"Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation."
Outline

• Brief history of libraries
• Libraries, archives, museums, collections, …
• Brief history of digital libraries
• Digital libraries today
• Future Digital Libraries
• Who supports research relevant to DLs in U.S.?
• Our roles, responsibilities
Brief History of Libraries

- Oldest
- Largest
- Most beautiful
- Most “different”
Ebla Tablets, Syria (2500 B.C. - 2250 B.C.)

- collection of ~1800 complete clay tablets, ~4700 fragments and many thousand minor chips found in the palace archive by Italian archaeologist Paolo Matthiae and his team in 1974–75

The archive was kept in orderly fashion in two small rooms off a large audience hall; one repository contained only bureaucratic economic records on characteristic round tablets, the other, larger room held ritual and literary texts, including pedagogical texts for teaching young scribes. Many of the tablets had not previously been baked, but when all were preserved by the fire that destroyed the palace.

= Preservation by destruction: 4,500 years
Oldest Libraries

Ebla Tablets, Syria - today

Looting rife, heritage sites destroyed:
The state of Syria's history
#SyriaWar Friday 20 May 2016 02:17 UTC
Damage to UNESCO world heritage sites in Syria war threatens country's legacy

Ancient History, Modern Destruction: Assessing the Status of Syria’s Tentative World Heritage Sites Using High-Resolution Satellite Imagery
AAAS 2014
Yellow circles indicate a single pit, yellow rectangles indicate multiple pits). Image ©DigitalGlobe | U.S. Department of State, NextView License | Analysis AAAS.
Oldest Libraries

St. Catherine's Monastery, Sinai, Egypt
• built between 548 and 565
• one of the oldest working Christian monasteries
• world's oldest continually operating library, possessing many unique books

Ligatus and the University of the Arts London:
Project for conservation and preservation of the world's oldest library.
Oldest Libraries

al-Qarawiyyin Library, Fez, Morocco
• founded in 859
• one of the oldest working library in the world
• includes a mosque, library, and university
• founded by Fatima El-Fihriya, daughter of a rich merchant

Restoring the world’s oldest library
Mar 1, 2016 / Karen Eng
ideas.ted.com

“Both Moroccans and foreign visitors will get to glimpse, for the first time, some of the library’s amazing and unique manuscripts, as well as to enjoy its architecture.”
Oldest Libraries – cont.

Malatestiana Library, Cesena FC, Italy
- opened 1452
- first European civic library, i.e. belonging to the Commune, rather than the church, and open to the public.
# Largest Libraries

<table>
<thead>
<tr>
<th>#</th>
<th>Name</th>
<th>Location</th>
<th>Catalogue Size</th>
<th>Visitors per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>British Library</td>
<td>United Kingdom, London</td>
<td>170 million+</td>
<td>1.75 million</td>
</tr>
<tr>
<td>2</td>
<td>Library of Congress</td>
<td>United States, Washington</td>
<td>160 million+</td>
<td>1.75 million</td>
</tr>
<tr>
<td>3</td>
<td>Library and Archives Canada</td>
<td>Canada, Ottawa</td>
<td>54 million</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>New York Public Library</td>
<td>United States, New York City</td>
<td>53.1 million</td>
<td>18 million</td>
</tr>
<tr>
<td>5</td>
<td>Russian State Library</td>
<td>Russia, Moscow</td>
<td>44.4 million</td>
<td>1.17 million</td>
</tr>
<tr>
<td>6</td>
<td>Bibliothèque nationale de France</td>
<td>France, Paris</td>
<td>40 million</td>
<td>1.3 million</td>
</tr>
<tr>
<td>7</td>
<td>National Library of Russia</td>
<td>Russia, Saint Petersburg</td>
<td>36.5 million</td>
<td>1 million</td>
</tr>
<tr>
<td>8</td>
<td>National Diet Library</td>
<td>Japan, Tokyo and Kyoto</td>
<td>35.6 million</td>
<td>654,000</td>
</tr>
<tr>
<td>9</td>
<td>National Library of China</td>
<td>China, Beijing</td>
<td>33.8 million</td>
<td>5.2 million</td>
</tr>
<tr>
<td>10</td>
<td>Royal Danish Library</td>
<td>Denmark, Copenhagen</td>
<td>30.2 million</td>
<td>850,000</td>
</tr>
</tbody>
</table>

