First Digital Computer
ENIAC (Electronic Numerical Integrator And Calculator)

• Built in 1946 at the University of Pennsylvania

• Result of military research funding – the need to more quickly calculate trajectories for artillery shells. But not finished until after the end of World War 2.

• 60,000 pounds
• 18,000 vacuum tubes
• Size of medium-sized house (1,600 square feet)

• Could only run one program at a time, which had to be fed into the computer as a sequence punch cards -- cards with holes punched into them to represent programming instructions.
Mid 1960's – Minicomputers

• About the size of a refrigerator, give or take.

• Only cost about $20,000 so most universities could afford one.

• Multiple Terminals (keyboard+monitor) -- Each was a dumb terminal that didn't have it's own processor. But at least different people could run programs on the same computer at the same time.

• Time Sharing -- If multiple programs were running, the minicomputer would share the processor cycles among the different programs.

It's funny that these were called minicomputers, because we now literally have computers in our pockets (smartphones), each with it's own processor, and some with multi-core processors.
The First "Internet" -- ARPANET 1969

• Funded by the US department of Defense
  ARPA – Advanced Research Projects Agency
• Original 4 Hosts at Universities in the Western USA
• Original plans call for 128 Hosts
There are 4 main things which caused Internet use to explode beginning about the late 1980s

• Desktop Computers start becoming affordable in 1980s, so average people started owning computers, not just scientists.

• US Government releases control of Internet around 1990. This causes massive investment in internet infrastructure by private companies.

• Tim Berners-Lee invents the World Wide Web in 1990.

• Marc Andreessen creates the Mosaic Web browser in 1993. This becomes the Netscape Navigator browser that takes the world by storm around 1995.
First desktop Computers available around 1980

• 1977 Apple II -- Eventually Apple would be the first desktop computer to feature
  – Floppy Disk Drives (1978)
  – Mouse (1983)
  – Windows Graphical User Interface (1983)

• 1981 IBM PC
  – Used Microsoft's DOS Operating System
  – Microsoft eventually patents the term *Windows*
  – Windows 1.1 (1985)
US Government releases control of the Internet

- 1986 -- Second generation Internet goes online. NSFNET, run by National Science Foundation.

- 1990 -- First year internet access could be obtained without filling out paperwork and requesting permission from the US Government.

- 1992 -- Internet control transferred to non-profit organization which eventually became the ISOC (Internet SOCiety). It's membership includes researchers from major technology companies and research universities around the world.

- The internet is over 20 years old.

- Tim Berners-Lee invents WWW while working at the CERN nuclear physics research lab (huge particle accelerator) in Geneva Switzerland.

- Initial goal was to enable physicists to share abstracts of physics research papers over the Internet as hypertext documents – documents with hyperlinks to other documents.

- Berners-Lee's larger goal was literally to create a Web of interconnected information of World-Wide scope.

- He actually called his invention the WWW, a term that collectively referred to the first Web browser and Web server software which worked together to deliver hypertext documents over the Internet.
Netscape Navigator Browser

• 1993 -- Marc Andreessen, a Computer Science graduate student at the University of Illinois, creates Mosaic Web browser, the first Web browser that could render graphics.

• 1994 -- Andreessen and friends form Netscape Communications Corporation, originally a privately held company.

• 1995 -- Netscape corporation goes public, even though the company was not profitable and didn't have a solid business model. Stock price triples on first day, raising almost 3 billion dollars. Of course, this unprecedented IPO from a company losing money is a major news story.

• This is when the world starts be aware of the WWW and Internet, although many people use the two terms interchangeably, still to this day.

• Explaining the difference between the two is kind of a long story ....
The Internet uses a 5-layer networking model, sometimes called the *Internet protocol stack*.
Physical Layer

• Electrons whizzing through copper cables.
• Visible light moving through fiber optic cables.
• Radio waves moving through the air.
• This is the domain of electrical Engineers -- voltage, amperage, wavelength, etc.

Data can be lost in this layer. Electrons slam into the nuclei of copper atoms, magnetic disturbances block radio waves, etc.

The networking protocols in the next layer up ensure reliable communication between computers on the same network.
Network Interface Layer

Ethernet – Forms networks the size of rooms or small buildings. Computers are linked with copper ethernet cables, similar to traditional telephone cables but more thick.

WiFi – Similar to Ethernet, but sends though the air (no wires), and typically slower. Most modern desktops/laptops can switch between Ethernet and Wi-Fi.

Cellular Networks (4G/5G) – Through air, but over much larger distances than Wi-Fi. Modern smart phones can switch between WiFi and 4G/5G cellular network connections.

Cable Modem – Network connections over coaxial TV cables.
Comparison of network-level data transfer rates.

<table>
<thead>
<tr>
<th>Network Link</th>
<th>Approximate Transfer Time</th>
<th>Typical Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gigabit Ethernet</td>
<td>4 minutes</td>
<td>1000 Mbps (1 Gbps)</td>
</tr>
<tr>
<td>Fast Ethernet, Wi-Fi</td>
<td>40 minutes</td>
<td>100 Mbps</td>
</tr>
<tr>
<td>Standard Ethernet, 4G</td>
<td>80 minutes</td>
<td>50 Mbps</td>
</tr>
<tr>
<td>Cable Modem, 3G</td>
<td>13 hours</td>
<td>5 Mbps</td>
</tr>
<tr>
<td>Dialup Modem</td>
<td>2 months</td>
<td>.05 Mbps (50 Kbps)</td>
</tr>
</tbody>
</table>

Table 1.1 Approximate transfer times for 30 gigabytes of MP3 files

For perspective, 30 Gig of mp3 files would be something like 8,000 to 10,000 songs.

