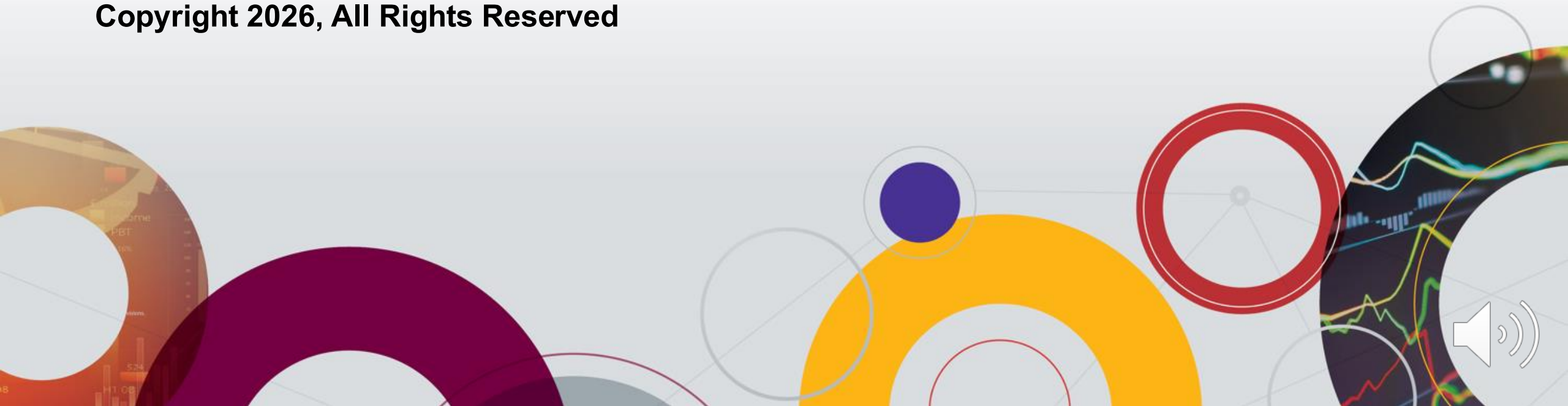


2.4b Computer Networks

10x10 – Introduction to Biomedical Informatics & Artificial Intelligence
William Hersh, MD, FACMI, FAMIA, FIAHSI
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World Wide Web (WWW)

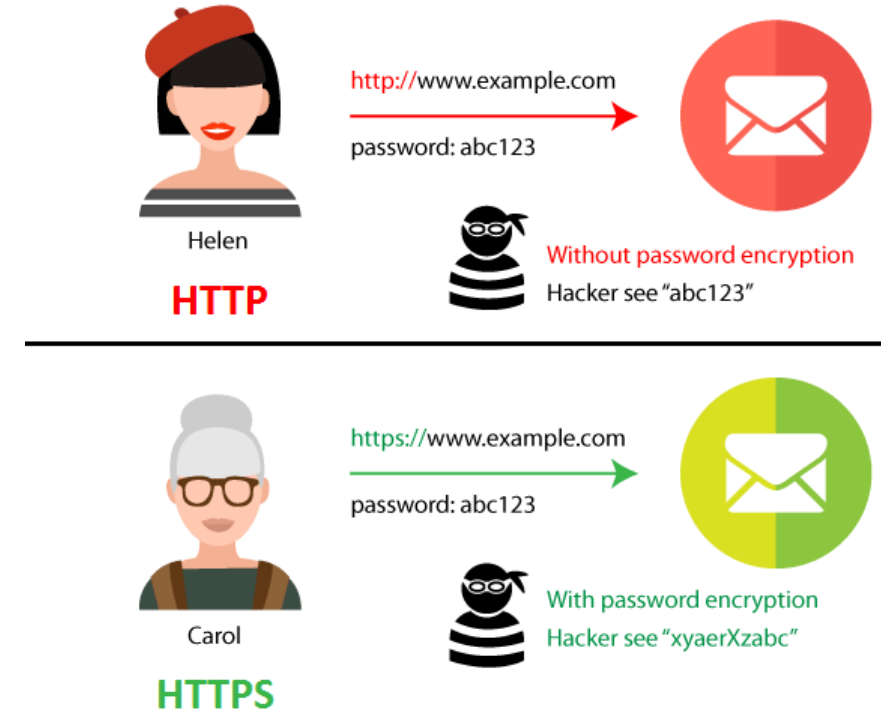
Was the “killer app” of the Internet; largely responsible for it becoming mainstream and ubiquitous