Most Beautiful Libraries

Strahov Monastery (1140) Library (1679), Czech Republic

The Strahov Library contains over 200,000 volumes, including over 3,000 manuscripts and 1,500 first prints stored in a special depository.
Most Beautiful Libraries

Library of Congress (1800)
George Peabody Library, Johns Hopkins University, Baltimore (1857)

“Cathedral of books”, 18th- and 19th-century volumes of archaeology, British and American history and literature.
Most Beautiful Libraries

Handelingenkamer, Netherlands (1876)

The library of the Dutch Parliament contains every record of parliamentary hearings and discussions. Because it was built before electric lighting made the storage of books a lot safer, the building was constructed with a massive leaded glass dome in the ceiling to allow in light and minimize the need for candles and gas lamps inside the library.
Most Beautiful Libraries

City Library of Stockholm (1918)
This round room called the Rotunde is the main reading hall of the. Photography by arndalarm Flickr.com
Most Beautiful Libraries

Conceived as a commemoration of the Ancient Library of Alexandria, the updated version is holds eight million books and features a 32-meter-high, 160-meter-wide glass-panelled roof with walls of Aswan granite carved with ancient scripts for an added element of ancient Egyptian mystique.
Most “Different” Libraries

The Biblioburro:
- Delivering Books Via Donkey in rural Columbia since 1990, founded by Luis Soriano, primary school teacher
- The Biblioburro has brought literacy and the joy of reading to an estimated 4,000 kids so far
Most “Different” Libraries

Picture Book Library, Iwaki City, Japan
- built in 2005
- for preschoolers
- book covers are visible
**Most “Different” Libraries**

**Library of the History of Human Imagination**

American inventor Jay S. Walker (and founder of Priceline.com) owns his own 3,600 sq. ft. private library in Ridgefield, Connecticut. The Library of the History of Human Imagination contains more than 50,000 volumes and artifacts, and was named the most amazing library in the world by *WIRED*. 
Libraries vs. Archives vs. Museums vs. Collections

- **Library**: a building or room containing collections of books, periodicals, and sometimes films and recorded music for people to read, borrow, or refer to.
- **Archive**: a place in which public records or historical documents are preserved
- **Museum**: a building in which interesting and valuable things (such as paintings and sculptures or scientific or historical objects) are collected and shown to the public
- **Collection**: a group of interesting or beautiful objects brought together in order to show or study them or as a hobby
Libraries vs. Archives vs. Museums

- Libraries
  - Library of Congress
  - National Library of Medicine
  - Personal libraries
    - François Mauriac (1885-1970):
      - "Show me what you read, and I'll tell you who you are"
  - Public libraries

- Archives
  - National Archives and Records

- Museums
  - Smithsonian

- Collections
  - http://www.hightechscience.org/robots.htm
Brief History of Digital Libraries

• October 1991: NSF sponsored a workshop at SIGIR to examine the role of the IR research community in the emerging environment of Internet, high performance text processing capabilities and ever-increasing volumes of digitized documents.

• Ed Fox and Michael Lesk drafted a White Paper, calling for a National Electronic Science, Engineering, and Technology Library.

• The term “Digital Library” was adopted and for follow-up workshops
Brief History of Digital Libraries: Courtesy of Steve Griffin

• Digital Libraries Initiative – Phase 1 (DLI-1)
  – broad areas of research
    • capturing data of all forms (text, images, sound, speech, mixed and multimedia, etc.) and descriptive information about the data (metadata)
    • categorizing and organizing electronic information in a variety of formats
    • creating advanced software and algorithms for browsing, searching, filtering, abstracting, summarizing and combining large volumes of data, imagery, and all kinds of information; and
    • utilization of networked databases distributed around the nation and around the world.
DLI-1 Projects: Courtesy of Steve Griffin

- Carnegie Mellon University
  - Informedia: Digital Video Libraries

- Stanford University
  - Uniform Access to Distributed Internet-based Resources
    - 1997: Larry Page and Sergei Brin presented a new PageRank algorithm that would enable more accurate search of the web
    - 1998: Google Inc. opened for business

