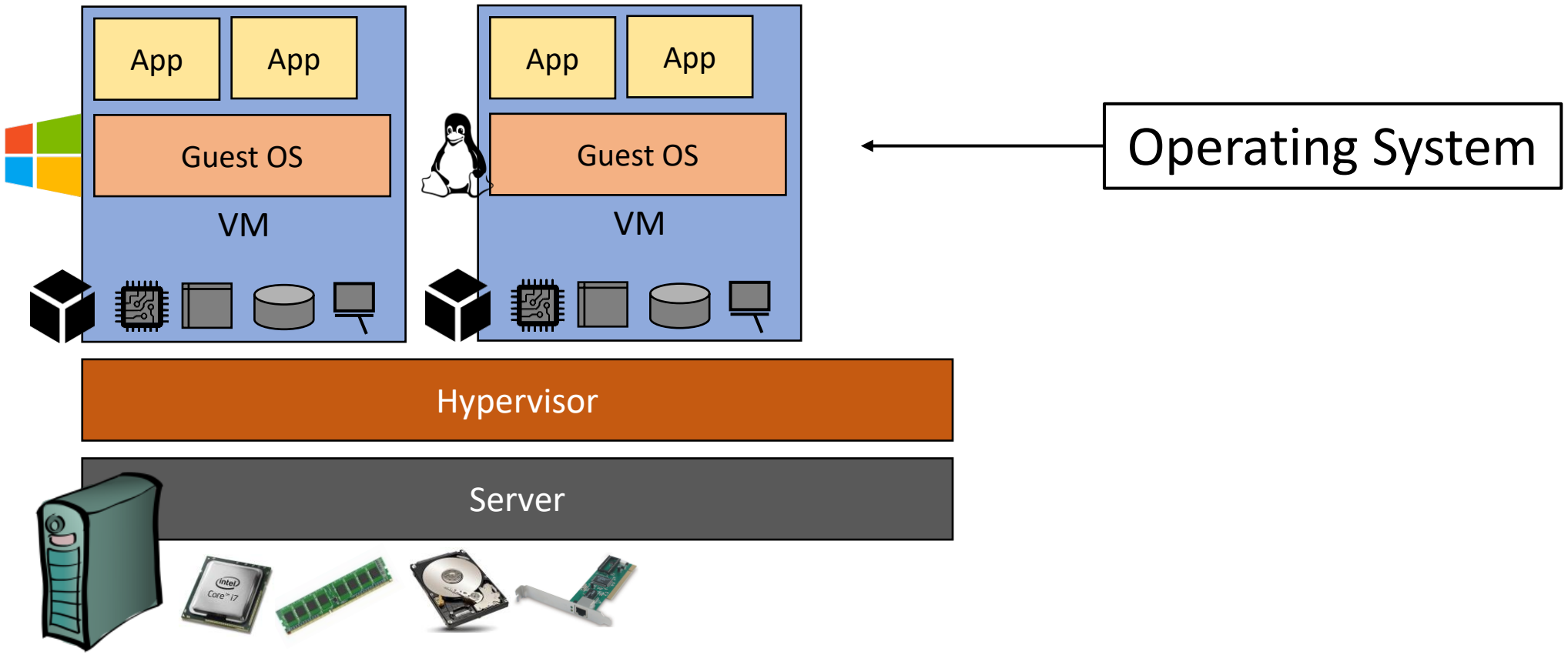
CompSci 401: Cloud Computing

Overhead of Virtual Machines

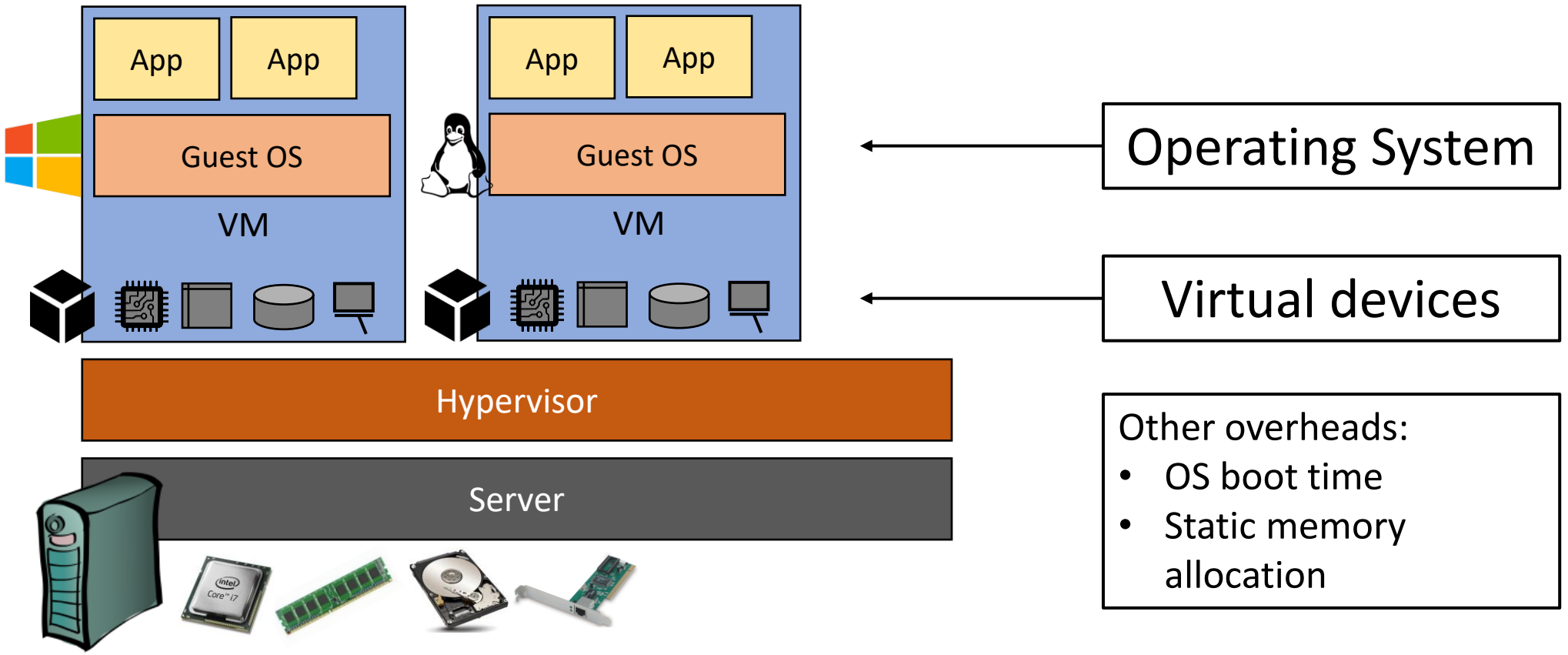
Prof. Ítalo Cunha

昆山杜克大学
DUKE KUNSHAN UNIVERSITY

VMs provide complete flexibility



VMs provide complete flexibility, at a cost



Virtual machines and autoscaling

- VM overhead is amortized when applications run permanently
  - Pay overhead for booting the operating system once
- VM overhead is amortized when multiple applications run in the OS
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Virtual machines are not a great match for highly dynamic cloud applications

