Long-Term Collections & Research Plan 2019-2023
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1. **EXECUTIVE SUMMARY**

The mission of the Denver Museum of Nature & Science (DMNS) is to be a catalyst! Ignite our community’s passion for nature and science. The DMNS envisions an empowered community that loves, understands, and protects our natural world. Our strategic objective is to increase the number and diversity of people who connect with the Museum around nature and science in ways that are meaningful to them. Central to this mission, vision, and strategic objective is scientific research and the creation, presentation, and preservation of collections. This document, the third iteration of a Long-Term Collections and Research Plan first published in 2008, presents the detailed intellectual underpinning of scientific research by, and collections of, the DMNS. The audience for this document is the staff of the Research and Collections Division, the Museum’s Senior Leadership Team, its President and Chief Executive Officer, the Board of Trustees, and anyone else who may be interested. This document is intended to guide curatorial decisions. Collection activities at DMNS are governed by the Board of Trustees–approved Manual of Collection Policies and its associated Ethics Policy Statement.

The Denver Museum of Nature & Science curates collections that it owns as well as those that it holds in trust for the citizens of Colorado, the United States, and the world. The research collections contain scientifically and culturally significant objects in archaeology, ethnology, geology, paleontology, health sciences, zoology and the library and archives. While generally focused on the Rocky Mountain West, the collections also contain objects from seven continents that bring the world to Denver and provide a broader intellectual and scientific context for the regional collections. The Museum maintains collections specifically dedicated to frequent educational use (i.e., the Education Collections). DMNS also acquires and maintains archives, image archives, library resources, and documentary artwork to record the history of the Museum, its core competencies, and its three-dimensional research and education collections, as well as to support the work of the Museum. The collections inform the history and evolution of life in the Rocky Mountain and Great Plains landscapes from the beginning of the Earth through the peopling of the Americas and up to the present day. The Museum engages present communities of Colorado and creates collections that facilitate this communication.

The Museum does not collect merely for the sake of collecting. Collections are built and refined by the Museum’s curators, archivists, and librarians, who work in concert with collection managers and conservator to maintain and care for the collections. Much of the Museum’s current collecting activity is targeted toward addressing scientifically significant research questions. The curators coordinate closely with the registrar to ensure the achievement of unambiguous title or trusteeship, regulatory compliance, and ethical standards. The curators make acquisition recommendations to the Vice-President of Research and Collections/Chief Curator, and to the president, all of whom are institutional collections officers responsible for decisions at the higher authority levels. Decisions above the signing authority of the president require approval by the Board of Trustees. Objects may be deaccessioned from the collections for a variety of reasons as outlined in the current Manual of Collection Policies.

Future collecting will be based on active research, salvage opportunities, acquisition of orphan collections, and opportunities to acquire significant regional icons and collections. Specifically, the Anthropology Department will work systematically to hone institutional understanding of the anthropology collections while enhancing dialogues with the multiple audiences the Museum serves. The Earth Sciences Department will continue to grow its vertebrate paleontology, paleobotany collections, and invertebrate paleontology collections at a moderate rate through active research and private donations. The mineral and rock collections are expected to grow slowly, supporting research and exhibit needs. The Health Sciences Department will build its collections to support its community-based research, focusing on human anatomy, physiology, and genetics. The Zoology Department will focus on the collection of regional biodiversity, but
include diversity from across the planet when appropriate and when the opportunity arises. The Education Collections will focus on the quality of the collection more than actively growing the collection. The archives and image archives will grow their collections through transfer of records and images from Museum departments. The rare book collection and library will grow their collection selectively to serve the documentation and research needs of the Museum. The Space Sciences Department will maintain the Museum’s scientific instruments collection.

Since scientific research is an important driver of collections acquisition, this document presents the five-year plan for research for each of the museum’s 14 curators and the five-year plan for each of the museum’s 35 collections.
### 1.1. Collection Summary