- University of California, Berkeley
  - Media Integration and Access

- University of California, Santa Barbara
  - Geographic Information Systems

- University of Illinois
  - Intelligent Search and the Net

- University of Michigan
  - Intelligent Agent Architectures
International Collaboration
• Europe and Japan
• Focus: Global Resource Discovery, Interoperability, Metadata, Multilingual Information Access, Intellectual Property And Economics

**D-Lib Magazine**
• 1995: funded by DARPA
• produced by the Corporation for National Research Initiatives (CNRI), editors Bill Arms and Amy Friedlander (now at NSF/CISE/ACI)

**DL Conferences**
• 1994, 1995: Annual Conferences on Digital Libraries (DL)
• 2001 - ….: Joint Conferences on Digital Libraries (JCDL)
• more than 20 additional awards
• interdisciplinary richness of the projects, the high levels of interaction between them and extensive partnering with private sector corporations and other organizations
  – The Visible Human Project
  – The arXiv Open Access E-prints Repository
  – The Universal Digital Library Million Books Project
  – Survivors of the Shoah Visual History Foundation
  – ISMIR - The International Society for Music Information Retrieval
  – Imaging of Manuscripts and Written Materials, Archeology, …
A **digital library** is a **special library** with a focused collection of digital objects that can include text, visual material, audio material, video material, stored as **electronic media** formats (as opposed to print, microform, or other media), along with means for organizing, storing, and retrieving the files and media contained in the library collection.

Digital libraries can vary immensely in size and scope, and can be maintained by individuals, organizations, or affiliated with established physical library buildings or institutions, or with academic institutions.

The digital content may be stored locally, or accessed remotely via computer networks. An electronic library is a type of **information retrieval** system.

Digital Libraries Today

- LoC, NLM, ...
- ACM Digital Library, IEEE Digital Library, CiteSeer, arXiv, Google Scholar...
- University libraries
- Software libraries, GitHub, ...
- Repositories
  - NOAA, NASA, Genome Data, ...
- Google, Microsoft Bing, Yahoo!, ...
- Amazon, Netflix, ...
- Flickr, Facebook, Twitter, ...
- Public libraries
- Kindle, smart phone, ...

- Whither the physical library?
Future Digital Libraries

• Will they be here?
  – Vint Cerf: “If 100 years from now the digital picture of our society is not accessible, we will be an enigma to the 22nd century.”
  • Newsweek, Tech & Science, 6/9/2016

• What should we preserve
  – Everything: cultural heritage
    • All possible digital items:
      – Holograms, games, MyLifeBits, emails, ...?
  – Can we store it all?
    • If not, who decides?

• Storage/Archival Technology
  – Vint Cerf: “Digital Vellum”
Sith Holocrons

At the end of our seventh day, with slaves running low, we penetrated the Sanctum of Sakkra-Kla. This sacred tomb had apparently lain undisturbed since its sealing more than ten thousand years before. It brimmed with wonders.

Here I found scrolls detailing Sith alchemy. I found the preserved body of a terentatek. I lost six more slaves to a rapacious pack of tuk’ata. And most impressive of all, I found the Holocron of King Nakgru.

Yes, holocrons exist in Sith Space. Sith Holocron are technologically identical to the Jedi Holocrons of the Republic, but they possess dark side refinements that make them ultimately superior.

Scholars know that a holocron is a box of crystalline lattices, which are capable of housing near-infinite amounts of priceless data. These matrices can be aligned only through precise and exhausting application of the Force. A completed holocron can be accessed only by another Force user. To navigate a holocron’s secrets, one must speak to its gatekeeper—a holographic echo of the device’s builder that retains a measure of the builder’s spirit. Constructing a holocron can take months, and a single misstep will collapse the device into dust.
Scientists at the University of Southampton in the UK have succeeded in creating five-dimensional (5D), ultra-high-density storage on standard silica glass discs that, unlike DVDs or Blu-rays, seem to be capable of storing data for an unlimited period of time without a reduction in data integrity. The scientists say that 5D optical storage could allow for densities as high as 360 terabytes per disc, and unless you crush it in a vice, these discs are so non-volatile that data stored on them should “survive the human race.”
Future DLs: Accessibility

Cloud: Accessible anywhere, any time

How are we going to find what we need, want, ... 