Important standards make it work

- Hypertext Transfer Protocol (HTTP)/Hypertext Transfer Protocol Secure (HTTPS)
 - Protocol by which Web browser on client communicates with Web server to access information based on Uniform Resource Locator (URL)
 - HTTPS adds encryption for security (Bernard, 2020)
- Hypertext Mark-up Language (HTML)
 - Instructions on Web page about how to format text, images, links, etc.

URLs take form

- scheme://host/[directory/]object
- e.g., <https://billhersh.info/10x10>
 - Omitting object after last / defaults to [index.html](https://billhersh.info/index.html)



Evolution of the Web

eXtensible Mark-Up Language (XML)

Javascript Object Notation (JSON)

HTTP Secure (HTTPS)

Representational State Transfer (REST)

Application Programming Interface (API)

Mobile Web and apps

eXtensible Mark-up Language (XML)

Whereas HTML is format for presentation, XML is format for *data*

- Computer platform/language neutral
- Human-readable (somewhat)

[Video](#) on digital text and difference between XML and HTML (Wesch, 2007)

[Tutorials](#) for HTML, XML, and related Web tools

XML example

```
<course>
<title>BMI 510/610 – Introduction to Biomedical and Health Informatics</title>
<instructor>
  <name rank="Professor">William Hersh</name>
  <email>hersh@ohsu.edu</email>
</instructor>
<students>
  <student>
    <name>Katharine Fultz Hollis</name>
    <email> fultzhol@ohsu.edu</email>
  </student>
  <student>
    <name>Andrea Ilg</name>
    <email>ilgan@ohsu.edu</email>
  </student>
  ...
</students>
</course>
```

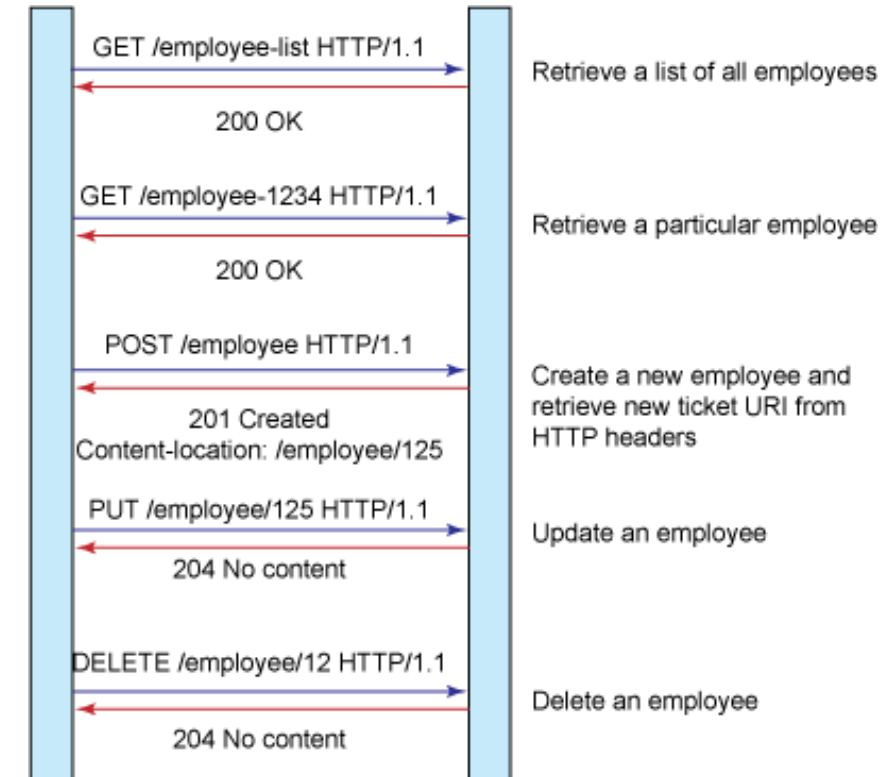
Alternative to XML: Javascript Object Notation (JSON)

```
{
  "title": "BMI 510/610 – Introduction to Biomedical and Health Informatics",
  "instructor": {
    "name": "William Hersh",
    "rank": "Professor",
    "email": "hersh@ohsu.edu",
  },
  "students": [
    {
      "name": "Katharine Fultz Hollis",
      "email": "fultzhol@ohsu.edu"
    },
    {
      "name": "Andrea Ilg",
      "email": "ilgan@ohsu.edu"
    },
    ...
  ]
}
```