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Process Management

Prof. Ítalo Cunha

昆山杜克大学
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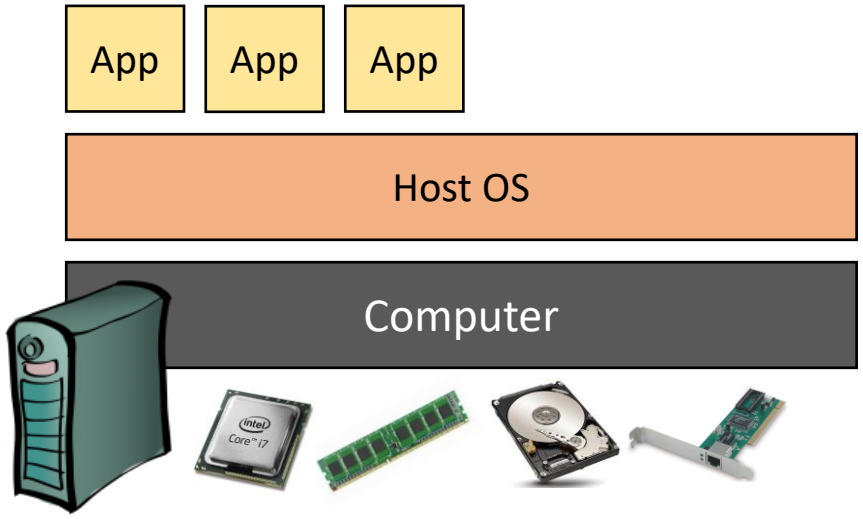
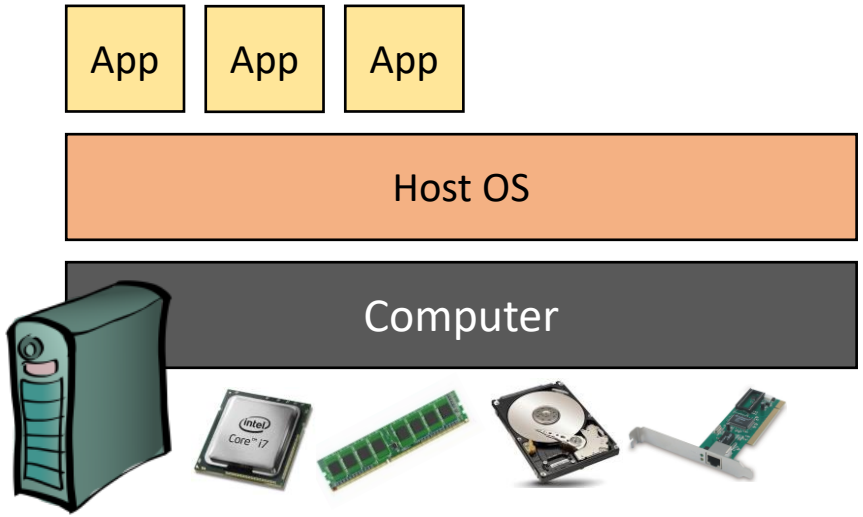
Operating systems manage applications



Operating systems manage applications

Applications in an operating system

- Start and terminate quickly
- More direct, efficient access to hardware
- Share memory effectively
- Can scale running instances on multiple servers



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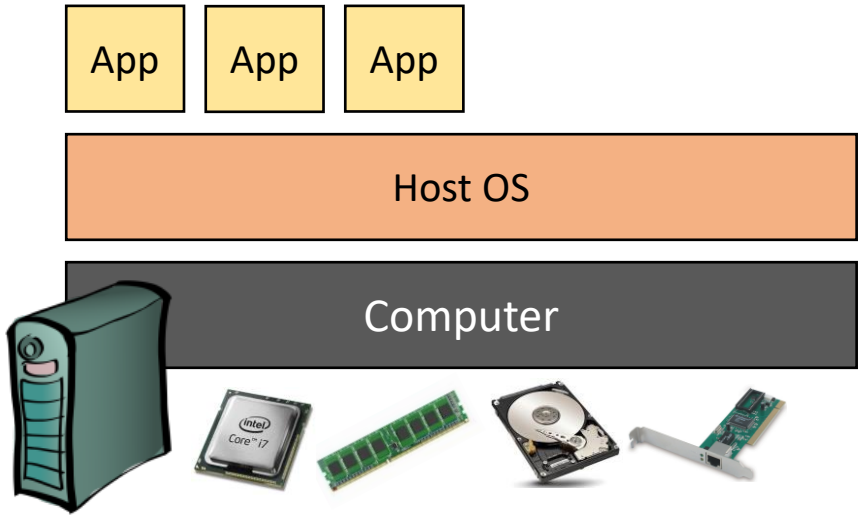

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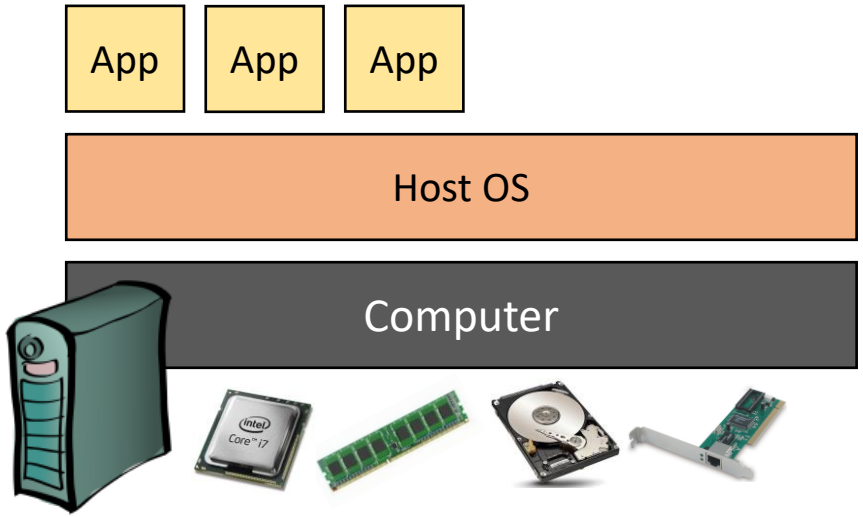