Vint Cerf: “I’m very concerned that digital content will be less and less accessible, not because we can’t find the bits, but because we don’t know what the bits mean.”
Future DLs: Accessibility

Power, Internet

“Would anyone care for fresh batteries?”
Future DLs

• Who creates the DL content?
  – Authors: writers, researchers, artists, politicians, citizens, students, …, everybody!
    • Quality
    • Credit
    • Intellectual Property Promotion and Piracy Prevention
    • Privacy, security

• Archiving
  – Internet Archive
  – Library of Congress Digital Collections & Services
    • John W. Kluge Center
      – Symposium on “Saving the Web: The Ethics and Challenges of Preserving What’s on the Internet”, June 16, 2016
Future DLs: Librarians

- Curation, organization, archiving, information/knowledge resource, ...
  - Metadata: Dewey Decimal Classification, Dublin Core?
    - Software, scientific datasets, social media, games, ...
  - URLs, DOIs?
  - DL contents description/summarization
  - Analysis: history, trends, new topics
  - Support for researchers, educators, students, public, ...
- Skill sets
  - Library science
  - Computer Science
  - Social Science
  - Privacy, security’
  - Policy, law, …
Future DLs: Users

- Scholars, researchers, educators, students, policy makers, public
- Service providers (e.g., travel, medical, ...)
- Personal information systems
- Search, recommender systems:
  - Google for datasets, software, ...
  - Multimedia: images, videos, audio, visualizations, tables, graphs, maps, structures, holograms, genome, ...
- Interfaces: multimodal, multilingual, ...
  - Apple's Siri, Amazon's Alexa, OK Google, MS Cortana, ...
  - Microsoft’s HoloLens, future Google Glass?
- Skill sets
  - Datathon: Matt Weber, Jimmy Lin (NSF & Canadian support)
Future DLs: Search

How to query is the question
Future DLs: Search

What do we delegate to DLs?

“Go ask your search engine.”
New Yorker, 1/2000
Future DLs: Recommender System

Based on your profile, you may enjoy:

- **The Odyssey**: War veteran takes forever to get home then kills everyone.
- **Wuthering Heights**: A sort-of brother and sister fall in love. It's foggy.
- **Walden**: Man sits outside for two years. Nothing happens.
- **Beowulf**: Hero kills monster. Blah, blah, blah. Dragon kills Hero.
- **Inferno**: All hell breaks loose.
"THE REASON HE’S NEVER SEEN A CONSTELLATION IS HE’S CONVINCED THERE REALLY ARE WHITE LINES CONNECTING THE STARS."
Future DLs: Analytics

Katy Borner: Maps of Science

Visual Interfaces to Digital Libraries, 2003, Springer
Future DLs: Analytics

Katy Borner: Maps of Science

NSF Funding

NIH Funding
Ke, Visvanath & Börner

Mapping the Evolution of Co-Authorship Networks

(Won 1st price at the IEEE InfoVis Contest, 2004)
Future DLs: Knowledge Life Cycle

We need to update the current knowledge with discovered knowledge effectively
Future DLs: User Skills

• Skill sets
  – Multiple platforms, modalities for search
  – Data science
  – Interpretation of results
  – Privacy, security, etc. awareness
  – Ethics

• Who teaches the skills
  – Schools
  – Universities
  – Employers
  – Libraries
  – ???

• Datathon: Matt Weber, Jimmy Lin (NSF & Canadian support)
Interfaces:
- Multi-media, multi-modal, multi-representational, multi-cultural, multi-interest, multi-connected, multi-disciplinary
  - Apple's Siri, Amazon's Alexa, OK Google, MS's Cortana…
  - Microsoft’s HoloLens, future Google Glass?
  - Virtual reality
  - Haptics
  - ???
Future DLs: Interfaces

Dilbert Comic Strip by Scott Adams

2016 Scott Adams Inc. Distributed by Universal Uclick

June 12, 2016 • The Washington Post Magazine
Future DLs: Interaction

Audio books
Text to Braille

Dr. Seuss
(Theodor Seuss Geisel, 1904 – 1991)

This is the front cover art for the book *I Can Read with My Eyes Shut!* written by Dr. Seuss. The book cover art copyright is believed to belong to the publisher, Random House, or the cover artist.
Who supports research relevant to DLs in US?