<table>
<thead>
<tr>
<th>DEPARTMENT</th>
<th>COLL #</th>
<th>COLLECTION</th>
<th>CURATOR &amp; PLAN AUTHOR</th>
<th>COLLECTION MANAGER</th>
<th>TOTAL CUBIC FEET USED (1/1/2019)*</th>
<th>AVAILABLE CUBIC FEET (12/2019)</th>
<th>% COLLECTION SPACE USED (including growth 1/1/2019)</th>
<th>OBJECTS IN COLLECTION - DOCUMENTED + BACKLOG (1/1/2019)</th>
<th>CATALOGUED SPECIMENS OR LOTS (1/1/2019)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthropology</td>
<td>1</td>
<td>World Ethnology</td>
<td>O'Connell</td>
<td>Altamira</td>
<td>8,055</td>
<td>9,805</td>
<td>82%</td>
<td>5,546</td>
<td>5,639</td>
</tr>
<tr>
<td>Anthropology</td>
<td>2</td>
<td>American Ethnology</td>
<td>O'Connell</td>
<td>Altamira</td>
<td>31,490</td>
<td>37,982</td>
<td>83%</td>
<td>21,170</td>
<td>21,566</td>
</tr>
<tr>
<td>Anthropology</td>
<td>3</td>
<td>Archaeology</td>
<td>Nash/Koons</td>
<td>Altamira</td>
<td>6,058</td>
<td>14,650</td>
<td>41%</td>
<td>578,813</td>
<td>2,983</td>
</tr>
<tr>
<td>Earth Sciences</td>
<td>4</td>
<td>Micromount minerals</td>
<td>Hagadorn</td>
<td>MacKenzie</td>
<td>237</td>
<td>285</td>
<td>83%</td>
<td>30,418</td>
<td>14,748</td>
</tr>
<tr>
<td>Earth Sciences</td>
<td>5</td>
<td>Mineral Collection</td>
<td>Hagadorn</td>
<td>MacKenzie</td>
<td>3,953</td>
<td>4,879</td>
<td>81%</td>
<td>18,857</td>
<td>18,847</td>
</tr>
<tr>
<td>Earth Sciences</td>
<td>6</td>
<td>Rock Collection</td>
<td>Hagadorn</td>
<td>MacKenzie</td>
<td>332</td>
<td>449</td>
<td>74%</td>
<td>1,726</td>
<td>1,278</td>
</tr>
<tr>
<td>Earth Sciences</td>
<td>7</td>
<td>Meteorites</td>
<td>Hagadorn</td>
<td>MacKenzie</td>
<td>194</td>
<td>593</td>
<td>33%</td>
<td>686</td>
<td>686</td>
</tr>
<tr>
<td>Earth Sciences</td>
<td>8</td>
<td>Vertebrate Paleontology</td>
<td>Sertich/Lyon/Krause</td>
<td>MacKenzie</td>
<td>36,940</td>
<td>60,971</td>
<td>61%</td>
<td>1,555,174</td>
<td>118,700</td>
</tr>
<tr>
<td>Earth Sciences</td>
<td>9</td>
<td>Paleobotany</td>
<td>Miller</td>
<td>MacKenzie</td>
<td>4,745</td>
<td>7,980</td>
<td>59%</td>
<td>159,909</td>
<td>26,489</td>
</tr>
<tr>
<td>Earth Sciences</td>
<td>10</td>
<td>Invert Paleontology</td>
<td>Hagadorn</td>
<td>MacKenzie</td>
<td>1,250</td>
<td>1,710</td>
<td>73%</td>
<td>34,705</td>
<td>14,541</td>
</tr>
<tr>
<td>Health Sciences</td>
<td>11</td>
<td>Health sciences</td>
<td>Garneau</td>
<td>Busch</td>
<td>225</td>
<td>453</td>
<td>50%</td>
<td>27,738</td>
<td>1,732</td>
</tr>
<tr>
<td>Zoology</td>
<td>13</td>
<td>Arachnology</td>
<td>Cushing</td>
<td>Stephenson</td>
<td>582</td>
<td>616</td>
<td>94%</td>
<td>56,297</td>
<td>39,009</td>
</tr>
<tr>
<td>Zoology</td>
<td>14</td>
<td>Marine Invertebrates</td>
<td>Cushing</td>
<td>Stephenson</td>
<td>2,351</td>
<td>2,351</td>
<td>100%</td>
<td>43,728</td>
<td>31,128</td>
</tr>
<tr>
<td>Zoology</td>
<td>15</td>
<td>Entomology</td>
<td>Krell</td>
<td>Stephenson</td>
<td>3,338</td>
<td>4,531</td>
<td>74%</td>
<td>1,078,111</td>
<td>104,540</td>
</tr>
<tr>
<td>Zoology</td>
<td>16</td>
<td>Botany</td>
<td>Krell</td>
<td>Stephenson</td>
<td>76</td>
<td>76</td>
<td>100%</td>
<td>4,557</td>
<td>4,031</td>
</tr>
<tr>
<td>Zoology</td>
<td>17</td>
<td>Ornithology</td>
<td>Spellman</td>
<td>Stephenson</td>
<td>19,782</td>
<td>26,597</td>
<td>74%</td>
<td>54,741</td>
<td>51,804</td>
</tr>
<tr>
<td>Zoology</td>
<td>18</td>
<td>Eggs &amp; Nests</td>
<td>Spellman</td>
<td>Stephenson</td>
<td>855</td>
<td>855</td>
<td>100%</td>
<td>7,274</td>
<td>6,942</td>
</tr>
<tr>
<td>Zoology</td>
<td>19</td>
<td>Mammals</td>
<td>Demboski</td>
<td>Stephenson</td>
<td>20,372</td>
<td>25,398</td>
<td>80%</td>
<td>21,138</td>
<td>19,584</td>
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<tr>
<td>Zoology</td>
<td>20</td>
<td>Parasites</td>
<td>Demboski</td>
<td>Stephenson</td>
<td>30</td>
<td>40</td>
<td>75%</td>
<td>7,537</td>
<td>937</td>
</tr>
<tr>
<td>Zoology</td>
<td>21</td>
<td>Amphibians and Reptiles</td>
<td>Demboski</td>
<td>Stephenson</td>
<td>201</td>
<td>331</td>
<td>61%</td>
<td>595</td>
<td>100</td>
</tr>
<tr>
<td>Education Collections</td>
<td>22</td>
<td>Anthropology</td>
<td>Nash/Koons</td>
<td>Busch</td>
<td>1,481</td>
<td>1,600</td>
<td>93%</td>
<td>4,720</td>
<td>4,620</td>
</tr>
<tr>
<td>Education Collections</td>
<td>23</td>
<td>Biology</td>
<td>Demboski</td>
<td>Busch</td>
<td>4,640</td>
<td>4,800</td>
<td>97%</td>
<td>6,778</td>
<td>6,378</td>
</tr>
<tr>
<td>Education Collections</td>
<td>24</td>
<td>Geology</td>
<td>Hagadorn</td>
<td>Busch</td>
<td>192</td>
<td>250</td>
<td>77%</td>
<td>2,768</td>
<td>2,565</td>
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<tr>
<td>Education Collections</td>
<td>25</td>
<td>Health Sciences</td>
<td>Garneau</td>
<td>Busch</td>
<td>243</td>
<td>300</td>
<td>81%</td>
<td>1,652</td>
<td>1,652</td>
</tr>
<tr>
<td>Education Collections</td>
<td>26</td>
<td>Museology</td>
<td>Busch</td>
<td>162</td>
<td>175</td>
<td>93%</td>
<td>61</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>Education Collections</td>
<td>27</td>
<td>Paleontology</td>
<td>Miller</td>
<td>382</td>
<td>500</td>
<td>76%</td>
<td>3,257</td>
<td>3,137</td>
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<tr>
<td>Education Collections</td>
<td>28</td>
<td>Space Sciences</td>
<td>Yu</td>
<td>Busch</td>
<td>80</td>
<td>80</td>
<td>100%</td>
<td>182</td>
<td>176</td>
</tr>
<tr>
<td>Education Collections</td>
<td>29</td>
<td>Scientific Instruments</td>
<td>Yu</td>
<td>0</td>
<td>0</td>
<td>100%</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Library &amp; Archives</td>
<td>30</td>
<td>Rare Books</td>
<td>O’Connell</td>
<td>O’Connell</td>
<td>693</td>
<td>See Total Space</td>
<td>See Archives Total</td>
<td>2,507</td>
<td>2,507</td>
</tr>
<tr>
<td>Library &amp; Archives</td>
<td>31</td>
<td>Archives*</td>
<td>O’Connell</td>
<td>O’Connell</td>
<td>2,552</td>
<td>See Total Space</td>
<td>See Archives Total</td>
<td>34,993</td>
<td>34,993</td>
</tr>
<tr>
<td>Library &amp; Archives</td>
<td>32</td>
<td>Image Archives*</td>
<td>O’Connell</td>
<td>O’Connell</td>
<td>4,742</td>
<td>See Total Space</td>
<td>See Archives Total</td>
<td>188,491</td>
<td>188,491</td>
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<tr>
<td>Library &amp; Archives</td>
<td>33</td>
<td>Archives Oversized*</td>
<td>O’Connell</td>
<td>O’Connell</td>
<td>Unknown</td>
<td>See Total Space</td>
<td>See Archives Total</td>
<td>3,343</td>
<td>3,343</td>
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<tr>
<td>Library &amp; Archives</td>
<td>34</td>
<td>Library Books</td>
<td>O’Connell</td>
<td>O’Connell</td>
<td>5,067 linear ft</td>
<td>29,868</td>
<td>44%</td>
<td>228,734</td>
<td>228,734</td>
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<tr>
<td>Library &amp; Archives</td>
<td>35</td>
<td>Library Periodicals*</td>
<td>O’Connell</td>
<td>O’Connell</td>
<td>Included above</td>
<td>5,951</td>
<td></td>
<td>5,951</td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL**: 3,943,548, 797,882

