CSCI 1670/2670
Operating Systems

Staff

- **Professors**
  - Tom Doeppner
  - Malte Schwarzkopf
- **Head TAs**
  - Ayman Benjelloun Touimi
  - Matthias Yee
- **UTAs**
  - Angel Arrazola
  - Alexander Cueva
  - Tomas Dougan
  - Brandon Gong
  - Mithi Jethwa
  - Mason Lee
  - Daniel Liu
  - Jason Ni
  - Nicholas Yarnall
  - Kyle Yeh

The Course

- Implement threads
- Learn about operating systems
- Implement one (Weenix)
  - file-system-related components (1670)
  - most of the rest of it (1690, 2670)

Workload Components

- Four moderate programming assignments
  - UThreads: simple user-level threads package
  - MThreads: more sophisticated user-level threads package
  - VFS: system calls and high-level file system
  - S5FS: low-level file system
- One large programming assignment: Weenix
  - combines VFS and S5FS, as well as Processes, Drivers, and Virtual Memory
- Four homeworks
- In-class TopHat questions

Workload by Course

- 1670 Section 1
  - quizzes: 10%
  - homeworks: 40%
  - moderate programming assignments: 50%
- 1670 Section 2
  - homeworks: 44.44%
  - moderate programming assignments: 55.56%
- 1690
  - large programming assignment: 100%

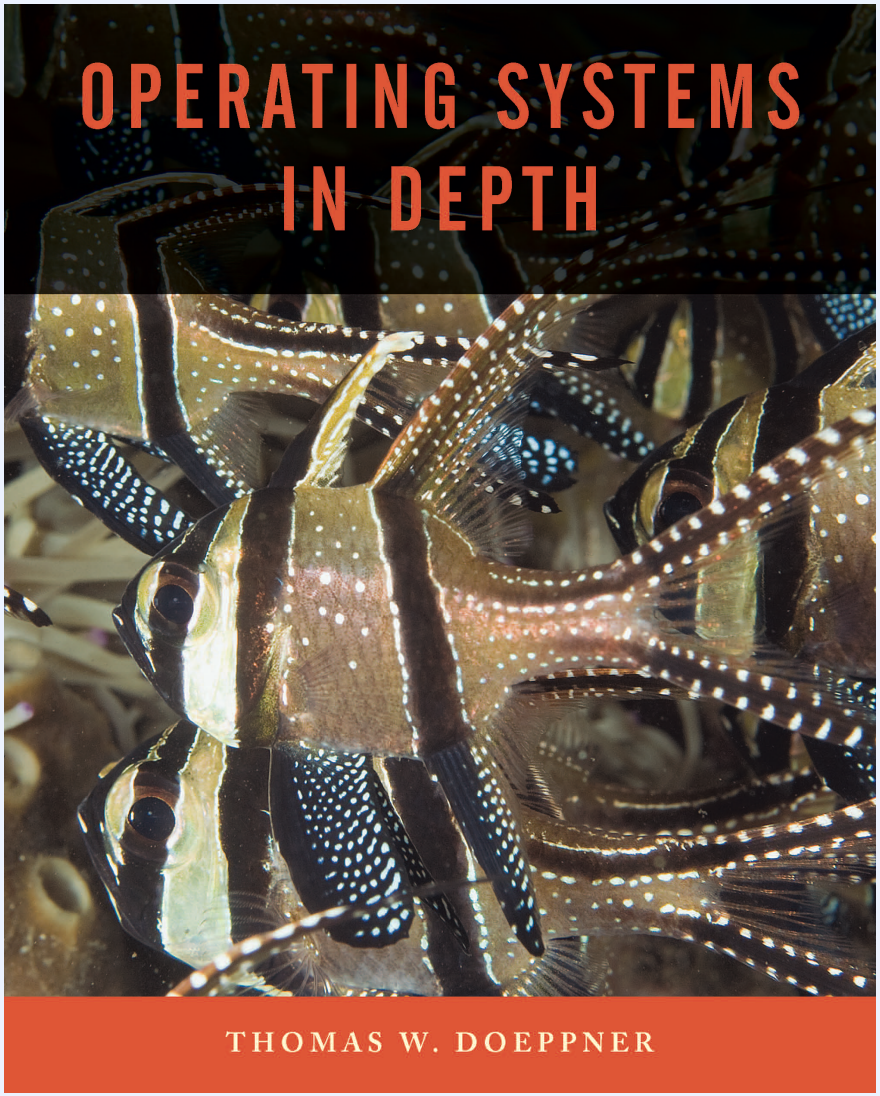
Workload by Course

- 2670 Section 1
  - quizzes: 6.67%
  - homeworks: 26.68%
  - moderate programming assignments: 33.32%
  - large programming assignment: 33.33%
- 2670 Section 2
  - homeworks: 28.58%
  - moderate programming assignments: 35.71%
  - large programming assignment: 35.71%

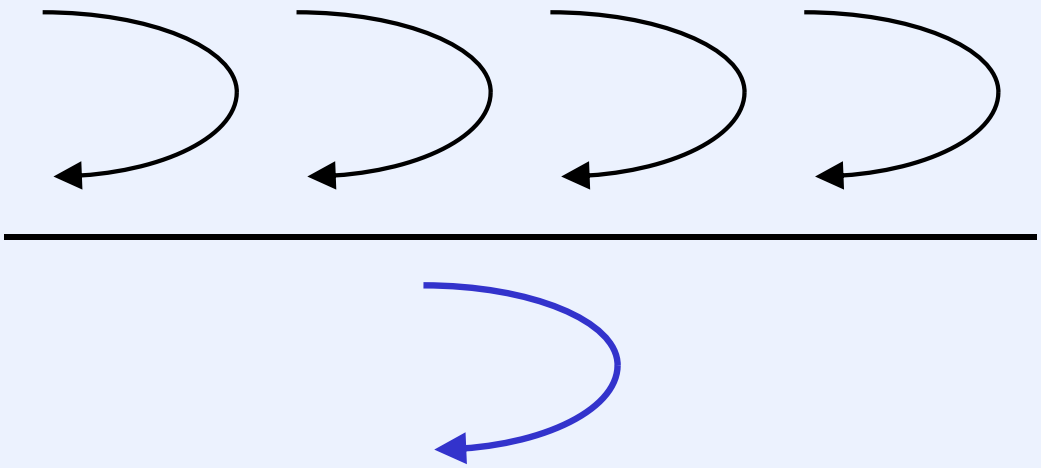
Skills Needed

- Ability to write and debug largish programs in C with POSIX threads
  - CSCI 330/1330 or CSCI 300/1310 (you may want to review POSIX threads and signals material from 330 lectures)
- Basic computer architecture
  - CSCI 330/1330 or CSCI 300/1310