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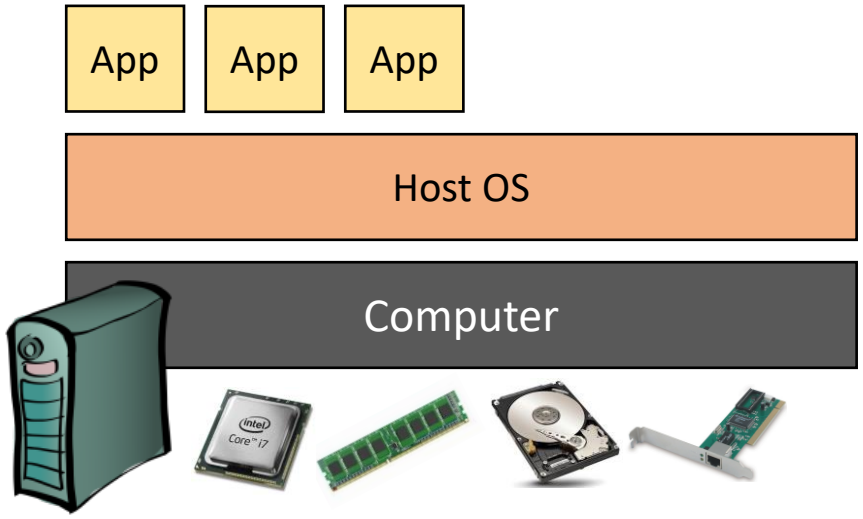
Isolation facilities in operating systems:

- Virtual address spaces isolate memory
- User IDs and filesystem permissions isolate data

Operating systems manage applications



Applications in an operating system

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OSes do not enforce complete isolation

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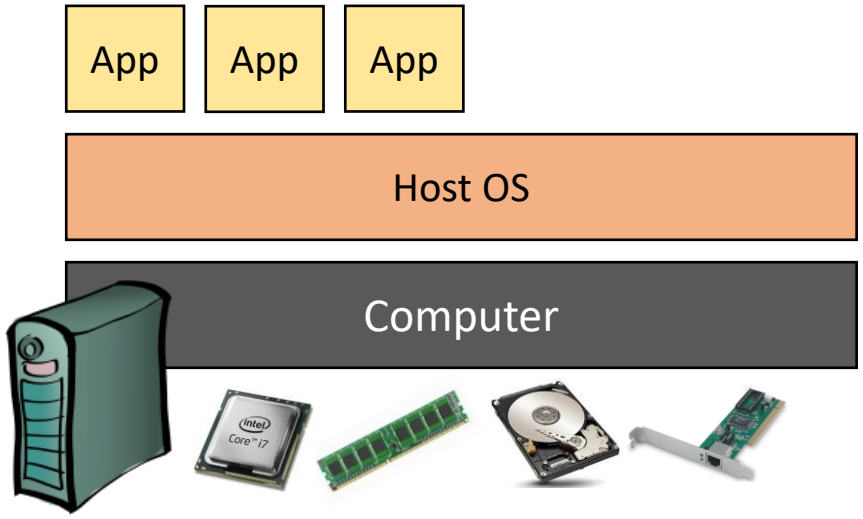
- Shared metadata
  - What processes are running

Operating systems manage applications



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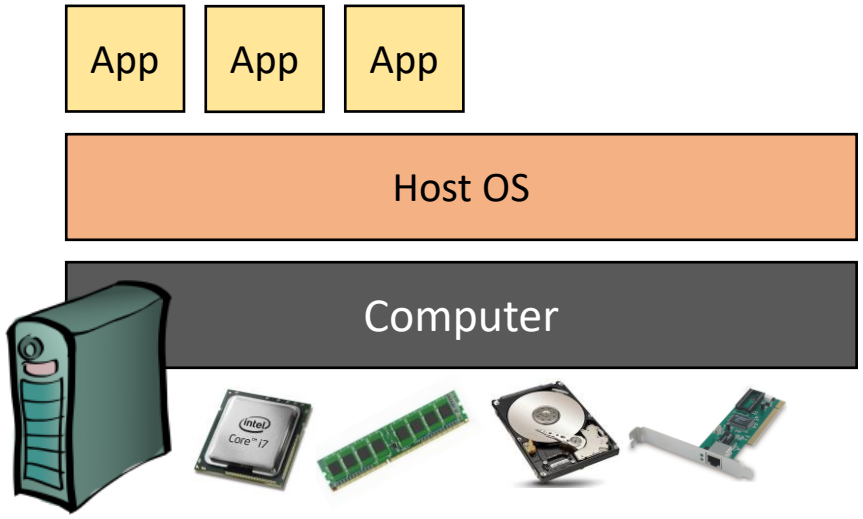

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Sharing leaks information from one application to another