* As archival material and periodicals typically measured in linear feet, number of EMu records used for these collections.
### 1.2. Summary of Projected Growth or Shrinkage of Collections

<table>
<thead>
<tr>
<th>DEPARTMENT</th>
<th>COLLECTION</th>
<th>CURATOR(S)</th>
<th>Projected growth or shrinkage of collection 2019-2023</th>
<th>Change in collection volume 2019-2023</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthropology</td>
<td>World Ethnology</td>
<td>Colwell</td>
<td>Slight growth in line with collection plan</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>American Ethnology</td>
<td>Colwell</td>
<td>Slight growth in some subcollections in line with collections plan</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Archaeology</td>
<td>Nash, Koons</td>
<td>Growth in some subcollections in line with collections plan</td>
<td>+</td>
</tr>
<tr>
<td>Earth Sciences</td>
<td>Micromount Minerals</td>
<td>Hagadorn</td>
<td>No change expected, unless historically relevant collections become available</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mineral Collection</td>
<td>Hagadorn</td>
<td>Modest growth through strategic acquisitions or opportunistic donations</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Rock Collection</td>
<td>Hagadorn</td>
<td>Moderate to substantial growth through donations or opportunistic collection</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Meteorites</td>
<td>Hagadorn</td>
<td>No change expected</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Vertebrate Paleontology</td>
<td>Sertich, Lyson, Krause</td>
<td>Growth from research-driven fieldwork and donations</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Paleobotany</td>
<td>Miller</td>
<td>Growth from research-driven fieldwork and donations</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Invertebrate Paleontology</td>
<td>Hagadorn</td>
<td>Substantial growth from donations, field collecting, and salvage</td>
<td>+</td>
</tr>
<tr>
<td>Health Science</td>
<td>Health Science</td>
<td>Garneau</td>
<td>Growth from accessioning 2018/2019 human genetics samples</td>
<td>+</td>
</tr>
<tr>
<td>Scientific Instruments</td>
<td>Scientific Instruments</td>
<td>Yu</td>
<td>No change expected</td>
<td>0</td>
</tr>
<tr>
<td>Zoology</td>
<td>Arachnology</td>
<td>Cushing</td>
<td>Growth from field collections and donations</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Marine Invertebrates</td>
<td>Cushing</td>
<td>Growth from field collections and donations</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Entomology</td>
<td>Krell</td>
<td>Steady growth from field collections and donations</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Botany</td>
<td>Krell</td>
<td>Minimal growth from acquisitions</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Ornithology</td>
<td>Spellman</td>
<td>Steady growth from field collections, salvage, and transfers</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Eggs &amp; Nests</td>
<td>Spellman</td>
<td>Minimal growth from donations or transfers</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Mammals</td>
<td>Demboski</td>
<td>Steady growth from collecting, transfers, and salvage</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Parasites</td>
<td>Demboski</td>
<td>Steady growth in parallel with growth of vertebrate collections</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Amphibians and Reptiles</td>
<td>Demboski</td>
<td>Slow growth from salvage and transfers</td>
<td>+</td>
</tr>
<tr>
<td>Chief Curator</td>
<td>Dioramas</td>
<td>Demboski, Schiller, O'Connell</td>
<td>No change expected</td>
<td>0</td>
</tr>
<tr>
<td>Education Collections</td>
<td>Anthropology</td>
<td>Nash, Colwell, Koons</td>
<td>Minimal growth from donations or transfers</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Biology</td>
<td>Demboski, Spellman, Krell, Cushing</td>
<td>Minimal growth from donations or transfers</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Geology</td>
<td>Hagadorn</td>
<td>Minimal growth from donations or transfers</td>
<td>+</td>
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<tr>
<td></td>
<td>Health Sciences</td>
<td>Garneau</td>
<td>Minimal growth from donations or transfers</td>
<td>+</td>
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<tr>
<td></td>
<td>Museology</td>
<td>Schiller</td>
<td>Minimal growth from donations or transfers</td>
<td>+</td>
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<tr>
<td></td>
<td>Paleontology</td>
<td>Sertich, Miller, Lyson, Hagadorn, Krause</td>
<td>Minimal growth from donations or transfers</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Space Sciences</td>
<td>Yu</td>
<td>Minimal growth from donations or transfers</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Scientific Instruments</td>
<td>Yu</td>
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<td>0</td>
</tr>
<tr>
<td>Library &amp; Archives</td>
<td>Rare Books</td>
<td>O'Connell</td>
<td>Slow growth from transfers and occasional acquisitions</td>
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<td></td>
<td>Library Books &amp; Periodicals</td>
<td>O'Connell</td>
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<td>Archives</td>
<td>Schiller</td>
<td>Growth from transfers and donations</td>
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</tr>
<tr>
<td></td>
<td>Image Archives</td>
<td>O'Connell</td>
<td>Growth from transfers and donations</td>
<td>+</td>
</tr>
</tbody>
</table>

+ = Increase in collection size  
0 = no change in collection size  
- = Decrease in collection size
2. OVERVIEWS

2.1. Anthropology

Department Focus & Collections
The Department of Anthropology aspires to curate the best-understood and most ethically held anthropology collection in North America. We pursue entrepreneurial and collections-based research to document and better understand the human communities of the Rocky Mountain region and beyond while adhering to the guiding principles of respect, reciprocity, justice, and dialogue. The anthropology collections’ strengths include the American ethnology collection, the world ethnology collection, and the American archaeology collection. The world archaeology collection is somewhat anomalous, consisting largely of poorly sourced artifacts.

Current Research
Steve Nash will conduct research on dendrochronology, the history of archaeology, and the Mogollon occupation of New Mexico. He will also continue his research on the Russian gem carvings of Vasily Konovalenko. Chip Colwell will explore how human societies relate to and understand material culture, using the Native American ethnology collection as a point of departure. Michele Koons will conduct research on the Front Range archaeology of Colorado, the Mogollon of New Mexico, and the Moche of Peru.

Future Plans for Collections
Over the next five years, the Anthropology Collections Synthesis Project and Indigenous Inclusiveness Initiative will continue to work systematically to hone institutional understanding of the anthropology collections while enhancing dialogues with the multiple audiences the Museum serves. Additions will be made to the anthropology collections through archaeological research by Nash and Koons and the opportunistic acquisition of well-documented donations and orphaned, scientifically collected ethnological, or archaeological collections. Under no circumstances will collections that violate the 1970 UNESCO Convention knowingly be considered for acquisition. Ethically and legally challenged collections will be considered for deaccession.

Audience Engagement
Through the acquisition and study of cultural collections we arm ourselves for meaningful encounters with a wide variety of Museum audiences, from students and scholars to Native communities and artists. Outreach programs, including those under the Indigenous Inclusiveness Initiative, the Indigenous Film Festival, and other Native American Science programs, the Hannah Marie Wormington and George McJunkin lectures, are continuing to build momentum, as are distance learning programs in partnership with other Museum divisions. We will continue to provide stimulating and relevant content through adult programs, evening classes and lectures, regional tours, temporary exhibitions, and behind-the-scenes tours. We will continue to propose improvements to existing education programs and anthropology exhibitions with the goal of renovating the Native American cultures hall.