Representational state transfer (REST)

RESTful architecture for handling “state”

- Internet clients and servers respond to each other in asynchronous manner
- Need a means for maintaining “state” that does not require continuous connection
- Representational State Transfer (REST) developed in dissertation of Fielding (2000) and now widely used (Pautasso, 2007)



Application programming interface (API)

APIs allow computer applications to communicate and exchange data over networks

Growing important in many industries, including healthcare (Allen, 2017)

Important examples in healthcare

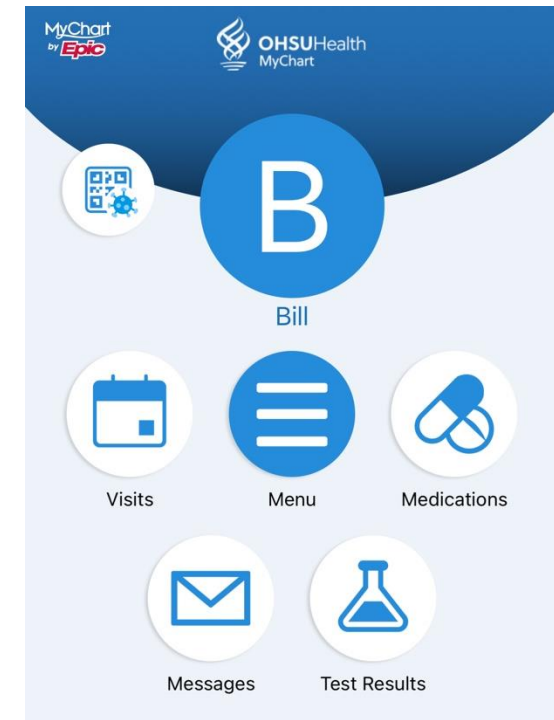
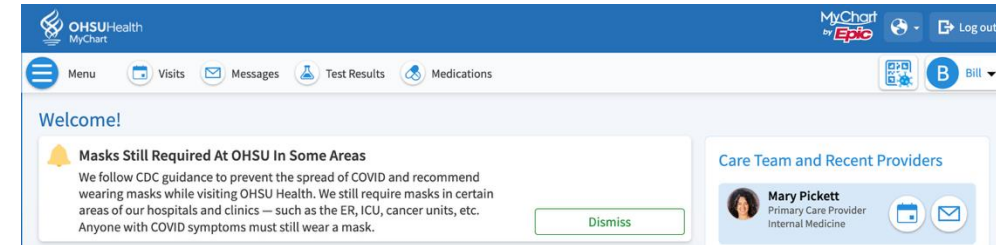
- Fast Healthcare Interoperability Resources (FHIR) – emerging standard for clinical data, required as part of Cures Rule (ONC, 2020) for patient-based and clinician applications (CMS, 2020)
 - Growing use of APIs by digital health companies to access EHR data; most but not all FHIR-based (Barker, 2024)
- [Google Cloud Healthcare API](#)
- [Amazon Web Services](#) for health and life sciences

Mobile Web and apps

Smartphones have Web browsers, with increasing numbers of sites having “full” and “mobile” sites

- Mobile sites optimized for small screens of smartphones

Mobile devices also have apps, which are discrete applications that provide similar functions to Web sites but are more self-contained