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Containers

Prof. Ítalo Cunha

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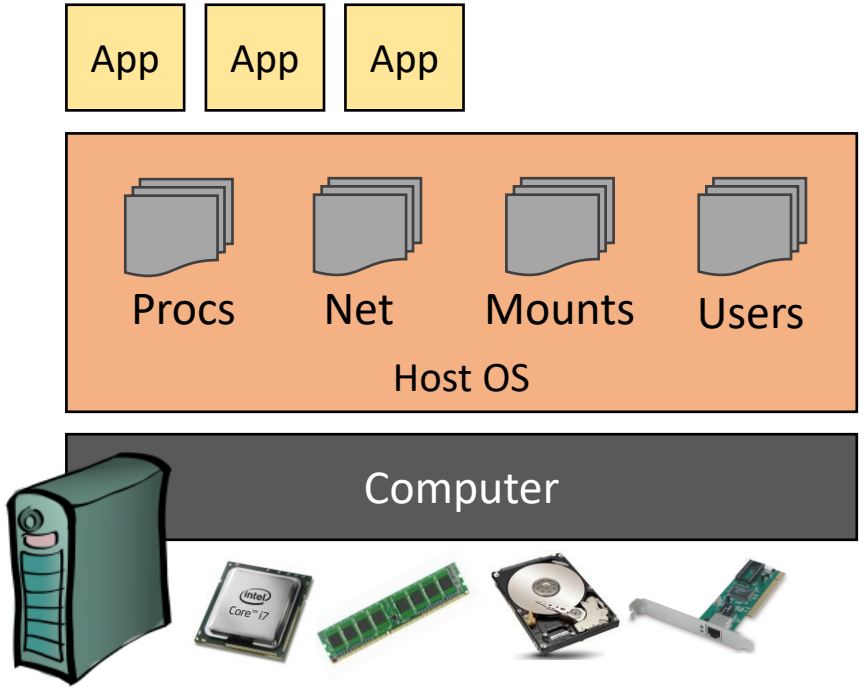
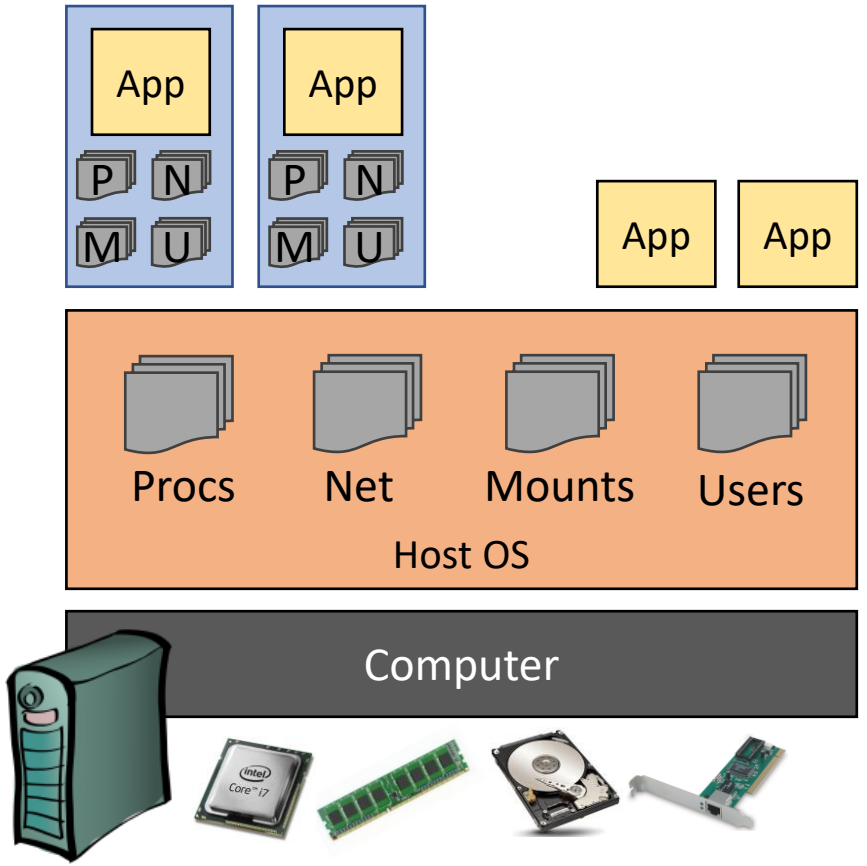
Shared resources within operating systems

- Operating systems manages resources that are shared across apps
- Protection and isolation mechanisms are not thorough



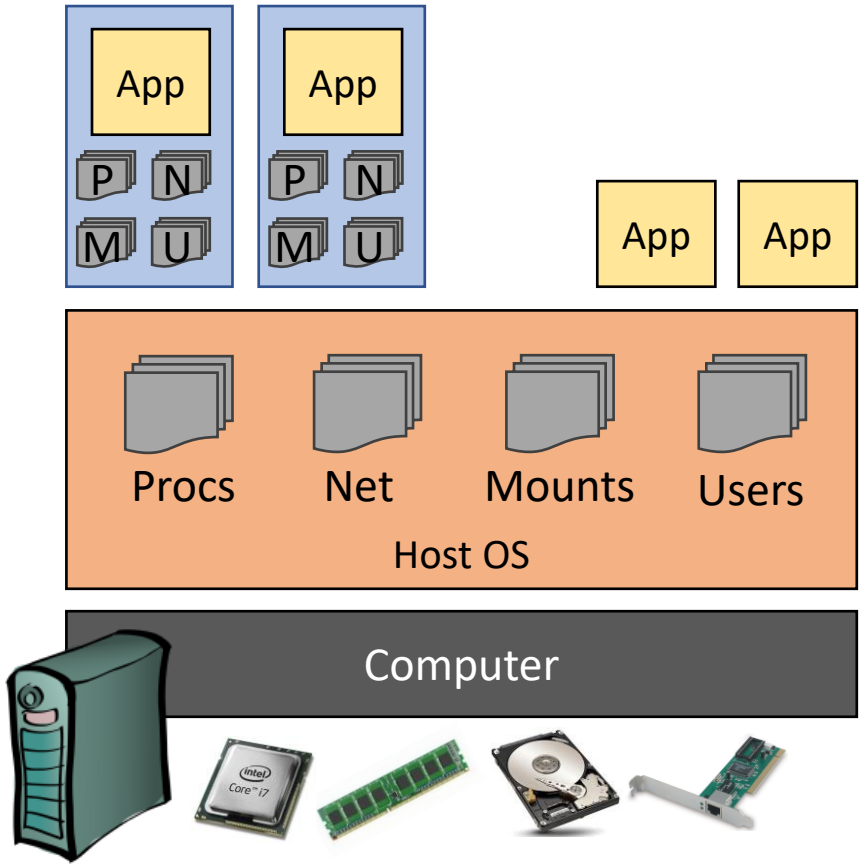
Containers have dedicated resources

- Containers do not share any resources with the host OS



Containers have dedicated resources

- Containers do not share any resources with the host OS
- Linux namespaces:
  - Mount (filesystem)
  - Processes
  - Network
  - Interprocess communication
  - Users
  - Name resolution