2.2. Earth Sciences

Department Focus & Collections
The Department of Earth Sciences conducts specimen- and field-based research that spans the globe including in East Africa, Madagascar, South Africa, and the Middle East. We also deeply engage in projects across the Rocky Mountain region that often have direct local impact and community participation. Our team’s scholarship is diverse and presently includes the evolution of Cretaceous ecosystems; the causes and recovery of mass extinctions; the integration of paleoclimatology,
geochronology, and tectonics in Rocky Mountain basins; and the linkages between Mesozoic biogeography and Gondwanan plate tectonic fragmentation.

Our paleontological collections primarily originate from the Rocky Mountain region; however, we also have world-class fossil vertebrate collections from Madagascar and synoptic global collections of micromount minerals and trilobites. In the framework of geologic time, the vertebrate paleontology collection consists predominantly of Cenozoic mammals, Jurassic and Cretaceous dinosaurs, and Cretaceous seaway fish and reptiles; it includes many complete skeletons. The paleobotany collection consists principally of Cretaceous-Eocene leaves and is the third largest collection of its kind in the nation. The invertebrate paleontology collection’s main strengths are Cambrian-Ordovician trilobites, Cretaceous mollusk, and Eocene insects.

Our geological collections include gems and minerals primarily from Colorado and includes a number of regionally iconic specimens. The micromount mineral collection is the second largest in the nation and contains specimens from around the world. The rock collection includes historically relevant specimens, a suite of regional building stones, as well as scientifically important specimens such as a collection of K-Pg boundary blocks from around the world. The meteorite collection was one of the nation’s first, and has samples from around the world with a significant portion from Colorado.

Current Research
Joe Sertich studies Jurassic and Cretaceous archosaurs from the American West as well as maintaining an active research program focused on dinosaurs and crocodylimorphs from the southern supercontinent Gondwana. Tyler Lyson’s research focuses on the causes and recovery of mass extinctions, and the origin of turtles. David Krause studies the Late Cretaceous vertebrates and ecosystems of Gondwana, particularly Madagascar, as well as the evolutionary history of mammals after the K-Pg mass extinction. James Hagadorn’s research focuses on late Precambrian, Paleozoic, and Mesozoic marine and terrestrial rocks and fossils to better understand large-scale environmental and ecological changes. Ian Miller’s research is focused on Jurassic through Eocene fossil floras and the evolution of plant ecosystems in deep time.

Future Plans for Collections
The Earth Sciences collections primarily reside in the Avenir Collections Facility. Here, the collections have potential for many years of growth at the current level of acquisition activity by the Earth Sciences curatorial team. In the rock and mineral collections during the past five years, duplicate or context-less mineral and rock specimens have been deaccessioned. In the next five years, these collections are expected to slowly grow in size in support of research and exhibition needs. Moderate continued growth is expected in both the vertebrate paleontology and paleobotany collections through active research and fieldwork and through acquisition of private collections. Finally, continued moderate growth of the invertebrate paleontology collection is expected through addition of rare specimens and systematic collections from North American strata.

Audience Engagement
We engage in outreach that makes paleontology and geology relevant and inclusive for all audiences, including the next generation. In particular, we focus on outreach activities that convey our sense of curiosity and discovery and increase our community’s appreciation of the utility of earth science to our society, economy, history, and future, and we hope that the Department is a catalyst for such sentiment. We have a strong network of alumni who are either scientists or science advocates and we continue to build this group. We also develop, lead and participate in programs that increase access to earth sciences for underrepresented groups internally and externally through our mentoring programs (teens,
undergraduate and postgraduate interns, postdocs and volunteers), our collaborations with regional partners (e.g., CC, CSU, CU-Boulder, USGS, Mines), our work with the Experiences and Partnership teams at the Museum, and our story-telling, in all its forms (TV, radio, print, books, lectures, tours, hands-on-tables, social media, and the like). Finally, we provide access to more than a million specimens from our collections to researchers and educators, and we actively involve community scientists in research, outreach and collections work. Our curatorial staff is productive in publishing scholarly research in professional journals and in conveying that research to the general public. Our curators are also engaged in service activities for a variety of professional scientific societies.

2.3. Health Science
Department Focus & Collections
The Health Sciences Department directly connects the community to health science content in a way that is relevant to people’s everyday lives. We do this through visitor and citizen-science participation in authentic research studies conducted in the audience-focused and community-based Genetics of Taste Lab, through partnerships with community groups, multiple levels of volunteers and interns, and by supporting exhibits and museum programming, that makes health science accessible to our audiences. The department also utilizes authentic human anatomical specimens (DNA, tissue, organs, and whole body) to help connect audiences to their own bodies and their own health.

Current and Future Research
The departmental curatorial and research staff conduct studies to understand the genetic underpinnings of sensory perception, food choice and preference, and the role in nutrition in overall health. Research is conducted in annual studies (Nov-Aug in the Genetics of Taste Lab, onsite crowdtasting events through Museum Programs, and external partnerships through curatorial adjunct positions).

Future Plans for Collections
DNA Subcollection: The department will continue research studies centered on human population genetics and thus will continue to collect human DNA samples. Annually this amounts to approximately 1500 samples a year added to the collection.
Tissue (Histopathology) Subcollection: We anticipate that from 2019-2023 we will continue to review the Shikes histopathology collection, documenting and cataloging each slide in EMu, and rehousing.
Organ/Body (wet, dry and plastinate): We anticipate no growth in this subcollection. We continue to monitor how environment affects the plastinates.
Historical Medical Subcollection: We anticipate no major growth, although we continue to welcome pacemakers as we build a complete collection.

Audience Engagement
Health by its nature is a personal and impactful subject for our visitors, and the Health Sciences Department research and outreach for that reason are uniquely interwoven. The department has successfully established the world’s first truly community-based molecular genetics lab, utilizing visitors as research participants and volunteer community scientists for data collection and analysis. The lab space where the research is conducted is open to viewing 364 days a year within the Expedition Health exhibition. Visitors to the exhibition can participate in the Genetics of Taste research study, and through enrollment experience authentic scientific discovery in a way that is personally relevant. The infrastructure of this study design was evaluated in 2011-2012. It showed that our novel community-based model is a proven mechanism used to take a concept as remote as the Human Genome Project and make it as real, meaningful, and concrete as a person’s ability to taste. In addition to research, the department supports numerous health programming events internally and with external outreach partners, engaging thousands of people a year in face-to-face activities and via the internet.
2.4. Space Science
Department Focus & Collections
The Department of Space Sciences aims to educate Museum visitors and our local community with accurate and scientifically sound information regarding the space sciences. The Space Sciences department also curates the Scientific Instrument Collection that is composed of instruments that have been used by Museum staff members or have been part of historically important experiments.