NSF

- CISE:
  - **Information & Intelligent Systems Division**
    - Information Integration & Informatics Program
      » IR, multimedia, social media, social networks, data mining, analytics, visualization, databases, informatics, integration, provenance, ...
    - **Robust Intelligence**
      » NLP, speech, audio, image/video recognition, knowledge representation, machine learning, inference, agents, ...
    - **Cyber-Human Systems**
      » HCI, cognition, social systems, collaborative systems, games, ...
  - **Advanced Cyber Infrastructure**
    - Data Infrastructure Building Blocks (DIBBs)
    - Software Infrastructure for Sustained Innovation (SI2)
  - **Computer and Network Systems (CNS)**
    - CISE Research Infrastructure (CRI): Community Infrastructure
“The modern age has a false sense of security because of the great mass of data at its disposal. But the valid issue is the extent to which man knows how to form and master the material at his command.
“The modern age has a false sense of security because of the great mass of data at its disposal. But the valid issue is the extent to which man knows how to form and master the material at his command.

Johann Wolfgang Goethe, 1832
Big Data

“... AND WHAT’S MORE, MY DATABASE HAS MORE DATA THAN YOUR DATABASE!”
Who supports research relevant to DLs in US?

• NSF-wide:
  – Big Data
  – CyberLearning
  – Smart & Connected Health
  – Smart & Connected Communities
  – Major Research Infrastructure

• BIO, EHR, SBE, GEO (e.g., EarthCube), MPS, ENG
NSF director unveils big ideas, with an eye on the next president and Congress

Science, Jeffrey Mervis, May 10, 2016, 3:30 PM

• Research
  – Harnessing data for 21st century science and engineering
  – Shaping the human-technology frontier
Your Involvement

• Get to know your Program Directors
  • Review Program Solicitations or Award Abstracts
  • Send an email message to request a phone conversation or visit
  • Program Directors can:
    • advise on appropriate program(s) for your proposed research
    • provide general suggestions on writing a proposal
  • Program Directors cannot:
    • provide detailed comments on your proposal draft
    • discuss a pending proposal

• Send your best ideas to NSF: consistent with program focus and goals
• Work within your institutions to support collaborative, interdisciplinary research
• Keep us informed of your accomplishments
• Call our attention to things that need improvement
• **Suggest new research areas, activities, etc.**
• Participate in NSF-funded events, workshops, etc.
• **Organize planning workshops for new research directions or activities**
• Consider participating in the Computing Community Consortium: http://www.cra.org/ccc

• Plan to serve as a program director ("rotator") or division director
Who supports research relevant to DLs in US?

- NIH/NLM
- DARPA, IARPA, ...
- LoC
- NEH
- Google, Microsoft, Yahoo!? 
Who Else Supports DL Research?

• Most countries!
• Without buildings, physical items, DL is global!
• Working together will help everybody
• How can we collaborate?
  – Workshops
  – Research collaboration, visits, student exchange
Future Digital Libraries

• Not only history, facts, artifacts
• Home for
  – Imagination
  – Knowledge discovery
  – Global understanding
"Think and wonder, wonder and think."

Dr. Seuss: 
*Oh, the Thinks You Can Think!* (1975)

This is the front cover art for the book *Oh, the Thinks You Can Think!* written by Dr. Seuss. The book cover art copyright is believed to belong to the publisher, Random House, or the cover artist.
“Unless someone like you cares a whole awful lot, nothing is going to get better. It’s not.”

Dr. Seuss

*The Lorax* (1971)
“And will you succeed?
Yes you will indeed!
(98 and 3/4 percent guaranteed.)”

Dr. Seuss
*Oh, the Places You'll Go!*
(1990)
Thank you!

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