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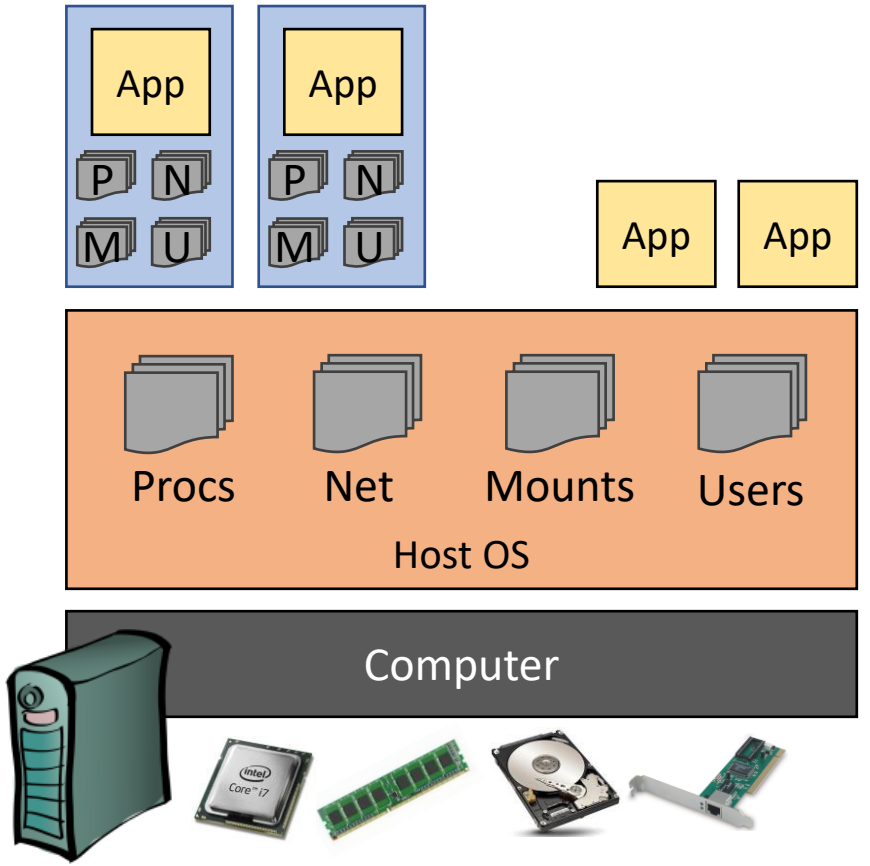
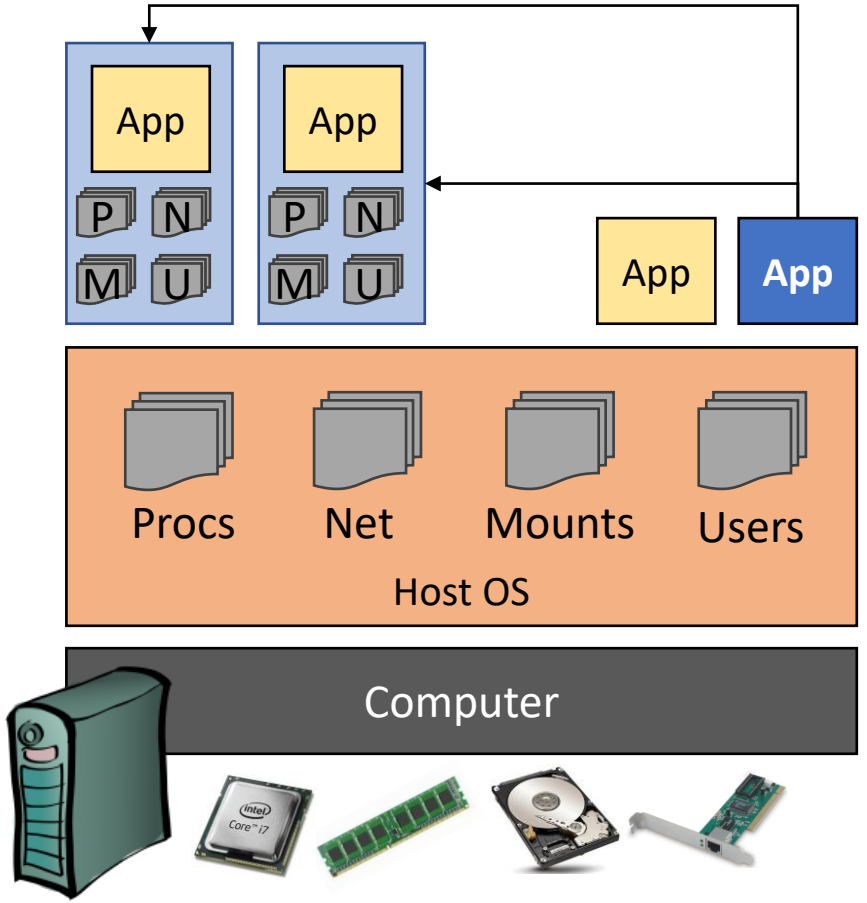


Controlled sharing of resources

- Privileged applications on the host can manage and inspect containers
  - Usually limited to management software like Docker or LXC