Current Research
Ka Chun Yu’s research interests have forked off in two different directions. His astronomy education research includes work on understanding naive understandings that students may hold before formal astronomy instruction, and how to use immersive visualizations in digital planetariums to convey complex astronomical concepts. His astrophysical research involves star formation, and includes multiwavelength observational studies of jets and outflows from young stars, surveying young clusters using near-infrared photometry, and large-scale, multiwavelength analyses of star forming regions.

Future Plans for Collections
The Scientific Instruments Collection is not being used for active research, and there are no plans to grow it. However, after additional discussions, the Chief Curator and Space Sciences Curator can allow for exceptions to be made for new, limited acquisitions to the Collection.

Audience Engagement
The Space Sciences Department engages Museum audiences directly by giving public talks, making media appearances, developing live and pre-recorded planetarium shows, and participating in teacher professional development. Indirect audience engagement is done primarily through the training of volunteer Museum Galaxy Guides who work in Space Odyssey. The Department also advises other Museum departments when questions involving space science content arise.

2.5. Zoology
Department Focus & Collections
Curators in the Zoology Department are collections-based biologists who study evolutionary patterns and processes. The curators’ taxonomic foci include major invertebrate (Arachnida, Insecta) and vertebrate (Aves, Mammalia) classes, and research questions are primarily focused on understanding biodiversity in the American West, and beyond. Curators use fieldwork, collections, and laboratory work (genomics, morphology, microscopy, biochemistry, informatics, etc.) to study evolutionary relationships, taxonomy, basic natural history, biogeography, phylogeography, ecology, speciation, conservation, chemical ecology, host-parasite co-evolution, and even paleontology. Curators are also charged with building and enhancing the research collections they curate to support the broader scientific community and contribute to the public good.

The Zoology collections, five major collections and four smaller collections, consists of approximately 1.27M specimens or 30% of the Museum’s total holdings. The arachnology (spiders and their relatives) collection (60,000 vials), one of the largest in the country, includes specimens from 10 orders. Strengths are in Araneae and Soligugae, and the majority of the collection (84%) is from the Rocky Mountains and Great Plains ecoregions. The entomology (insect) collection’s strengths are in the orders Lepidoptera (moths and butterflies) and several families of Coleoptera (beetles), including a globally significant collection of scarab beetles. The collection is the second largest entomology collection in the state (1M plus). The marine invertebrate collection (~45,000 lots) is worldwide in coverage with particular strengths in material from the Caribbean, western Mexico and the Pacific (including Hawaii, the
Philippines and Australia). The mammal collection, which has more than doubled in size over the last decade, covers 7 continents, but is particularly strong with its Colorado focus, and more recent focus on Front Range urban mammal diversity. Small mammals such as rodents, bats, shrews, and lagomorphs make up the bulk of the collection. The ornithology collection (~55,000 specimens), one of the largest in the American West, with holotypes, paratypes, extinct taxa, and many species of conservation importance. Both vertebrate collections span the last 150 years, are focused on the Rocky Mountain regions (>75%) and have significant frozen tissue and parasite collections associated with them.

The four smaller collections include the egg and nest collection (~7,300 specimens) which is worldwide in focus, the botany collection (~4,500 specimens), which in regional in focus and includes specimens representing 240 families, the amphibian and reptile collection which includes about 1,000 specimens primarily regional and exotic (Denver Zoo), and the parasite collection (~7,500 lots) which rapidly grows in parallel with the bird and mammal collections. Four of the collections, arachnids, birds, insects, and mammals, are actively growing and are currently available on-line through Arctos or Symbiota, with data published to a different portals including SCAN, GBIF, iDigBio, GGBN, BISON, VertNet, InvertEBase, SEINet, and GenBank.

Current Research
Zoology curator research over the next five years will continue to very active, collaborative, and specimen-based. Paula Cushing will be focused on her NSF project investigating North American camel spiders, continuing her long-running citizen science project (Colorado Spider Survey), and research on the biogeography of myrmecophilic (“ant lover”; live symbiotically with ants) spiders. John Demboski’s research will continue to focus on resolving evolutionary relationships among small mammals, primarily chipmunks and shrews, phylogeographic research on select species, and more in-depth examination of interspecific zones of hybridization in the Rockies. Frank Krell will continue focus on scarab beetle taxonomy and diversity, with projects focused on the region (Colorado Scarab Survey, Bison Beetle Project, and the Westcliffe Project). In addition, he will also be working on projects centered on African beetle ecology, and dung beetle chemical ecology. Garth Spellman will continue to develop and expand regional collaborations focused on local species such as rosy finches and rock wrens framed around questions of climate change and behavioral traits using genomic methods. In addition, he will expand work focused on extinct avian taxa and continue work on hybrid zones in the American West.

Future Plans for Collections
Zoology curators will continue to grow their collections in a smart and focused manner, concentrating on the solid representation of regional species but also including worldwide species when appropriate (e.g., Solifugae, Scarabaeidae). Collections growth will occur through active fieldwork, salvage, transfers, and donations, and will always be framed around building for the future but remaining thoughtful of current space and resource constraints.

Audience Engagement
Zoology curators will continue to actively engage in a variety of internal and external outreach opportunities including, but not limited to, lectures, workshops, museum programming, media opportunities, mentoring students, and behind the scenes in collections. We will also continue collaborations and partnerships with external colleagues at the regional institutions such as the Denver Zoo, The Bird Conservancy of the Rockies, Denver Botanic Gardens, the Butterfly Pavilion, CO Parks and Wildlife, USFWS, as well as local and non-local universities. Through these outreach efforts we will engage the public around science in general, the museum’s mission and vision, and of course, our own research programs, by presenting exciting scientific findings in an accessible format. We will also
continue to bring our collections to the floor and beyond, where they can be showcased for our audience.

### 2.6. Education Collections

**Collection Focus**

The Education Collections’ mission is to support science education programing firstly within the walls of DMNS, but secondarily in our community writ large. The Education Collections serve as the public’s primary access point into the DMNS Collections. As such, the focus of the collections is broader than it is deep. Acting as a resource for all programing that DMNS generates, the collections need to be wide ranging in nature in order to be an effective and available resource for educators to draw from in a timely manner. Accordingly, the collections hold objects and specimens that are representative of the science and programing that the museum has produced.

**Future Plans for Collections**

The Education Collections moved into the western half of Figgins Collections Range during the summer of 2018. Within the next 3-5 years, the Alfred M. Bailey Library is expected to move into the eastern half. We will be exploring how these two collections might be a greater asset to the institution by sharing the same physical space. As such, this particular section of the LTCRP will be added to as those ideas are developed and are implemented.

Additionally, during the fall of 2018, we will be revisiting the Policies and Procedures that govern the operation of the Education Collection. This will also be a moment to challenge the “because-thats-the-way-weve-always-done-it” operations of this department.