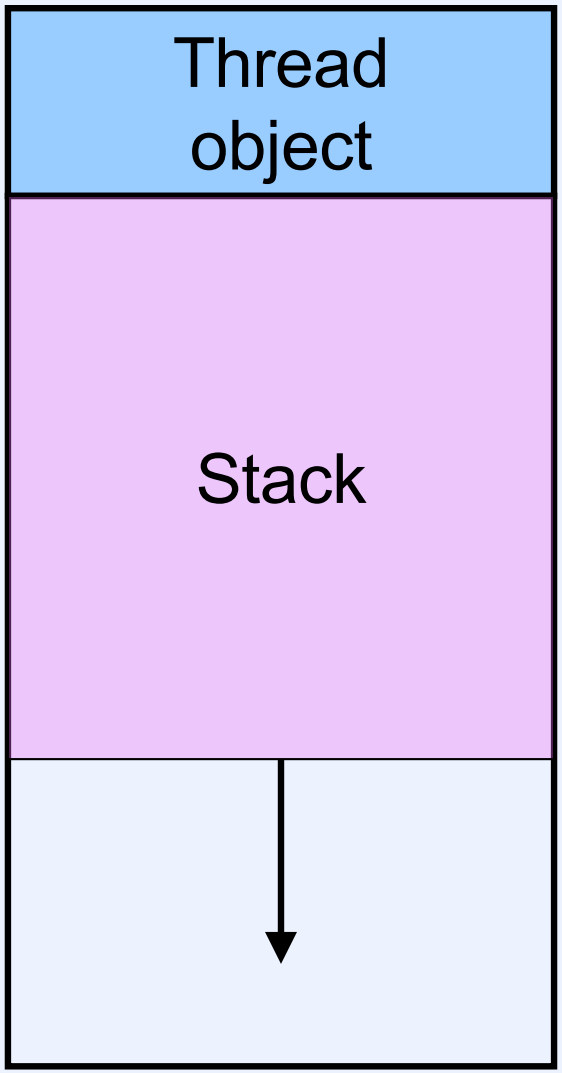
Textbook



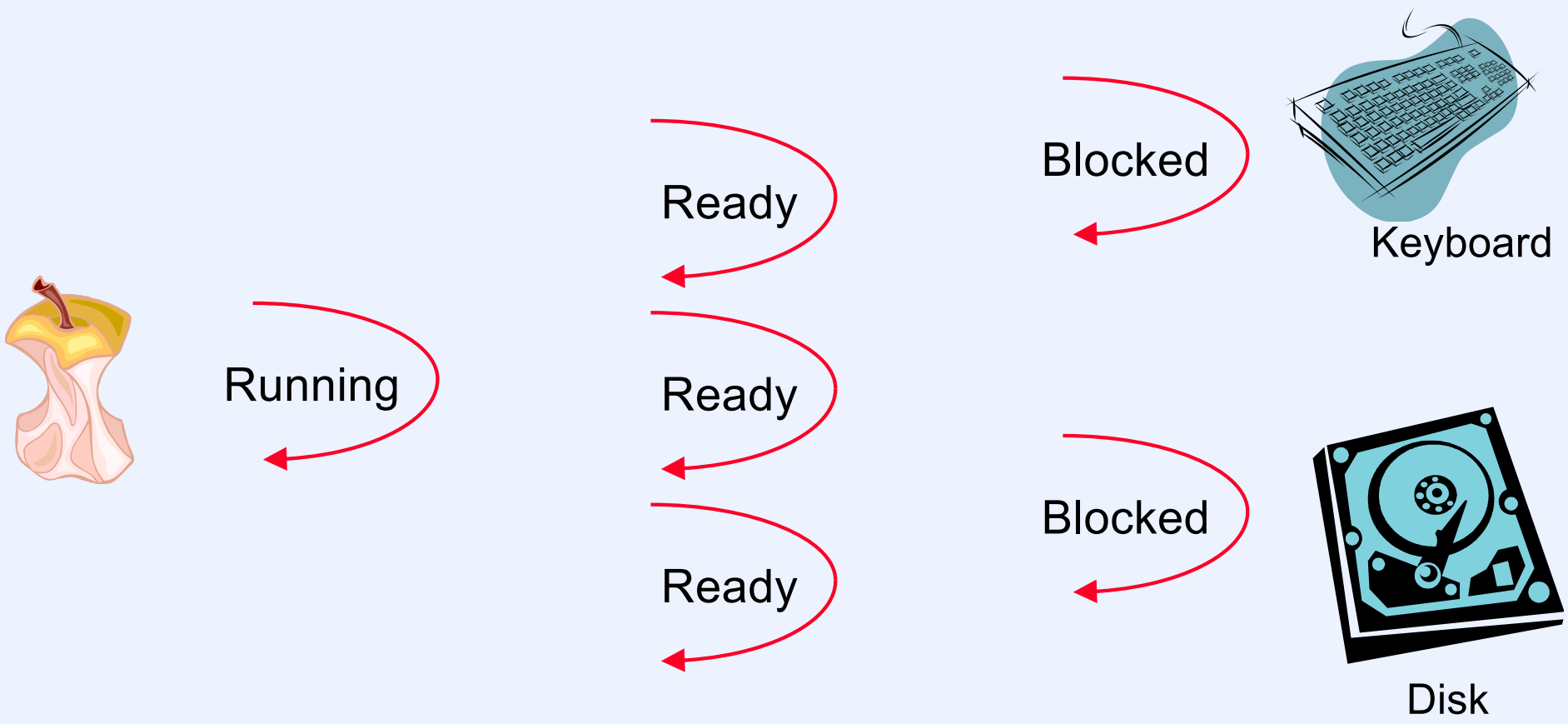
UThreads



UThread Implementation



Multiplexing Threads (1)



Multiplexing Threads (2)