Controlled sharing of resources

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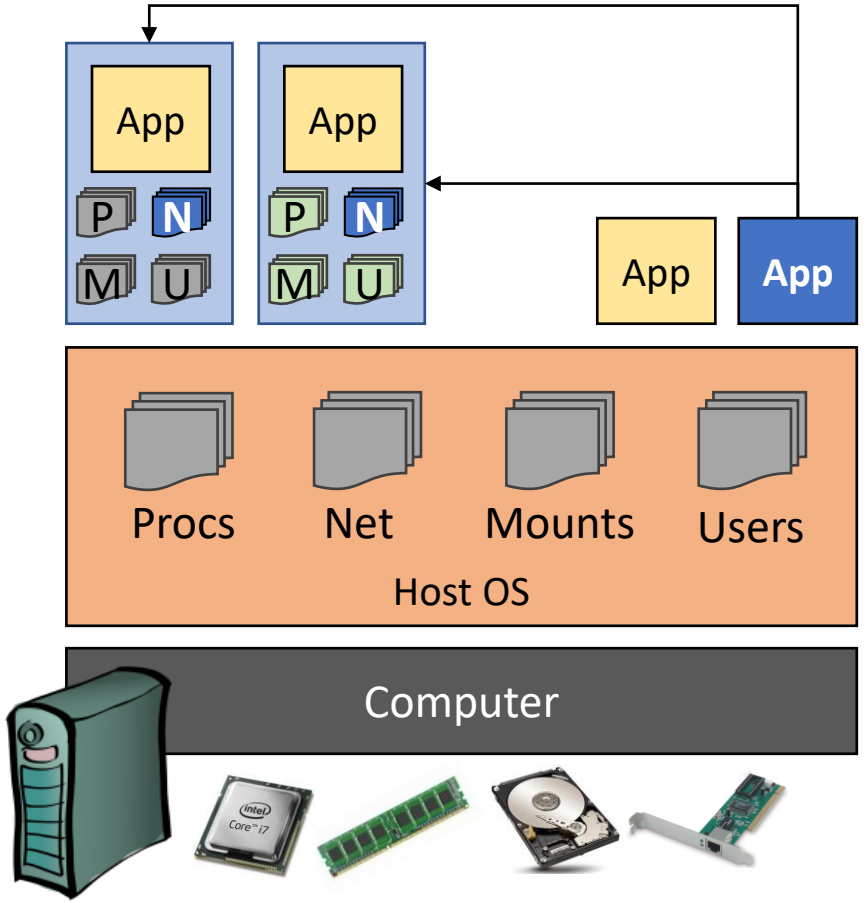
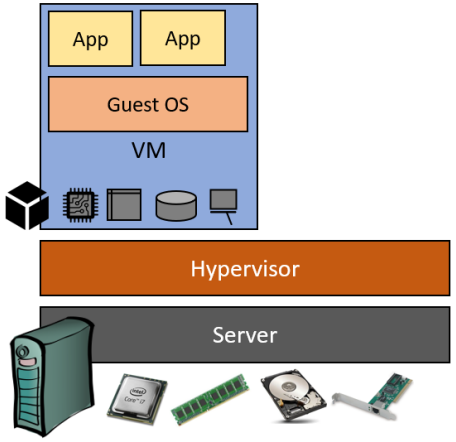
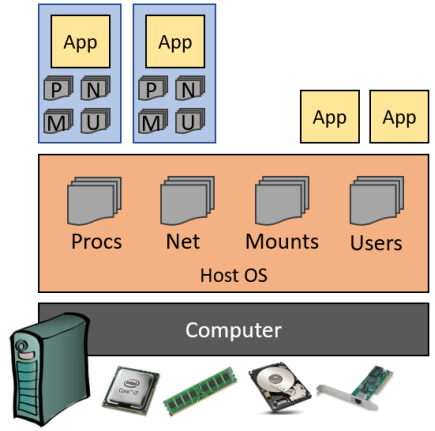
  - Usually limited to management software like Docker or LXC
- Containers can be configured to share namespaces
  - Useful when building sets of containers that cooperate





VM vs containers



Virtual Machines

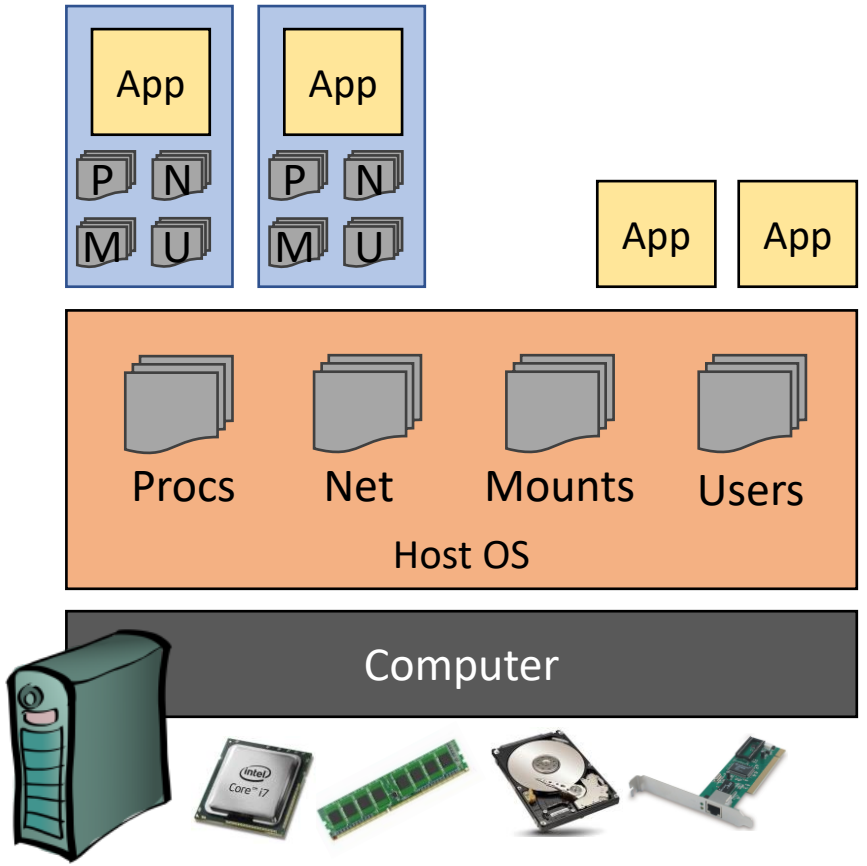
- Slow boot/shutdown sequences
- Operating system overhead
- Total isolation between VMs
- Complete flexibility

Containers

- Fast startup/teardown
- Small resource tracking overhead
- Fine-grained control of isolation
- Runs on host operating system

Containers run on the host OS

- Applications within containers are limited to the host OS
- Cannot run Windows applications on Linux containers
  - Need a virtual machine for that
- Applications cannot use features not supported by the OS kernel
  - May require kernel updates