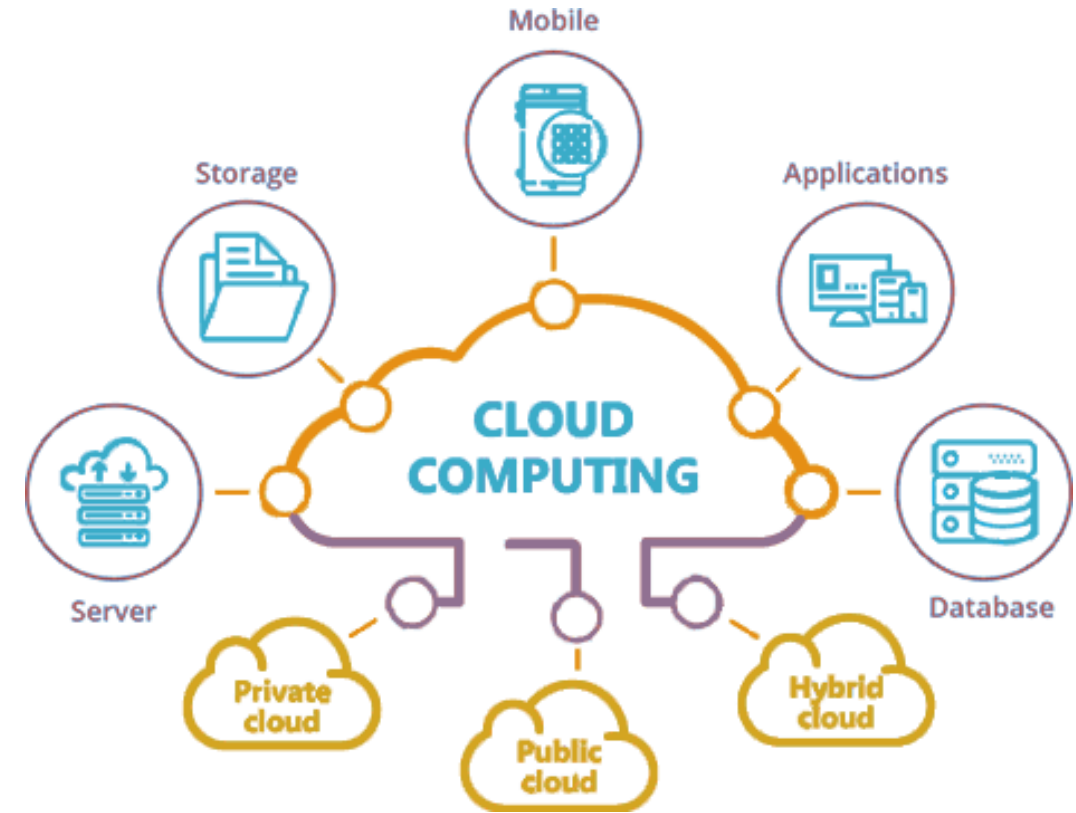
Cloud computing

“Cloud” computing views applications and data distributed virtually across the Internet (Ruparella, 2016)

Location of servers, data, code, etc. can be anywhere on the Internet

Growing number of vendors offer “services”: Amazon, Google, Microsoft, Apple, etc.

After initial hesitation, growing use by healthcare organizations (Ross, 2019)



Cloud computing details (Ruparella, 2016)

Cloud delivery models

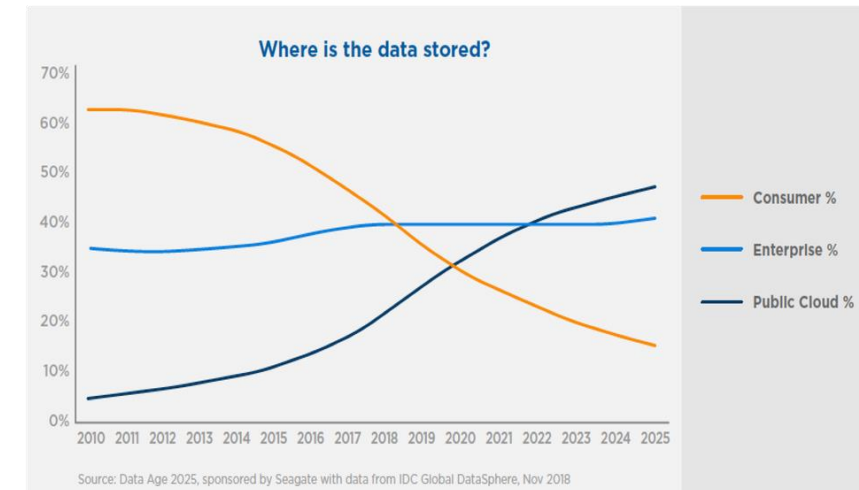
- Public cloud – offered by cloud provider, accessible by any client
- Private cloud – enterprise having exclusive use of isolated cloud
- Hybrid cloud – coordinated external cloud and internal resources