Running

Running

Running

Running

Ready

Ready

Ready

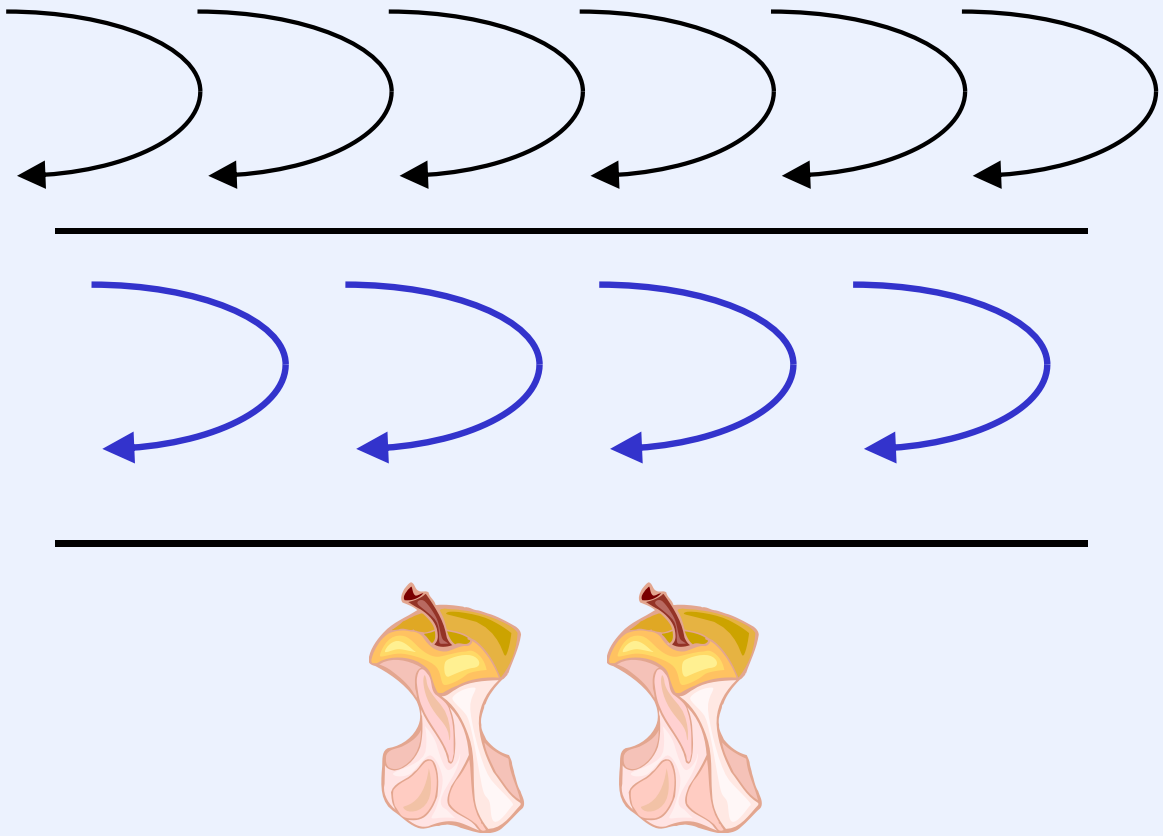
Blocked

Blocked

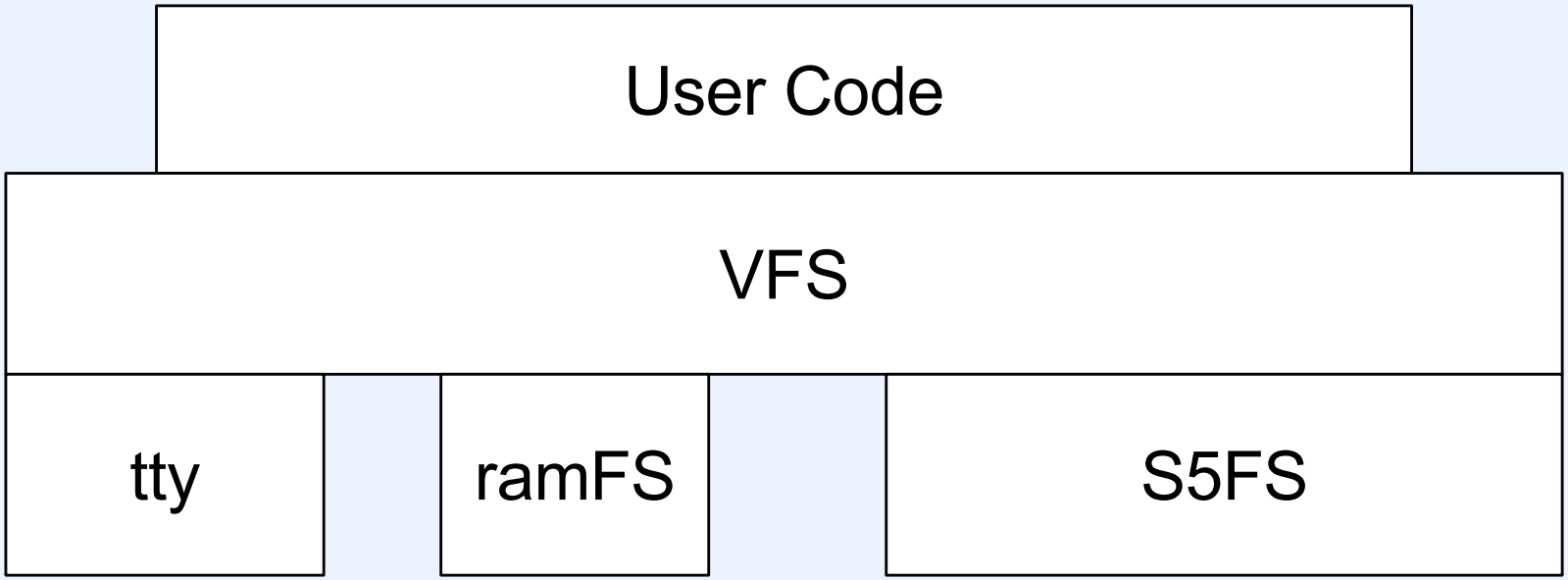
Keyboard

Disk