Concerning collections growth, it is our intent to focus on the quality and representation within the collection – not quantity. During the move into Figgins Collections Range, we have been actively editing the collections, replacing objects and specimens with higher quality examples obtained from “no data” collections that are being jettisoned from the research departments. This process will continue for the foreseeable future. There are some institutional philosophical questions we would like to address in the coming months/years. As such, this section as well should be considered a living document into the future.

**Audience Engagement**

We love science at DMNS, and access to real museum objects is central to the Inquiry Learning that is at the core of the science programs offered at DMNS. Inquiry Learning is an activity-oriented learning process that reflects scientific investigation, specifically the observation, experimentation, and reasoning used by scientists. Object based activities are invaluable as part of the Inquiry Learning pedagogy. Object based activities are just that, activities where a teacher works with the students to use well-thought-out initial questions to stimulate the students thinking about their objects and to develop further, deeper questions. Education Collections is the source of these objects, from bald eagles to amoebas, which allow the development of such engaging programming. Working primarily with the DMNS Museum Programs and Exhibits Departments, the DMNS Education Collections combines our understanding of science education pedagogy with collections care and scientific knowledge. We bring that perspective to our strategic initiative teams and exhibit core teams throughout the institution. This directly results in more museum collections on the floor for the public to interact with and learn from.

### 2.7. Library and Archives

**Focus & Collections**
The Bailey Library and Archives is the official manager and repository of the Museum’s document, image, and publication collections. It makes those resources accessible to Museum personnel and audiences to support the Museum’s educational, collecting, and research mission. The archives collection consists of the Museum’s official textual records (1900 to present) and donated collections of records that document the Museum, its collections, associated organizations and individuals, and its disciplines (ca. 1870 to present). The image archives collection consists of analog items in all formats (including artwork) dating from the late 1800s to the present, and digital image files created since 1998, many by the staff photographer. Museum staff created most of the images, but donated collections also document the Museum, its collections, and its disciplines. The library’s rare-book collection holds rare and valuable items dating from 1773 that have come to the Museum from donations and purchase and focus on the Museum’s disciplines.

Future Plans for Collections
The archives and image archives collections continue to grow, mainly through transfer of records and images from the Museum’s departments. More and more of the collections will be electronic and stored and managed on computer servers, requiring specialized software and the involvement of technology staff in the process. The rare book collection will selectively, and largely passively, grow to serve the documentation and research needs of the Museum. The archives will still prefer to collect hard copy documentation for ease of preservation, but will implement an electronic records management system to collect, store, and manage documents that must be preserved electronically in order for them to be useful. The image archives will still receive analog images through donation. Much of the collections will increase in their value to researchers, especially the film and video collections. A digital asset management system (DAMS), LUNA, is used for the management of the Museum’s digital images. The library will focus on primarily serving Museum staff, as well as volunteers and potentially scholarly researchers. Archives, Image Archives, and Rare Book collections are managed in the Avenir Collections Center. The Library will be moving to the Figgins space on the second floor, likely in 2019-2020.

Audience Engagement
The Bailey Library and Archives will collaborate with each of the Museum’s departments to make more of their collections available through library and archives channels. The department will continue to expand its Web presence with catalogs, finding aids and online access to images. Access to collections will be governed by laws and professional standards and best practices listed in the Museum’s Manual of Collection Policies.

3. CURATOR RESEARCH PLANS

3.1. Anthropology

3.1.1. Stephen E. Nash, Director of Anthropology Branch & Senior Curator of Archaeology

Nature of Research
Archaeology is a uniquely historical social science; museums are uniquely historical institutions. My research over the last three decades focused on the historical intersection between archaeological field research, collections acquisition and care, and the development of archaeological knowledge, method, and theory. I have a keen interest in the development and application of archaeological dating techniques, particularly tree-ring dating in the American Southwest, and have facilitated new research on old collections through focused efforts to catalog, computerize, and publish existing museum collections. This has led directly to work on a diverse array of projects from Indian Peace Medals to Russian gem carvings, in and on a range of archaeological, anthropological, and archival collections.

Personal Research History
I began my museum career working as a tour guide at the Museum of Science and Industry in Chicago in 1980, a position I held at various times through 1988. This experience, coupled with my father’s employment at The Field Museum during the 1960s, instilled in me an appreciation for collections-based museum work. My archaeological career began at field school in Flagstaff, Arizona, in 1984. Since then, I have worked on excavations and surveys in Arizona, California, Colorado, Illinois, New Mexico, and Utah, as well as such archaeological marvels as Neanderthal sites in southwestern France and Bronze Age sites in Israel. I have conducted tree-ring research on back-country cliff sites at Mesa Verde National Park in southwestern Colorado, and continue to analyze large tree-ring datasets to look for systematic bias that derives from historical contingencies (i.e. archaeological research foci, differential preservation, etc.). I am currently involved in archaeological research in the Mogollon Highlands area of west-central New Mexico, building on the Field Museum and other institutions’ work there over the last seven decades (see below).


I have published nearly two dozen peer-reviewed articles in journals ranging from *American Anthropologist* and *American Antiquity* to *Historical Archaeology, Journal of Archaeological Research, Journal of the Southwest, Arctic Anthropology*, and *Arizona Anthropologist*. I have published more than two dozen peer-reviewed book chapters on regionally focused topics ranging from the history of Southwestern archaeology, to lithic analysis and archaeological dating. In keeping with my belief that anthropology is, and should be, accessible to the lay public, I have published more than 20 popular articles in venues ranging from *Catalyst to Archaeology magazine to In the Field*, The Field Museum’s membership newsletter. Over the last two years, I have made contributions to a number of print and online encyclopedias, on topics ranging from dendrochronology to the climate and environment of the American Southwest and the history of archaeology. Finally, I have published numerous book reviews in regional and national journals and reviewed many unpublished manuscripts for various publishers.

Since the Avenir Collections Center opened in 2014, I have been working with scholars to publish analyses of previously unpublished portions of the Anthropology collections. Three projects come to the
fore: The Navajo Textiles Project, led by Laurie Webster, Louise Stiver, DY Begay, and Lynda Teller Pete. In 2017, they published *Navajo Textiles: The Crane Collection at the Denver Museum of Nature & Science* (University Press of Colorado), a stunningly beautiful introduction to the “best Navajo textile collection you’ve never heard of” (according to Webster). Similar projects are underway on the Peace Medal and Plains beadwork collections (see below).

In 2014, and building to two decade’s worth of archival and collections-based work, I began working in the Mogollon Highlands of west-central New Mexico on the Reserve Area Archaeological Project (RAAP). This project is in collaboration with Dr. Michele Koons of DMNS and DMNS Research Associate Dr. Deb Huntley. Through RAAP we are investigating changes in population density, settlement location, subsistence strategies, paleoclimate, social dynamics, and resource availability through time. Fieldwork has consisted of relocating and rerecording archaeological sites, locating new sites through pedestrian survey, and investigating features with ground-penetrating radar. In May 2018 we conducted the first excavations of the project at the highest known Great Kiva in the region, located 7,300 ft. above sea level.