Cloud services

- Software as a Service (SaaS) – applications
- Platform as a Service (PaaS) – platform for building and delivering applications
- Infrastructure as a Service (IaaS) – adds storage and networks

Growing size of data of storage; likely to increase in future (Reinsel, 2019)

Important to bring programs to data in data-intensive applications since need to move large amounts of data over networks can be bottleneck (Hecht, 2016)



Cloud computing in biomedicine (Navale, 2018)

Advantages

Resource outsourcing

Utility computing – pay for as much as you need

Many machines – as many as you need

Virtualization – probably easier in cloud

Challenges

Privacy – protecting personal and organizational data

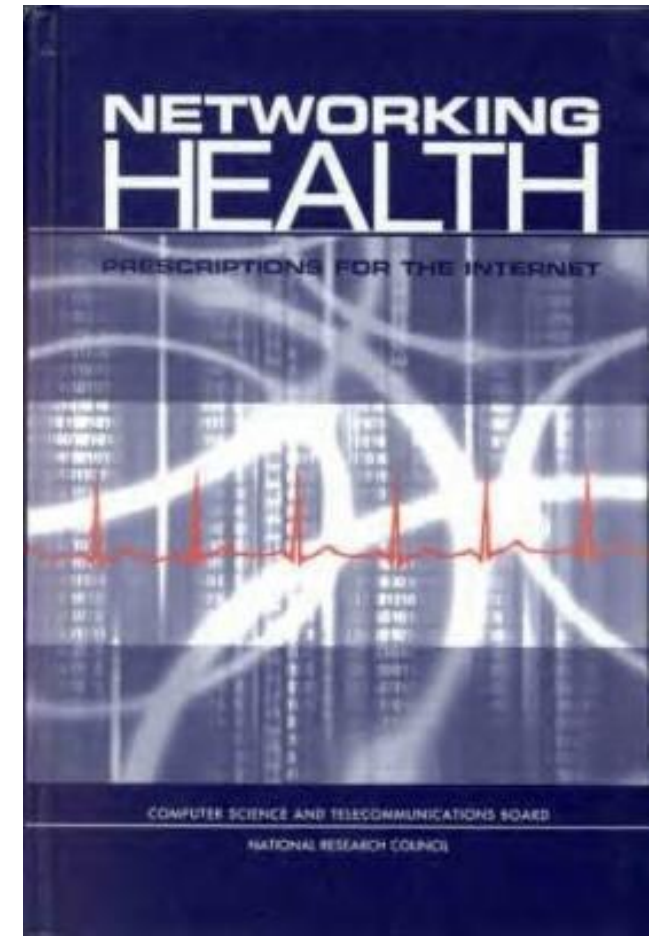
System protection – of internal systems opened to cloud applications and remote systems in cloud

Need robust bandwidth to move data to and from the cloud

Biomedical and health applications on the Internet and Web

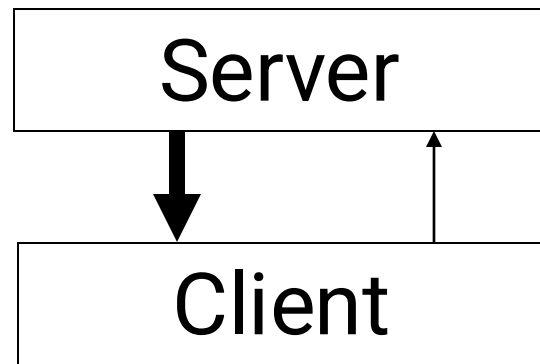
Networking Health (2000) report was first to outline technical and societal issues related to health and the Internet

- Nothing about health applications was unique, i.e., do not need a separate “health Internet,” but current infrastructure was inadequate for many applications and priorities
- “Availability” of networks more important than “bandwidth” for most clinical applications