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Docker

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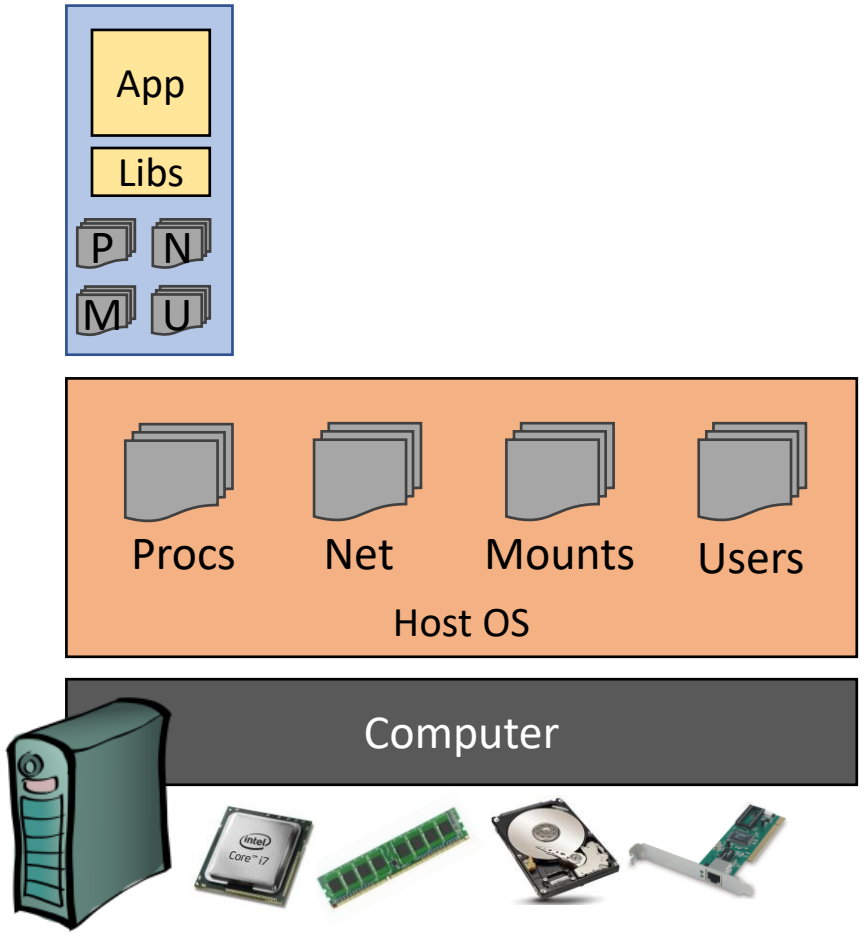
Docker containers

- Small containers running a single application
  - One container image per application
  - Small images speed up download
  - Single application speeds up startup time



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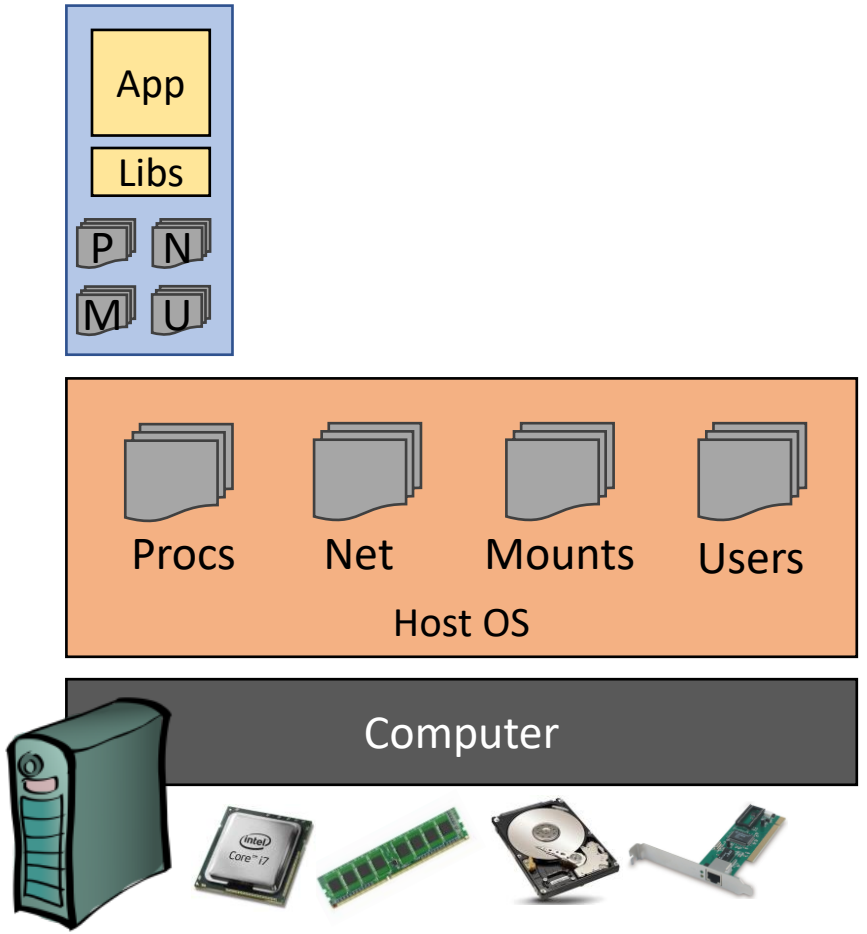
- Libraries and dependencies bundled in image
  - No dependencies on host OS
  - Works on all OSes