In 2016, I began writing the Curiosities column for *Sapiens*, an on-line magazine that makes anthropology accessible to the public. Since then, I have published nearly three dozen columns on artifacts, specimens, and ideas about artifacts, technologies, and humankind’s relationship to them. Several of those columns have been picked up by other on-line magazines including *Discover* and *Scientific American*. One column, entitled “What did Ancient Romans do without Toilet Paper?” went viral and has enjoyed ca. 225,000 reads in a three month period. All told, the Curiosities column has been read 600,000 times since its inception.

**Goals for the next 5 years**

My primary research goals for the next five years focus on the Reserve Area Archaeological Project, broadly defined. With Dr. Michele Koons, I will build on pedestrian survey in the area and may conduct additional excavations in the coming years. In 2017 DMNS took legal control over the WS Ranch collection from the University of Texas at Austin. The archives are in Denver; the collection will come to Denver in 2019. The WS Ranch Project was one of the last big (i.e. excavating entire rooms and structures, not just samples thereof) archaeological field schools in the American Southwest, operating out of the University of Texas at Austin from 1978 to 1994. It remains unpublished. Over the next five years I will work to get this material cataloged and available to the scholarly community. I will continue to publish on Paul Sidney Martin’s work at the Field Museum, including an article on Paul Sidney Martin’s archaeological work in Arizona from 1956 to 1974 (i.e. the “New Archaeology”) and then publish *Many Roads to the Truth: Paul Sidney Martin and North American Archaeology 1929 – 1972*. This book will be the first and only scholarly biography available on one of the true pillars in the development of North American archaeological knowledge, method, and theory, who was also a curator at The Field Museum in Chicago. Finally, I will edit the Southwest Symposium volume, tentatively entitled *Pushing Boundaries*, resulting from the 2018 conference we held at the Museum.

All of my proposed research, whether collections- or field-based, is designed to be easily understood by the general public, and to fit within an ethos that remains sensitive to heritage preservation. I will therefore continue to publish popular papers in *Sapiens* and other venues as opportunities arise.

**3.1.2. Chip Colwell, Senior Curator of Anthropology**

**Nature of Research**

Anthropology—the study of humanity—is both a mirror to reflect on ourselves and a window to see others. Anthropology plays a critical role at DMNS in terms of programs, outreach, permanent and
temporary exhibits, collections, and research. Since 1968, the North American Indian Hall has presented many of the Indigenous cultural traditions of this continent, and the collections of Native arts and objects has grown while also expanding to include representative objects from peoples around the globe. These collections present the opportunity not only to record past and present human diversity, but also provide a means by which visitors and researchers can investigate the wondrous expanse of the human experience.

**Personal Research History**

To date, I have published seven books and four edited books, and more than 50 peer-reviewed articles and book chapters. This research has primarily focused on Native American history and culture, with a focus on the DMNS collections, but have also ranged out to heritage law and management, research ethics, and museum studies. I have held research fellowships with the American Academy of Arts & Sciences, National Endowment for the Humanities, and US Fulbright Program. For this research I have garnered a range of awards, such as a Colorado Book Award, a National Council on Public History Book Award, and the Gordon R. Willey Prize of the American Anthropological Association. I have presented my research through scores of public talks and academic lectures, including the 2010 Bushnell Lecture at the University of Cambridge, 2016 Barbara A. and Edward G. Hail Lecture at Brown University’s Haffenreffer Museum, and the 2018 AIA Nancy Wilkie Lectureship in Archaeological Heritage at Texas A&M University.

**Goals for the next 5 years**

My goal to explore how human societies relate to and understand the world will be pursued by integrating research with the DMNS’s collection and engaging the Rocky Mountain Region’s diverse communities. I will continue to research and publish on Native American history and culture, and areas related to heritage and museums studies. Additionally, I will continue to seek out projects that build directly from the Museum’s collections, such as the current book manuscript “The Vanished Who Endured: Objects of Survivance from the American Indian School Experience” under review at the University Press of Colorado, and my next book project, tentatively titled “Stuffology: Why Humans Need, Love, and Loathe the Things in Our Lives.” These and other projects will be the basis of my research and public engagement, as well as my continuing responsibilities in contributing to the Museum’s programs and exhibits, and service to the discipline.

**3.1.3. Michele Koons, Associate Curator of Archaeology**

**Nature of Research**

My research projects all pursue a common theme: the examination of past sociopolitical dynamics and human-environmental interactions. Although I am currently doing research in different parts of the world on different kinds of societies, the questions I ask are the same: How do people interact with one another (politically, socially, and religiously), how do they move around the landscape, and how the environment constrains and facilitates movement and interaction between people. In my research I use different geophysical methods and remote sensing tools, as well as traditional archaeological techniques like excavation and pedestrian survey. I also specialize in ceramic analysis and radiocarbon dating.

**Personal Research History**

I came to the DMNS as a post-doctoral fellow in October of 2012—a few months after completing my dissertation at Harvard University. I was hired as curator of archaeology in December of 2013. My dissertation research involved mapping and excavating the previously unstudied Moche site Licapa II, located in the Chicama Valley on the northern coast of Peru. The goal of that research was to elucidate Moche political organization from the perspective of this medium-sized civic-ceremonial center through an examination of ceramics, architecture, and radiocarbon dating. Building off my dissertation, in
2013 I undertook a project in Peru looking at past land use and water strategies in the Chicama Valley. I continue to give invited lectures and conference papers on my Moche research and continue to publish aspects of this work with the plan of returning to the region in the near future.

In 2014, I began working in the Mogollon Highlands of west-central New Mexico on the Reserve Area Archaeological Project (RAAP). This project is in collaboration with Dr. Steve Nash of DMNS and DMNS Research Associate Dr. Deb Huntley. Through RAAP we are investigating changes in population density, settlement location, subsistence strategies, paleoclimate, social dynamics, and resource availability through time. Fieldwork has consisted of relocating and rerecording archaeological sites, locating new sites through pedestrian survey, and investigating features with ground-penetrating radar. In May 2018 we conducted the first excavations of the project at the highest known Great Kiva in the region, located 7,300 ft. above sea level. We are interested in understanding the community that used this kiva, including their subsistence practices and mobility patterns.

When I arrived at DMNS I wanted to launch a community-based public archaeological project. I formed a partnership with Dr. Mark Mitchell of Paleocultural Research Group (PCRG), who is a highly experienced Colorado archaeologist. In 2016 we initiated the Magic Mountain Archaeological Project to great success. The Magic Mountain site is recognized as one of the most important archaeological sites in northeastern Colorado. Nestled along Apex Gulch in Golden, CO, the site was a campground for mobile hunter-gatherers passing through the region from 5000 BCE to at least CE 1000. Our research aims to elucidate Early Ceramic period (200-1000 CE) mobility patterns through an investigation of the site’s material connections to the regional cultural landscape. We are also investigating deep deposits at the site that may relate to some of the earliest Coloradans. The project has run for three seasons (2016-2018) and we anticipate continuing public archaeology projects at Magic Mountain, or other similar sites in the area, in the future.

