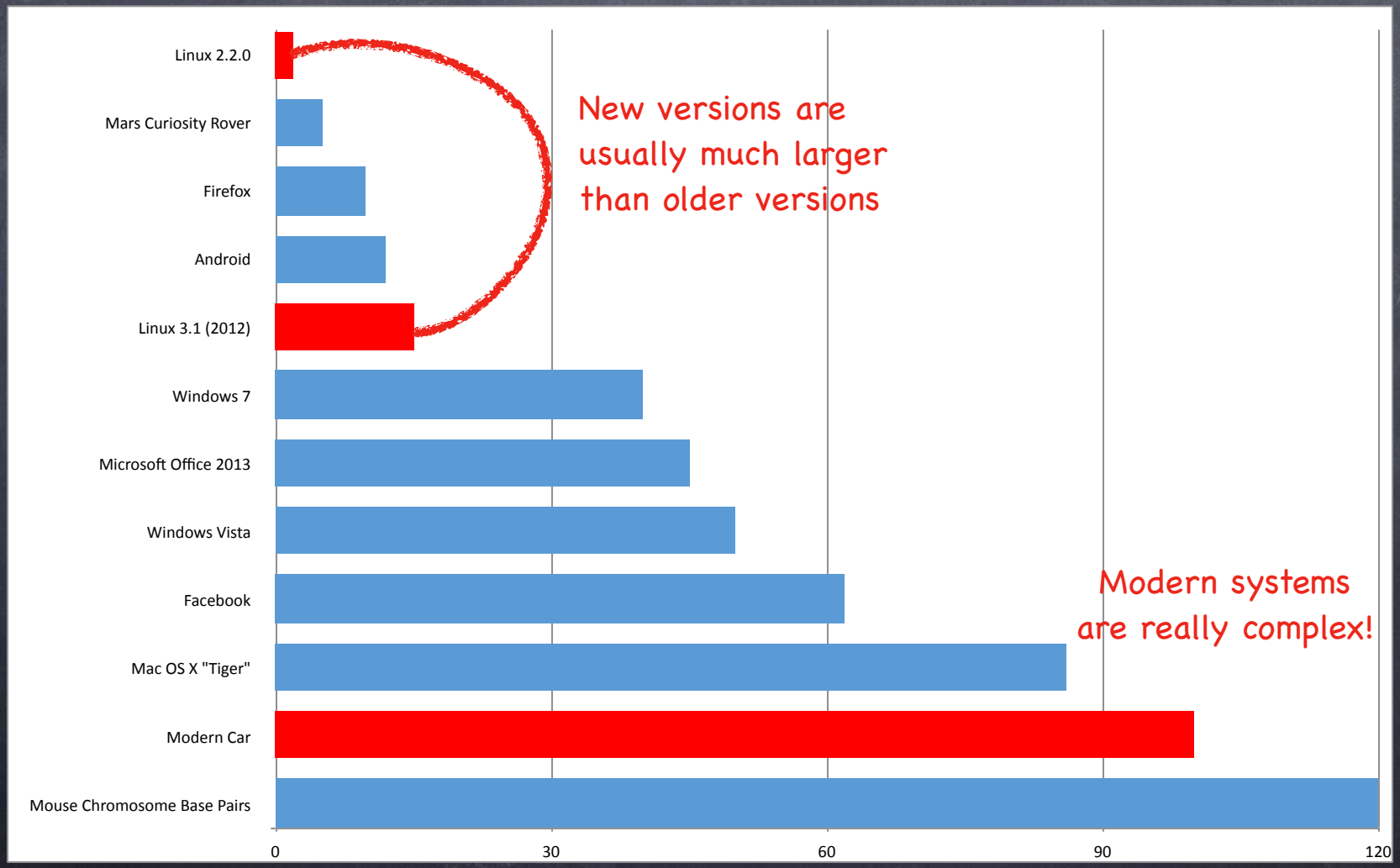


The Road Ahead

Virtualizing the CPU

- Process Abstraction and API
- Threads and Concurrency
- Scheduling

Virtualizing Memory

- Virtual Memory
- Paging

Persistence

- I/O Devices
- File Systems

Harmony

Your Automated Concurrency Tutor

source.hny

workspace > source.hny

```
import synch;

const N = 5;

def diner(which):
    let left, right = (which, (which % N) + 1):
    while choose({ False, True }):
        P(sema);
        lock(forks[left]);
        lock(forks[right]);
        # dine
        unlock(forks[left]);
        unlock(forks[right]);
        V(sema);
        # think
        ;
    ;
;
forks = dict{ Lock() for i in {1..N} };
sema = Semaphore(N - 1);
for i in {1..N}:
    spawn diner(i);
;
```

Issues in OS Design

- Structure: how is the OS organized?
- Concurrency: how are parallel activities created and controlled?
- Sharing: how are resources shared?
- Protection: how are distrusting parties protected from each other?
- Naming: how are resources named by users?
- Security: how to authenticate, authorize, and ensure privacy?
- Performance: how to make it fast?

More Issues in OS Design

- Reliability: how do we deal with failures??
- Portability: how to write once, run anywhere?
- Extensibility: how do we add new features?
- Communication: how do we exchange information?
- Scale: what happens as demands increase?
- Persistence: how do we make information outlast the processes that created it?
- Accounting: who pays the bill and how do we control resource usage?