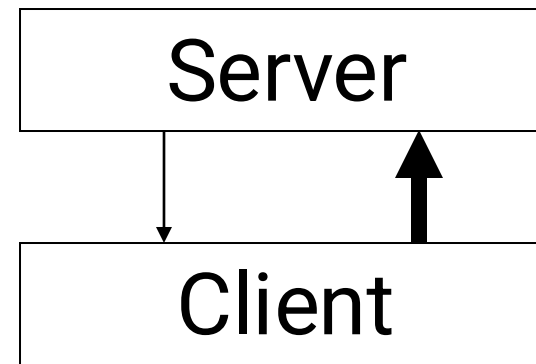


Bandwidth priorities have been a challenge for healthcare

Many Web applications prioritize higher speed downstream and can tolerate slower speed upstream, which may be opposite what is desired for applications like telemedicine



Optimal multicasting



Optimal telemedicine

Use of the Internet by healthcare personnel

Nearly all physicians use Internet (Google and Manhattan Research, 2012)

Most have multiple devices: 99% with desktop or laptop, 84% with smartphone, and 54% with tablet

Even physicians aged 55+ are heavy users: 80% own smartphone, 84% use search engines daily, and spend 9 hours per week online for professional purposes

Search engine use is daily activity, with 84% using daily, averaging 6 searches per day

Network neutrality

Network neutrality is the notion that transmission of content over the network should be neutral, i.e., not given higher precedence by service provider

For: will maintain choice and access to wide variety of content, prevent service providers from favoring certain content

Against: provides economic disincentive for development of networks and content, may compromise availability for certain applications, such as those in healthcare

Pits telecommunications company vs. many but not all Web sites; being fought in political arena

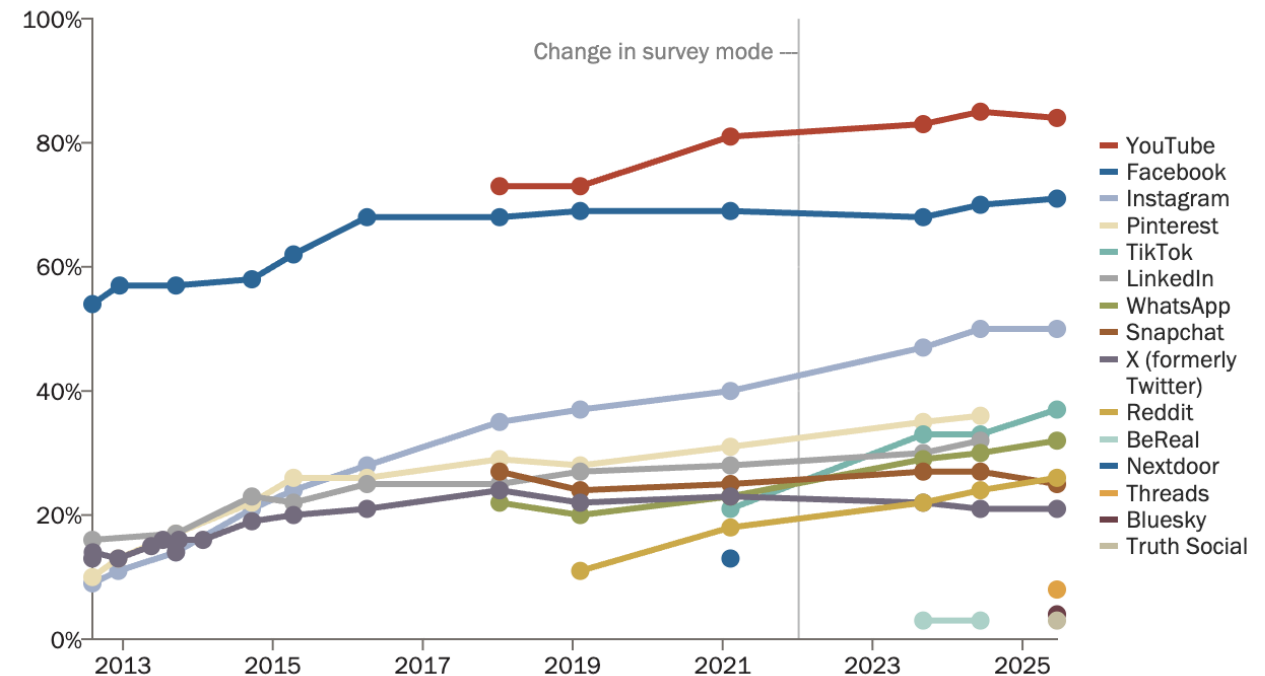
Another important type of networking: social networks