MThreads

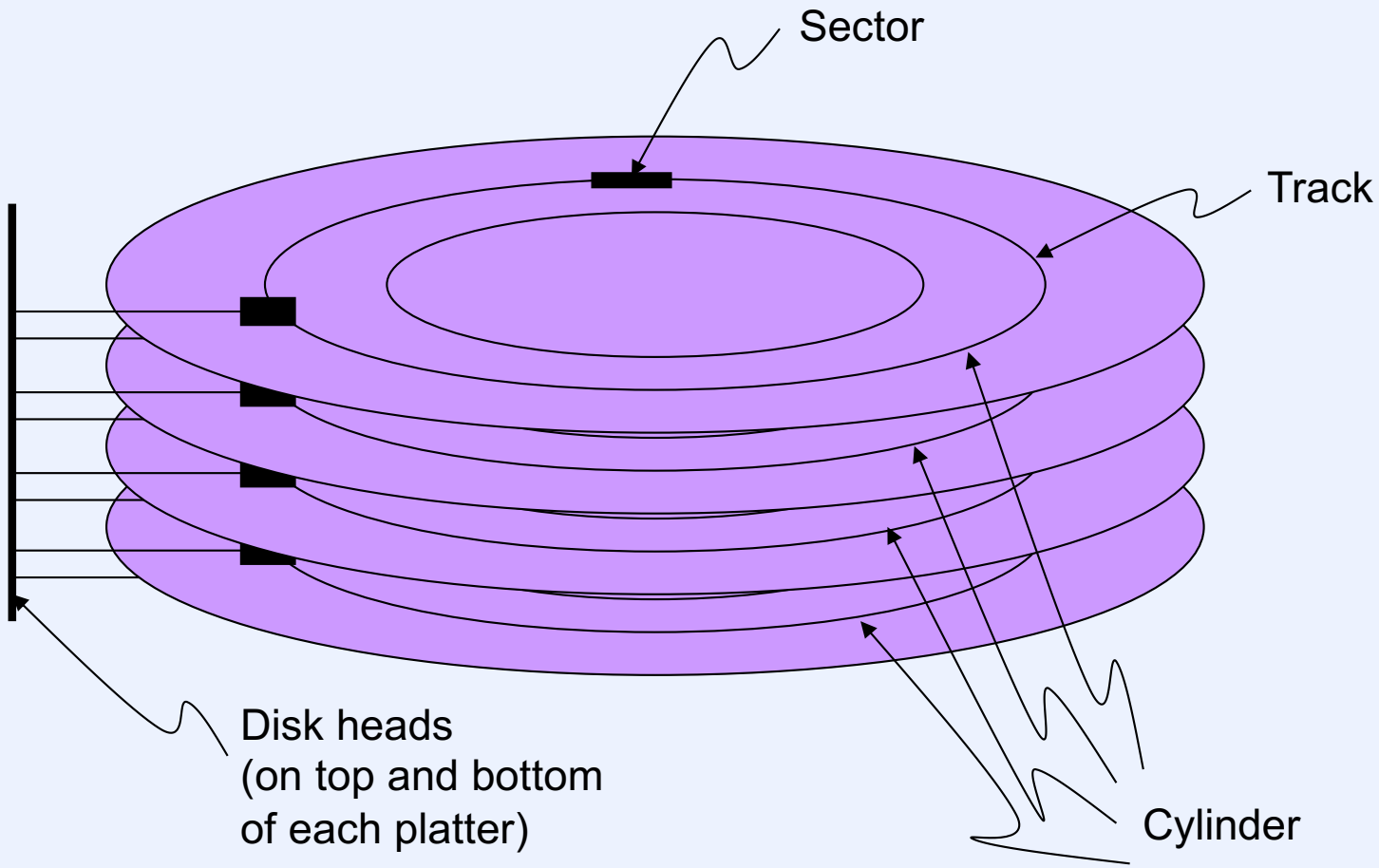


VFS

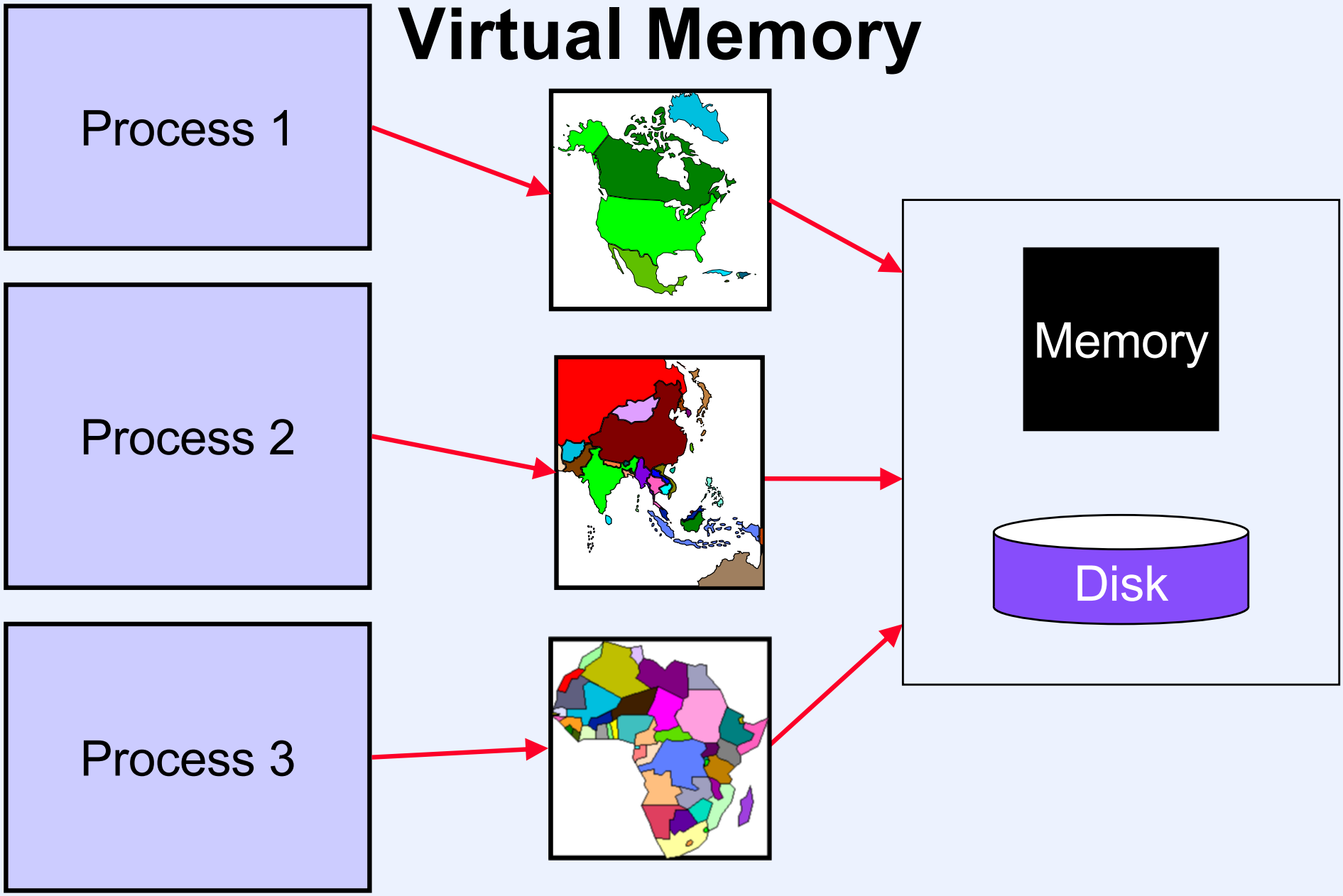


S5FS

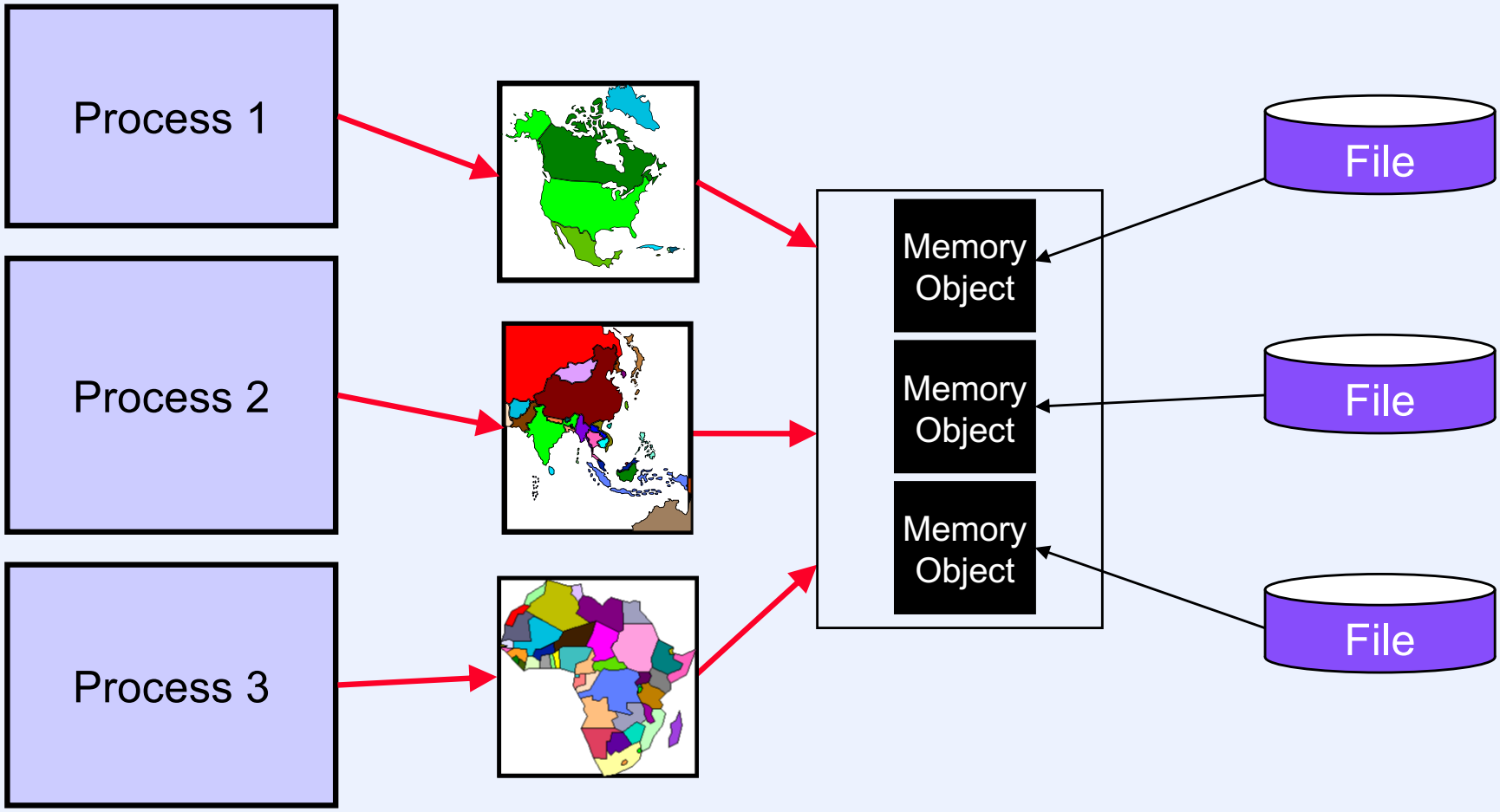
- It's on a disk!