The Process

Our first abstraction

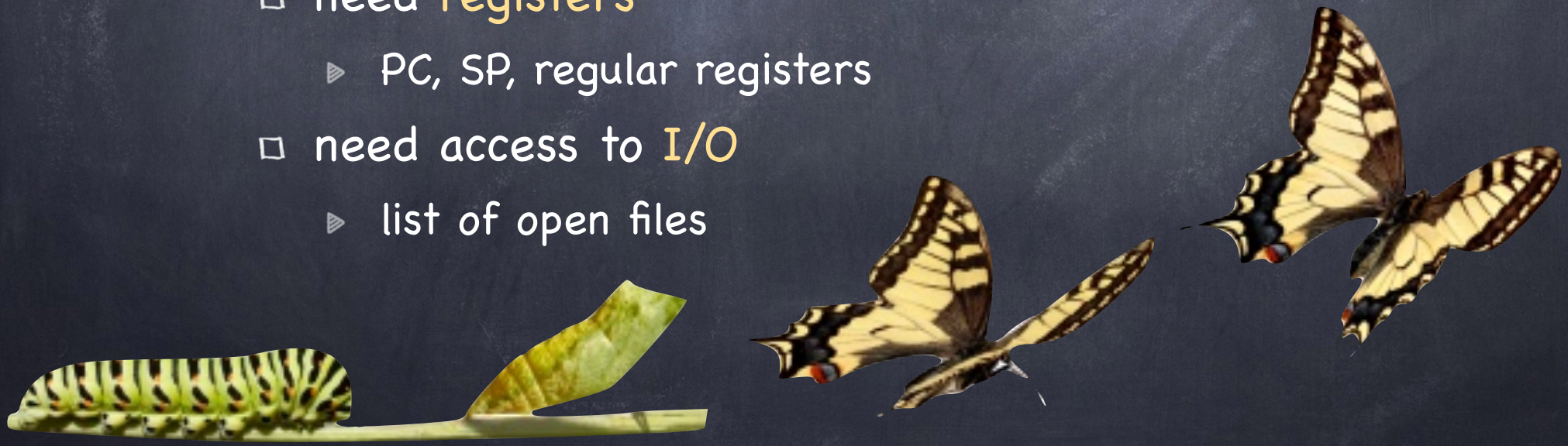
(Chapters 2-6)

What is a process for?

- It provides a program with the ecosytem it needs to run
- It is how a program experiences the machine it is running on:
  - Think "The Matrix"
- When a program dreams of a computer, it dreams of a process!

From Program to Process

- To make the program's code and data come alive
  - need a CPU
  - need memory
    - for data, code, stack, heap
  - need registers
    - PC, SP, regular registers
  - need access to I/O
    - list of open files



You'll Never Walk Alone

- Machines run (at least conceptually) multiple programs concurrently (which the OS must manage)
  - how should the machine's resources be mapped to these programs?
- OS as a referee...

You'll Never Walk Alone

- Machines run (at least conceptually) multiple programs concurrently (which the OS must manage)
  - how should the machine's resources be mapped to these programs?
- Enter the illusionist!

  - give every program the illusion of running on a private CPU
    - which appears slower than the HW machine's

Virtualize the CPU

  - give every program the illusion of running on a private memory
    - which may appear larger (??) than the machine's

Virtualize memory

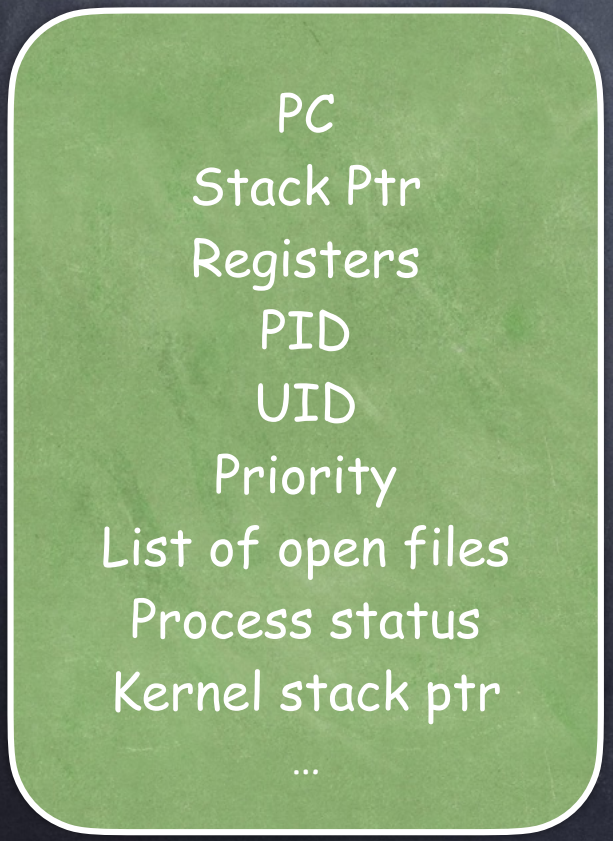
So, what does a process offer programs?

- The illusion of a dedicated CPU - that the OS must somehow "spin" baes on the physical processor
- The illusion of dedicated memory - the process' address space - that the OS must somehow "spin" based on physical memory
- A way to access I/O
- A chance to live!

The OS predicament

- Multiple programs may want to run concurrently
  - OS must support multiple processes
- How should it manage the HW resources at its disposal?
  - must multiplex!
  - could multiplex in space
    - What would it mean for Memory? For the CPU?
  - could multiplex in time
    - What would it mean for Memory? For the CPU?
- How to keep track of it all?

Process Magement by the OS



Process Control Block (PCB)

- A per-process data structure held by the OS
- Stores three types of information
  - Process identification
  - Process state (registers, PC, SP, MM Info...)
    - to seamlessly suspend and restart process
  - Process control
    - scheduling status, priority, CPU time used