This diagram is a bit out of date. Cable modems have gotten faster, depending upon how much you are willing to pay. Most cell networks don't support 5G yet, but that will get into the top two layers. Other than that, this gives a pretty accurate picture.
Inter-Network Layer – *IP Protocol* facilitates packet routing between totally different networks.
IP addresses

Example: 164.68.21.170

- Each number in the range 0-255
- Around 4 billion different IP addresses

Internet Assigned Numbers Authority (IANA) grants them for free in large blocks to Internet Service Providers (ISPs).

Class A block-- Example: 164.x.x.x
Class B block-- Example: 164.68.x.x
Class C block-- Example: 164.68.21.x
Other IP Features

• Data is divided into small packets, averaging about 1.5 K in size. If data were sent in huge chunks, all of it would need to be resent if a small part if it is lost or damaged. Small packets solve that problem.

• *Flow Control* -- Packet routers try to pick the optimal path to the destination based upon how busy neighboring routers are, not necessarily the shortest path. Packets from same transaction might take different routes.

• *Time To Live* -- A packet is only allowed a certain number of router "hops." If a packet has exceeded its TTL, a router will simply delete it.

The robust design of IP is a major contributor to the success of the Internet!
Transport Layer

The *Transmission Control Protocol (TCP)* coordinates the end-to-end conversation. Since IP does not guarantee delivery, the computers on each end must maintain a "conversation" until all the packets for that transaction arrive undamaged and the transfer of data is complete.
How TCP works:

On the Sending End, TCP does the following:
• Chops data into packets, each with a sequence number.
• Calculates a checksum for each packet and adds that to the packet.
  This is a count of the bits in the packet, used to test for data loss.
• Gives the packets to the IP layer to start delivery process.

As the IP layer receives the packets on the other end (receiving end), it passes them to the TCP layer.

On the Receiving End, TCP does the following:
• Re-calculates the checksum for each packet and checks that against the actual data in the packet to see if it has been damaged.
• Makes requests back to the sending computer to resend a packet if it is damaged or is never received.
• Re-assembles the original data according to the sequence numbers of the packets.
The combination of IP and TCP is referred to as the *TCP/IP internet protocol suite*. This enables data transfer between networks, hence the term inter-net, or simply internet.

**Inter-Networking (TCP/IP)**  
*End-to-end Coordination (TCP)* -- Two computers maintaining a conversation until the transaction is complete.  
*Inter-Networking (IP)* -- Routing packets between networks. Routing infrastructure is mostly maintained by large phone companies.

The bottom two layers are usually lumped together as simply the network connection. Unless a computer can "talk" to another computer via networking, it is effectively isolated.

**Networking**  
*Networking protocols* -- Two computers sharing data over Ethernet, Wi-Fi, 4G/5G, Cable Modem, etc.  
*Physical* – Different networking technologies use copper, air, fiber-optic..
Application Layer

- How useful is the Internet to humans? That depends upon how useful the internet-capable software applications that humans use can become.

- Very early on, internet-capable software was developed for:
  - Remote Login (telnet/ssh)
  - Robust Messaging (email)
  - File Transfer (FTP)

- Internet productivity was limited mostly to scientists until:
  - Proliferation of personal computers enabled mass emailing.

The World Wide Web was a clever software invention (killer app) that helped revolutionize how humans could use the Internet infrastructure.

For many years, most packets on the Internet were generated by email software. Packets generated by WWW software quickly changed that!
Humans type named addresses like www.lfc.edu into browsers. But Internet routing uses IP addresses. So a Browser must first ask a DNS server to look up the IP address associated with the named address before it can actually surf to a Web page. The DNS lookup generally happens in a fraction of a second.
The DNS service is based on a hierarchy. The **top-level domains** such as .com are at the top of the hierarchy.

When you buy a **Virtual Domain** such as cknuckles.com, you own the rights to something abstract (just words), hence the term *virtual*.

When a domain is assigned to an IP address, it becomes a **Fully Qualified Domain Name (FQDN)**, which usually has a prefix like www. www.cknuckles.com  <----- DNS Record ----> 164.68.21.170

This association is a *DNS record* that browsers can look via DNS. A FQDN is also called a *named address*, in contrast to a numeric IP addr.
Virtual Hosting refers to hosting multiple named addresses (Web sites) on the same server. The DNS records for each named address point to the same IP address.

Requests for different named addresses are sent to different folders by the Web Server Software, the software that answers the requests from the Web browser software on the client side.

Even though named addresses are converted into IP addresses for Internet travel, the requested named address is still sent to the Web server.
URL -- Uniform Resource Locator

You have seen many URLs like  http://www.cknuckles.com  
A URL has three primary components

```
protocol://named.address.com/directory/path/to/document.html
```

The **how** part is a protocol like *http* (hypertext transfer protocol), or the secure version *https*. This protocol specifies how Web browsers communicate with Web servers to facilitate the delivery of Web pages. Other protocols such as *ftp*: in the how part of a URL initiate a file download, rather than temporary Web page transfer.

The **where** part is an address, which is usually a named address, but can be a raw numeric IP address (which bypasses the DNS lookup).

The **what** part specifies a specific resource on the server, like a Web page.
The *what* part of a URL can be a path that descends into subfolders in the Web site.

Some URLs (2 and 5 above) request a specific page. But 1, 3, 4 actually request a folder. If there is a *default file* present in the folder, that Web page will be served. But there is no default file in the folder for request 4. That can result in a directory listing of all files in the folder being returned to the Web browser.