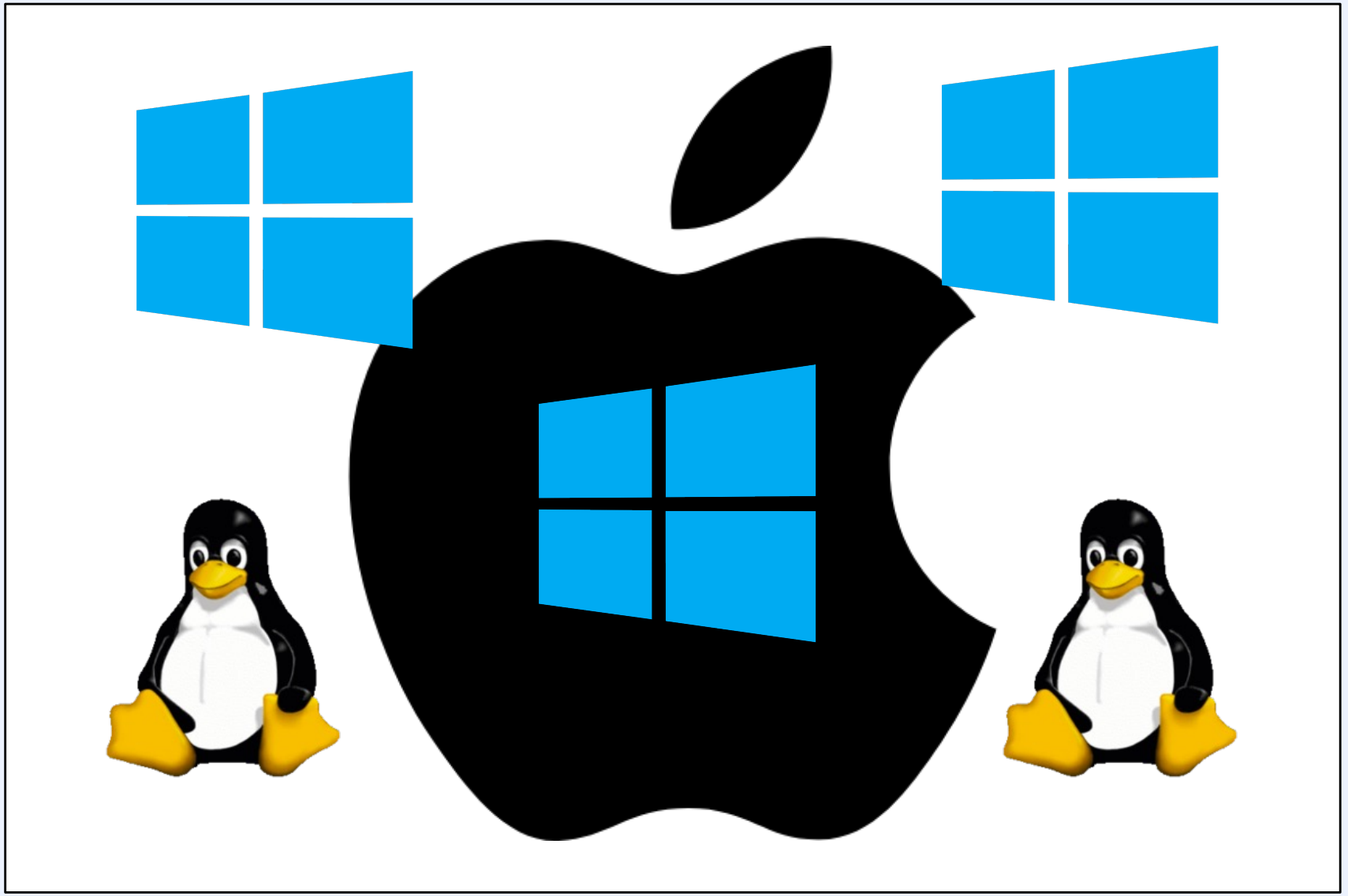
Virtual Memory



Virtual Memory + VFS



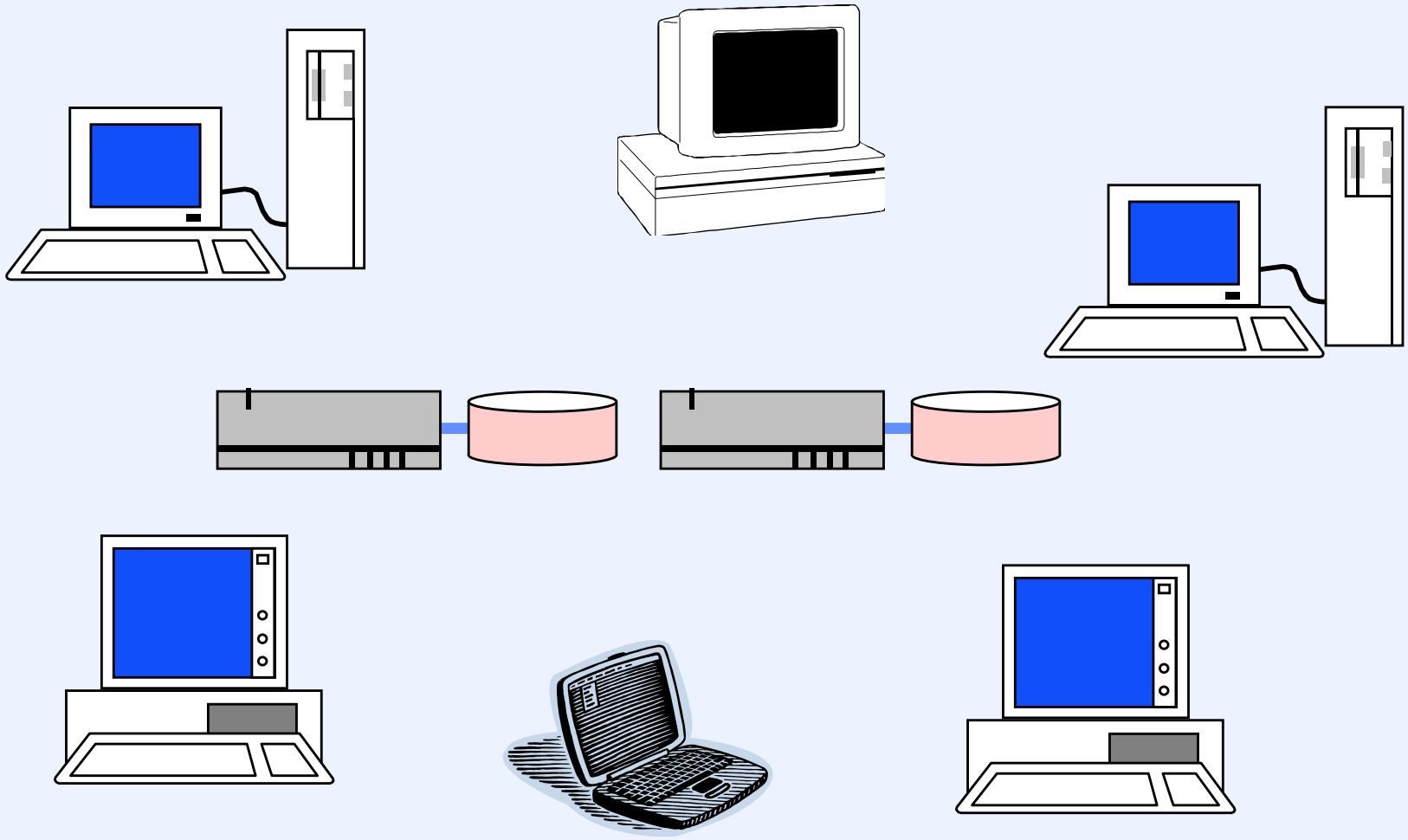
General Virtualization



OS-Level Security

- Authentication
  - who are you?
- Authorization
  - what are you allowed to do?
- How is all this enforced?
  - Windows/Mac/Linux
  - SELinux (security-enhanced Linux)
  - capability-based systems

Distributed File Systems



1960s OS Issues

- Multiprogramming
- Time sharing
- Software complexity
- Security

2025 OS Issues

- Multiprogramming
  - not just one computer, but server farms
- Time sharing
  - voice, video, sound, etc.
- Software complexity
  - a much bigger problem than could possibly be imagined in the ’60s
- Security
  - ditto