Individuals and content tied together by various “connections,” e.g.,

- Friends on Facebook
- Following on X/Twitter and BlueSky
- Connections on LinkedIn
- Videos on YouTube and TikTok
- Photos on Instagram

Algorithms serve “feeds” based on user interests and other factors

Ubiquitous use by all [according to Pew](#)



Also concerns for social networks

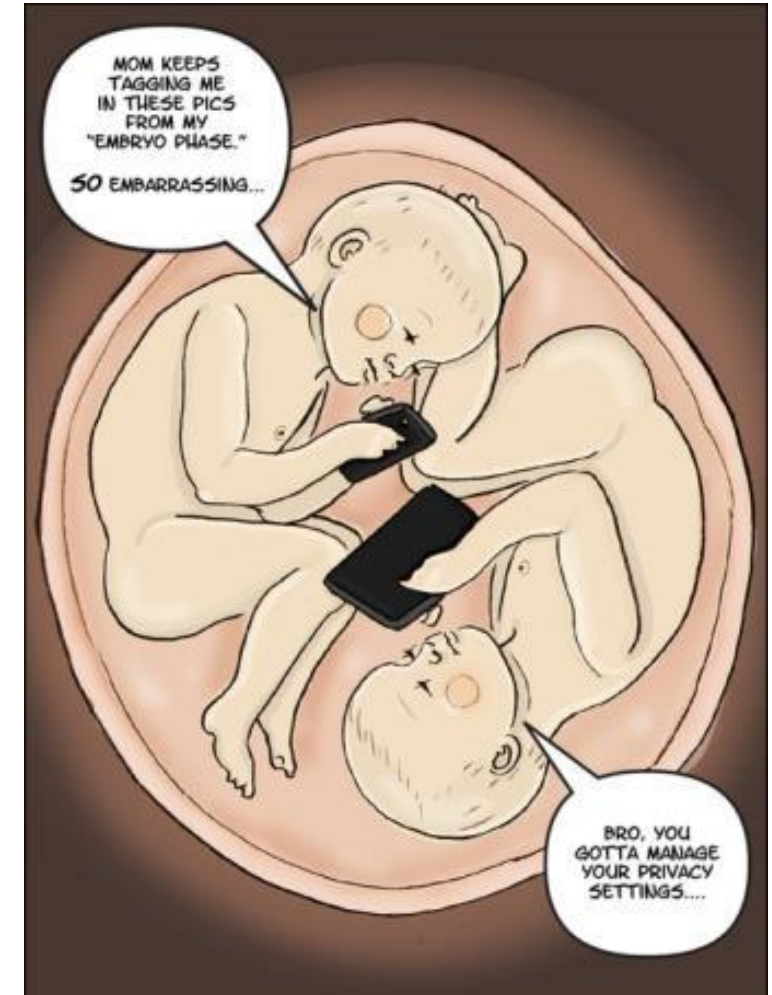
Concerns over ethics and professionalism and how use fits within social contract between medical profession and society (Ennis-O-Conner, 2020), leading to

- [AMA Code of Ethics for social media](#)
- Calls for transparent privacy policies and consent for data use (Petersen, 2018)

Also growing concerns over social media and Internet use by children and teenagers, with recommendations for safe use (Jenco, 2024)

Migration of scientists from X/Twitter to BlueSky – concern over changes have led migration of researchers and scientists from X/Twitter to BlueSky (Kupferschmidt, 2024; Palmer, 2024; Biever, 2025)

But social media has permeated our culture



Internet of Things (Fu, 2020)

“Things” connected to the Internet

Including medical things, such as

- Monitoring devices, e.g., glucometer, fitness devices
- Medical devices, e.g., pacemakers

As with all technologies, potential for

- Good: easy access and control
- Bad: nefarious uses, privacy issues (Fu, 2020)