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- Libraries and dependencies bundled in image
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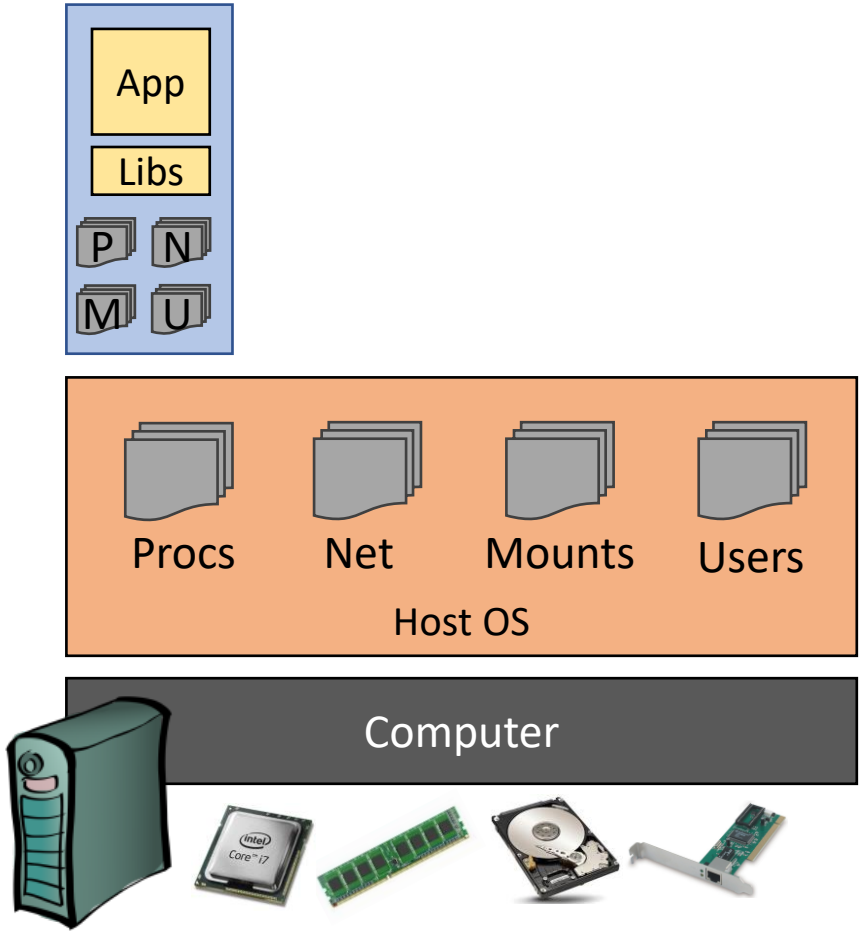
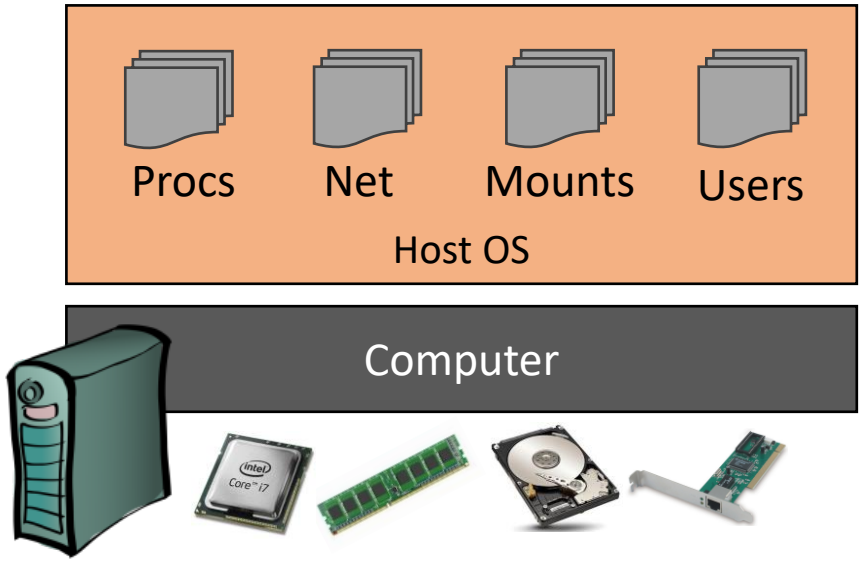
  - Works on all OSes
- Read-only images
  - Changes to container to not persist upon restart
  - Reproducible execution
    - Container starts from a known state every time



Building Docker containers

- Tooling around the development and deployment of containers
  - Dockerfile set of instructions
- Extensive image registry (DockerHub)
  - Ready-to-use containers/applications
  - Building blocks for more complex containers



Dockerfile: a container recipe

Django uses Python

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FROM python:3.7-slim-buster

# Install dependencies
RUN apt-get update
RUN apt-get install --no-install-recommends -y bird
RUN apt-get install --no-install-recommends -y libgit2-27 libgit2-dev
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# Copy application to container
RUN mkdir -p /usr/src/app
WORKDIR /usr/src/app
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# Install modules in requirements.txt
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Set the application to run inside the container

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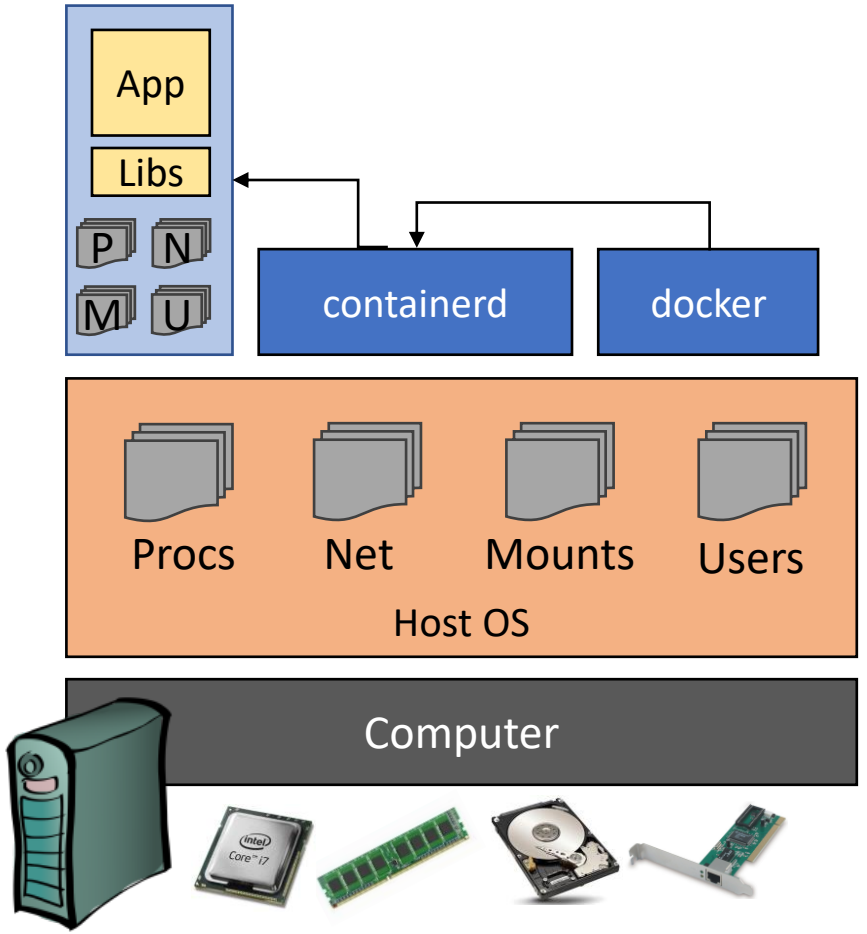
Docker container runtime

- Container runtime controls container
- User issues commands to the runtime using CLI tools or network APIs
- Runtime sets up required components in the operating system
  - Creates and destroys namespaces
  - Configures namespaces
    - For example, the network and volumes



Open source and standards

- Docker is a toolset
- The container runtime has been standardized and open-sourced
  - containerd.io
- Other controllers for the container runtime exist
  - Kubernetes
  - Red Hat Podman

Linux Containers (LXC)

- LXC is another tool to run containers on Linux
  - Relies on the same technologies (namespaces)
- Different approach from Docker
  - More similar to a virtual machine
  - Larger images with a complete user environment
  - Multiple applications running in the container
  - State persists between executions of the same container