In the Beginning …

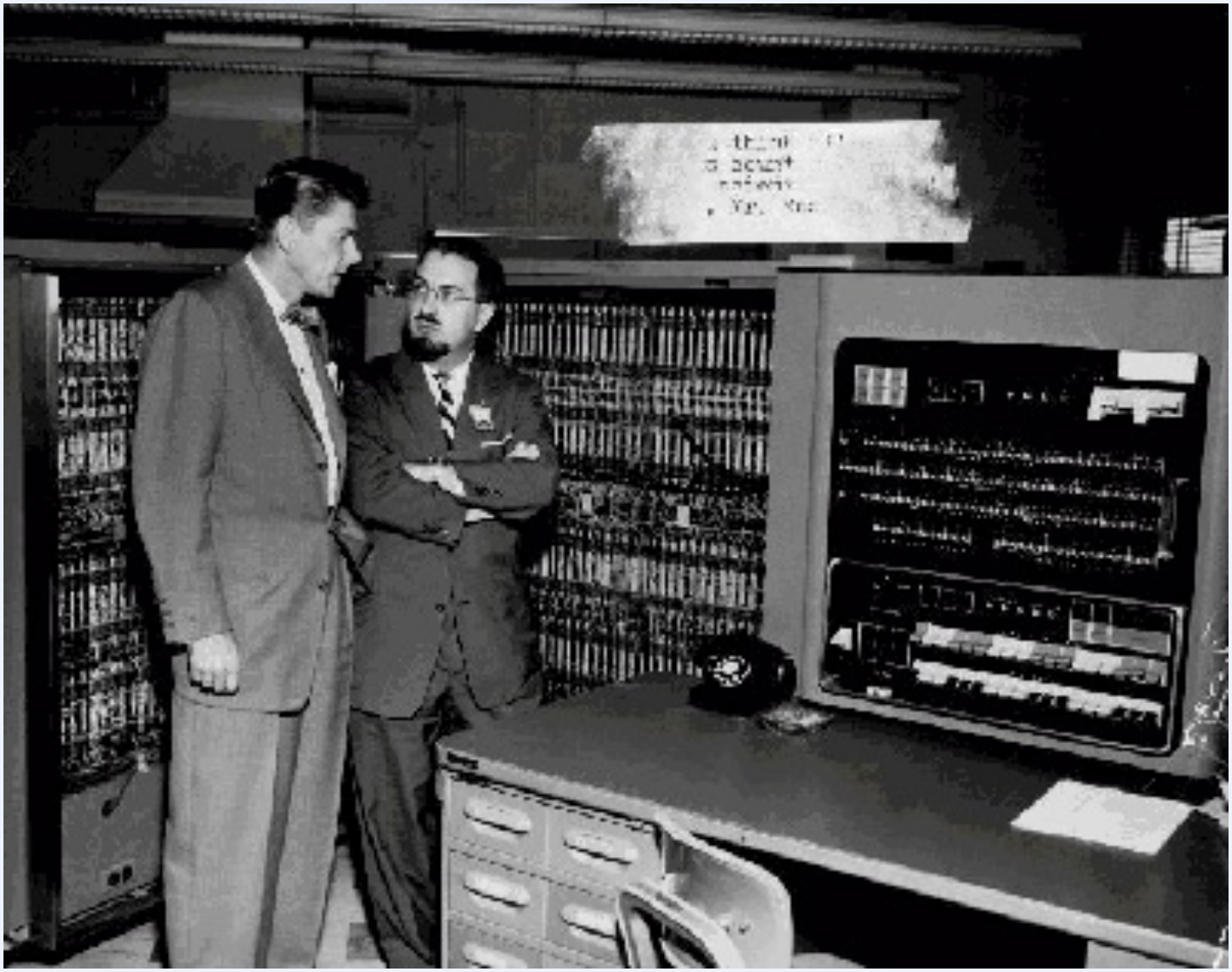
- There was hardware
  - processor
  - storage
  - card reader
  - tape drive
  - drum
- And not much else
  - no operating system
  - no libraries
  - no compilers

1950s

Commercial data processing

Scientific computing

IBM 701



OS:

Initially, none

IBM 650

OS:

none

1960s

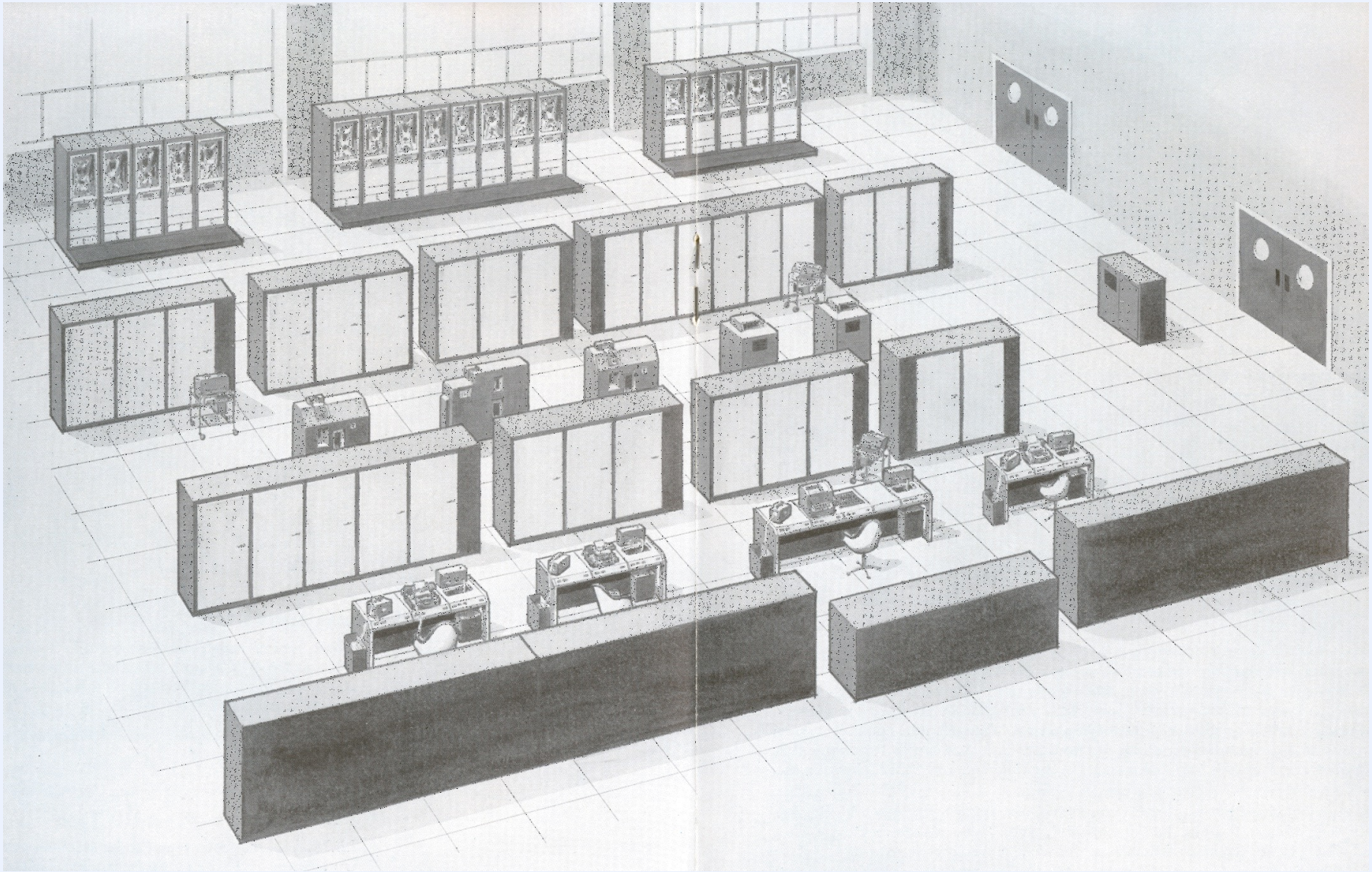
Commercial data processing

Scientific computing

Time sharing

Laboratory computing

Atlas Computer

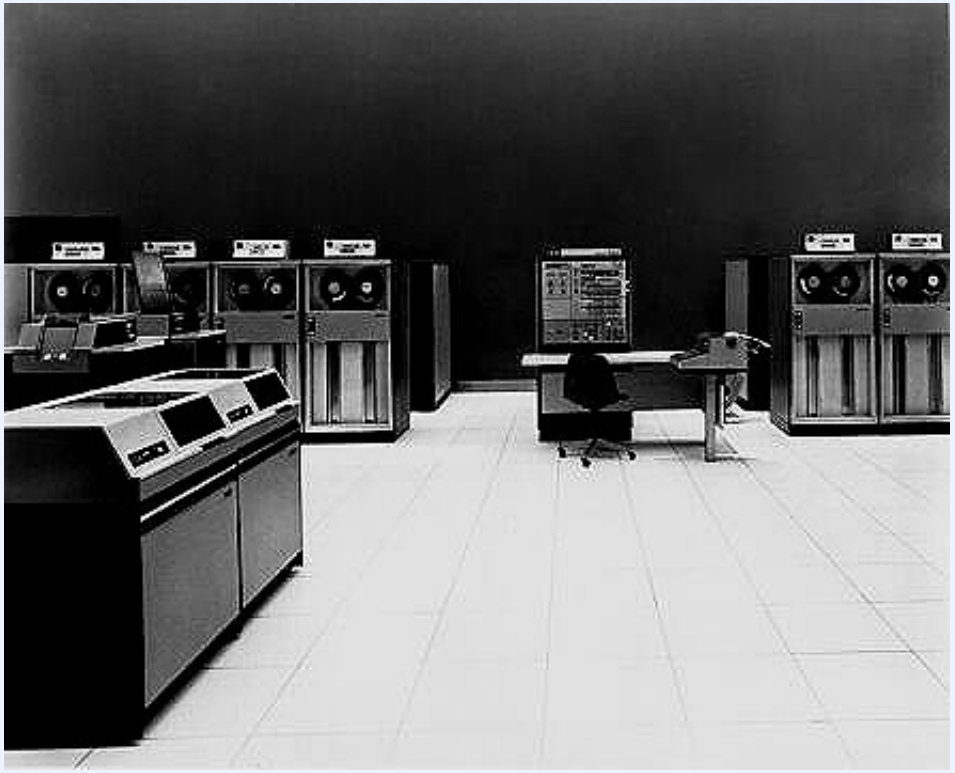


IBM 7094

OS:

CTSS
(among others)

The IBM Mainframe



OS:

OS/360

Multics

DEC PDP-8

OS:

many:
ranging from primitive to interesting (a multi-user time-sharing system; a virtual-machine system)

Unix

History of Concurrency

- Multiprogramming
  - 1961, 1962: Atlas, B5000
  - 1965: OS/360 MFT, MVT
- Timesharing
  - 1961: CTSS (developed by MIT for IBM 7094); BBN time-sharing system for DEC PDP-1
  - mid 60s
    - Dartmouth Timesharing System (DTSS)
    - TOPS-10 (DEC)
  - late 60s
    - Multics (MIT, GE, Bell Labs)
    - Unix (Bell Labs)

History of Virtual Memory

- 1961: Atlas computer, University of Manchester, UK
- 1962: Burroughs B5000
- 1972: IBM OS/370
- 1979: 3 BSD Unix, UC Berkeley
- 1993: Microsoft Windows NT 3.1
- 2000: Apple Macintosh OS X

1970s

Commercial data processing

Scientific computing

Time sharing

Laboratory computing

Personal computing

Hobbyist computing

IBM's Dominance Continues

OS:

OS/370

Scientific Computing

OS:

COS: single job at a time

Xerox Alto

OS:

single-user, single-computation

MITS ALTAIR 8800

OS:

none

CP/M

- Control Program for Microcomputers
  - 1974
  - first hobbyist OS
  - supported Intel 8080 and other systems
    - clear separation of architecture-dependent code
  - no multiprogramming
  - no protection

Apple II

OS:

initially: none
later: similar functionality as CP/M (not much)

Microsoft Enters the OS Business: Late 1970s

- It's called …
  - Xenix
    - a version of Unix
  - predominant version of Unix in the 1980s
  - used by MS internally into the 1990s

VAX-11/780

OS:

VMS
Unix

Both:

- **time sharing**
- **virtual memory**
- **access protection**
- **concurrency**

1980s

Commercial data processing

Scientific computing

Time sharing

Laboratory computing

~~Personal~~ Professional computing

~~Hobbyist~~ Personal computing

Two OSes Take Off

Unix

MS-DOS

IBM PC

OS:

PC-DOS
(aka MS-DOS)
(remarkably like CP/M)

The Computer Workstation

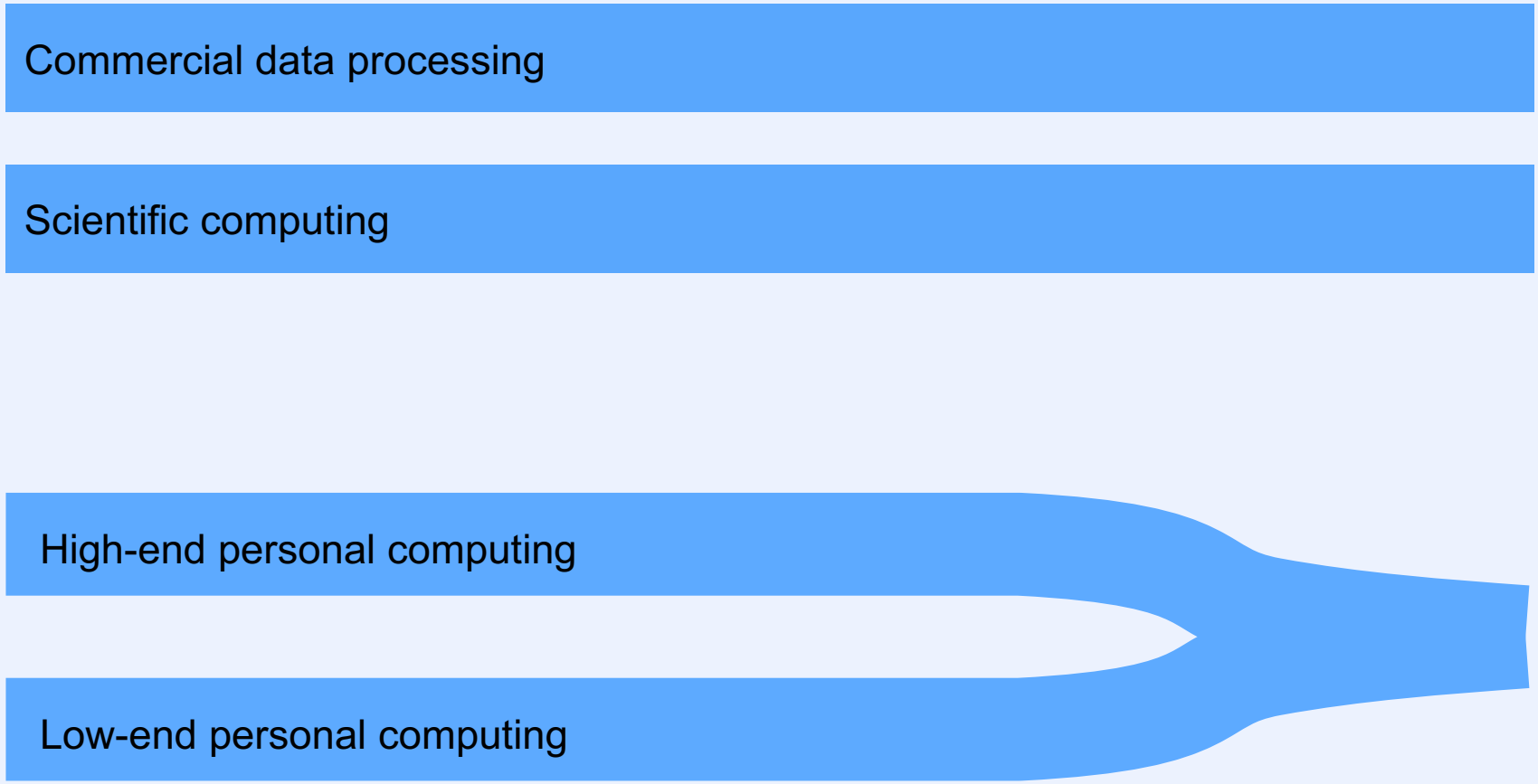
OS:

Aegis

supported:

- **virtual memory**
- **distributed file system**
- **access protection**
- **concurrency**

1990s



Toy Operating Systems

- 1987: Andrew Tanenbaum of Vrije Universiteit, Amsterdam, publishes *Operating Systems: Design and Implementation*
  - included is source code for a complete, though toy, operating system: Minix, sort of based on Unix
- 1991: Linus Torvalds buys an Intel 386 PC
  - MS-DOS doesn't support all its features (e.g., memory protection, multi-tasking)
  - rewrites Minix to support all this
- January 1992: Torvalds releases Linux 0.12
- January 1992: Tanenbaum declares Linux obsolete

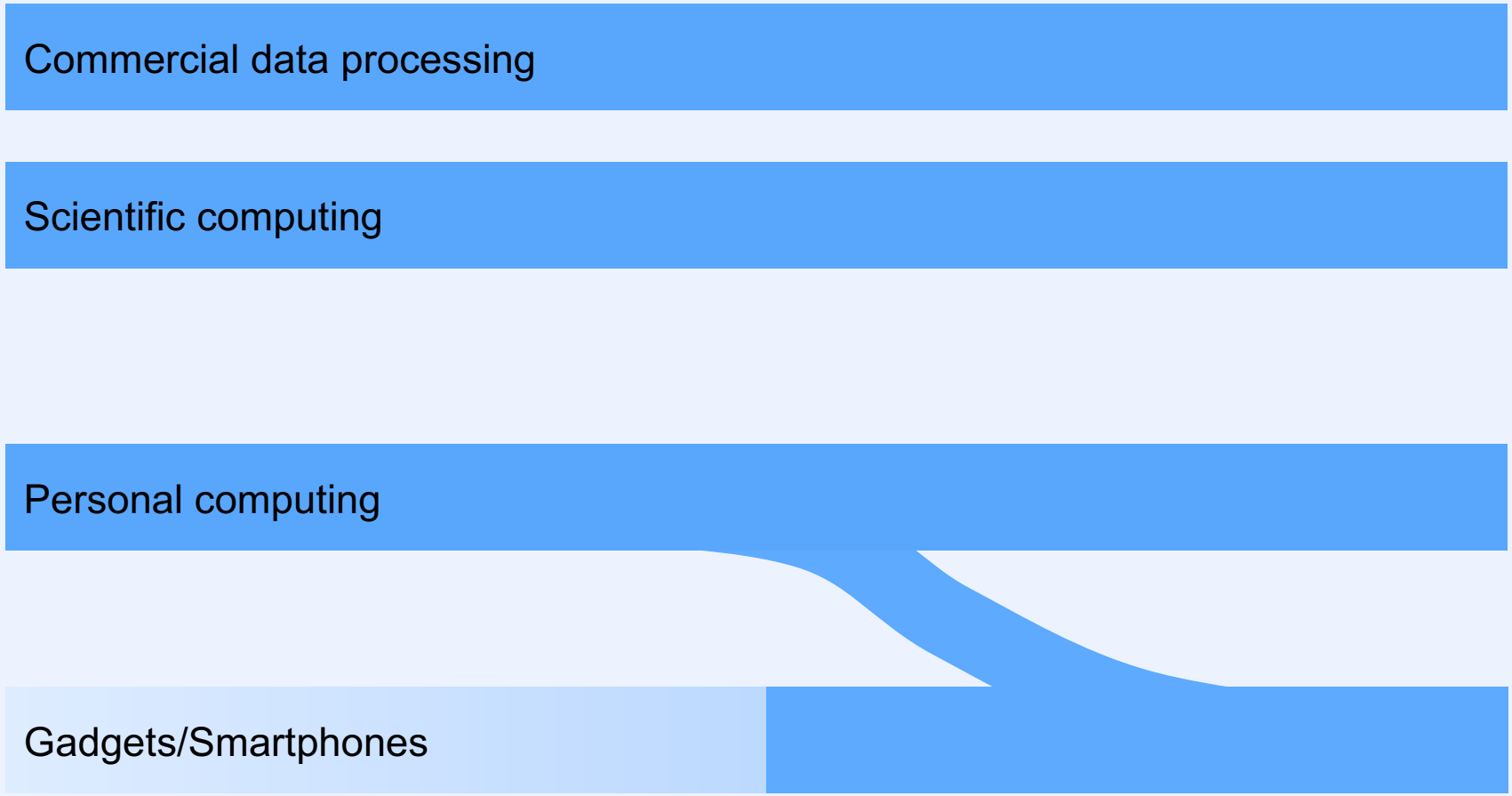
Late ’80s/Early ’90s

- 1988: Most major Unix vendors get together and form OSF to produce a common Unix: OSF/1, based on IBM’s AIX
- 1989: Microsoft begins work on NT
- 1990: OSF abandons AIX, restarts with Mach
- 1991: OSF releases OSF/1
- 1992: Sun releases Solaris 2
  - many SunOS (Solaris 1) programs are broken
- 1993: All major players but DEC have abandoned OSF/1
- 1993: Microsoft releases Windows NT 3.1
- 1994: Linux 1.0 released

Late ’90s

- 1996: DEC renames its OSF/1 “Digital Unix”
- 1996: Microsoft releases Windows NT 4
- 1996: Linux 2.0 released
- 1998: DEC is purchased by Compaq; “Digital Unix” is renamed “Tru64 Unix”
- 1999: Sun’s follow-on to Solaris 2.6 is called Solaris 7

2000s



The ’00s Part 1

- 2000: Microsoft releases Windows 2000 and Windows Me
- 2000: Linux 2.2 is released
- 2000: IBM “commits” to Linux (on servers)
- 2001: Apple releases Mac OS X, based on Unix and Mach (sort of like OSF/1)
- 2001: Linux 2.4 is released
- 2001: Microsoft releases Windows XP
- 2002: Compaq is purchased by HP
- 2003: SCO claims their code is in Linux, sues IBM; IBM countersues
  - August 10, 2007: judge rules that SCO is not the rightful owner of the Unix copyright, Novell is
  - Novell says there is no Unix in Linux
  - September 2007: SCO files for Chapter 11 bankruptcy protection

The ’00s Part 2

- 2004: Linux 2.6 is released
- 2005: IBM sells PC business to Lenovo
- July 2005: Microsoft announces Windows Vista
- January 2007: Microsoft releases Windows Vista
- Later in 2007: Microsoft starts hinting at Windows 7
- June 2007: Apple releases iOS for iPhone
- April 2009: Oracle announces purchase of Sun Microsystems
- July 2009: Google announces Chrome OS
- October 2009: Microsoft releases Windows 7

The ’10s Part 1

- January 2011: Microsoft announces Windows 8
- June 2011: first products shipped running Chrome OS
- April 2011: Linux 3.0 released
- July 2011: Apple drops “Mac” prefix for its OS: it’s now “OS X”
  - one million copies of OS X Lion sold on first day of release
- October 2011: deaths of both Dennis Ritchie and Steve Jobs
  - “Dennis Ritchie: The Shoulders Steve Jobs Stood On”
    - Wired Magazine, 10/13/2011
- October 2012: Microsoft releases Windows 8

The ’10s Part 2

- September 2014: Microsoft Announces Windows 10
  - Windows 9 skipped because it might be confused with Windows 95
- October 2014: Apple releases OS X 10.10 Yosemite
  - doesn’t work with Brown University wi-fi
  - November 2014 release of 10.10.1 doesn’t fix it ...
- April 2015: Linux 4.0 released
- July 2015: Microsoft Releases Windows 10
  - Brown’s CIS says “don’t switch yet”
  - August 2015: Brown’s card-access system switched to Windows 10
  - August 2015: Brown’s card access fails university-wide
- September 2015: Apple releases OS X 10.11 El Capitan
  - Brown’s CIS says “don’t switch yet”

The ’10s Part 3

- September 2016: Apple releases OS X 10.12 Sierra
  - Brown CIS says don’t switch
  - Brown CS tstaff says printing is broken
- December 2016: Apple releases OS X 10.12.2
  - twd switches
  - his D-Link router no longer supported printing
  - his Logitech mouse’s scroll wheel scrolled window in random directions
- January 2018: Meltdown and Spectre vulnerabilities disclosed
  - end of computing (if not civilization) as we know it?

The ’10s Part 4

- September 2018: Apple releases OS X 10.14 Mojave
  - no one switches
- October 2018: Apple releases OS X 10.14.1
  - twd switches
  - PowerPoint presentations in CS33 randomly switch to random photos
- March 2019: Linux 5.0 released
- October 2019: Apple releases OS X 10.15 Catalina

The ’20s Part 1

- November 2020: Apple releases OS X 11.0 Big Sur
  - twd upgraded his laptop
  - CIS-supported antivirus software won’t let machine shut down
    - fixed in 11.1
- October 2021: Apple releases OS X 12.0 Monterey
  - January 2022: OIT (formerly CIS) finally says it’s ok to use it
  - twd bought a new laptop that came with Monterey (12.0.1) installed
  - twd’s 7-year-old iMac was too old to run it
- October 2022: Apple releases OS X 13.0 Ventura
  - CSCI 330/1330 students who installed it regretted it

The ’20s Part 2

- September 2023: Apple announces OS X 14.0 Sonoma
  - OIT says many things don’t work
  - twd waits till 14.2.1 before switching
    - Logitech mouse’s tracking speed can’t be adjusted
- September 2024: Apple announces macOS 15.0 Sequoia
  - macOS reintroduced to differentiate it from iOS
  - twd gets new desktop with 15.0
    - no major problems!
    - now running 15.1.1

Friday

- Implementing threads
  - now is a good time to review POSIX threads