In 2016 I spearheaded a new round of research on the two Egyptian mummies and coffins in the Egyptian Mummies Hall at DMNS. Technology has greatly improved since the two mummies were last computed tomography (CT) scanned nearly two decades ago. When the mummies were slated to come off display in 2016 while the gallery was renovated, I pushed for a new round of analysis and sought out experts to execute this work. In April 2016, the Museum partnered with Children’s Hospital Colorado and with Egyptologists and other specialists from around the country to acquire updated CT scans of the mummies, CT scans of one of the coffins, radiocarbon dating, x-ray fluorescence and chemical analysis of the paints on the coffins, analysis of the coffin wood, analysis of the style and decoration of coffins, gas chromatography of the resins, linen analysis, isotope analysis of the skin/muscle of one mummy, and updated conservation efforts. These results will be publish through the University Press of Colorado.

Since 2004 I have been involved with research on the Tiwanaku culture of highland Bolivia. My Master’s thesis work was a largescale geophysical survey of the site of Tiwanaku and selected excavations based off of the results. I continue to pursue research on Tiwanaku, which builds on my MA work and a collection of Tiwanaku pottery at DMNS.

**Goals for the next 5 years**

I intend to continue to grow the archaeology program at DMNS. I undertook the first substantial inclusive excavations for this institution in over two decades and will continue to push the boundaries of archaeological research and outreach by trailblazing new and innovative ways the public can participate in meaningful and hands-on ways. Work at Magic Mountain or another accessible site close to the museum will continue for several years at least. I also plan to continue work in the Reserve region.
of NM. We intend to apply for large grants for this project to grow it over the next few years. I am considering a small project in Peru in the upcoming years. I will have many opportunities to publish articles on the work that is ongoing and I look forward to doing so in well-known journals and popular outlets.

Over the next five years we will be moving the archaeology collection and I will be very involved in this process. In that massive effort I look forward to the discoveries we make in the collection and the opportunities these may bring for new research projects and collaborations. Finally, I am eager to take on more leadership roles at DMNS, in professional organizations, and in the community.

3.2. Earth Sciences

3.2.1. Ian Miller, Director of the Earth and Space Sciences Branches & Associate Curator of Paleobotany

Nature of Research

I believe it is critical to examine scientific problems from multiple perspectives, particularly as part of a team of collaborators striving to answer large questions about the history of life and how Earth has changed over the last 400 million years (the time period of terrestrial plants). As a museum curator and research scientist, I involve paleobotanical collections in nearly every aspect of my work. Overall, I aim to focus my research on questions that integrate plant phylogeny, paleoecology, paleoclimatology, geochronology and tectonics. Though the fields may seem disparate at first glance, the interaction between flora, ecosystems, climate, lithospheric processes, and mantle dynamics are intimately linked on geologic time scales. With precise and accurate geologic dates, the integration of these fields allows for investigation of long-term ecological dynamics that involve floral and faunal composition (e.g. paleoecology of dinosauria), food web dynamics (e.g. recovery of plants following the K-Pg extinction), and elevational or latitudinal gradients (e.g. Cretaceous angiosperm diversification, ecological radiation, and poleward migration; regional paleoclimate). This integration also provides key information toward deciphering the dynamics of greenhouse climate systems (i.e. Late Cretaceous through Eocene), which has become increasingly important for creating realistic scenarios of the near future in light of current warming. Finally, this approach allows for a well-rounded investigation of tectonic problems such as terrane transport, ancient plate velocities, gneiss dome emplacement, and plateau/range paleoelevation, longevity, and formation.

My research focuses on Jurassic through Eocene rocks in the Western Interior of North America and encompasses the following five tracks: (1) paleobotanical proxies for and statistical analysis of paleoclimate, paleolatitude, and paleoelevation; (2) characterization of pre-angiosperm North American ecosystems; (3) evolutionary history and ecology of Late Cretaceous and Early Paleogene plants; (4) taxonomic analysis and nomenclature of fossil floras; and (5) the tectonic evolution of the Western Cordillera of North America. Complementary methodological research seeks to (a) improve reliability and accuracy of paleoclimate proxies based on leaf physiognomy through statistical analysis of modern climate and living floras, (b) intercalibrate isotopic and fossil-based methods used to estimate paleoclimate, (c) refine existing paleobotanical techniques for estimating paleolatitude and paleoelevation and (d) standardize and advance the rapid online publication of large monographic treatments of fossil floras. For most of my research, I rely on large museum-based collections of fossil leaves. As a result, I actively promote an extensive, local field program focused in the Western Interior of North America.
Personal Research History
I first discovered geology and paleontology growing up in eastern Washington State while scavenging mine tailings for fool’s gold and pulling clams out of road cuts. I attended the Colorado College (CC) in Colorado Springs and majored in Geology. There, I received my first true taste of the spectacular geology and paleontology of the American West. While at CC, I volunteered at DMNS under Kirk Johnson (curator of paleobotany at that time), who, with Paul Myrow, advised me on my undergraduate thesis, which focused on the flora of the Early Cretaceous Winthrop Formation in Washington State. My field collections of this flora as a college student, which were later to become the focus of my PhD thesis, form one of the “significant collections” in the DMNS Paleobotany Collection. Between college and graduate school, I worked for two years as a field geologist in New Mexico. There, in the context of my work, I was fortunate enough to travel extensively in the American Southwest learning the local geology and applying that knowledge to public and private development projects.

In 2001, I began graduate school at Yale University, where I studied paleobotany and tectonics with Leo Hickey and Mark Brandon. My education there (a sort of “dual major” in paleobotany and tectonics) has allowed me to synergize paleobotany sub-disciplines as disparate as Cretaceous plant taxonomy, angiosperm leaf physiognomy, and fossil plant diversity analysis with modern climatology, lithospheric deformation and mantle dynamics. This experience for me not only highlighted many central challenges in geology but also helped me to learn that true advances in classic problems can be achieved through interdisciplinary research and collaboration. In particular, for part of my thesis, I used a novel approach to quantitatively estimate the paleolatitude of displaced terranes on the west coast of North America using fossil leaves.

During my graduate years, I maintained an extensive field program in Washington State focused on building large collections of fossil plants from numerous sites including the Winthrop, Pipestone Canyon and Ringold formations, the exploration for new fossil plant sites in the Swauk, Chumstick, and Ellensburg formations, and increasing collections at the Yale Peabody Museum of exceptionally preserved fossils by collecting, in particular, the Republic flora from the Klondike Formation.

In 2006, I began work as a postdoctoral fellow at DMNS. In 2008, I became Curator of Paleobotany; in 2010, I was promoted to Chair of the Earth Sciences Department; and in 2012, I became the Director of the Earth and Space Sciences Branch. At DMNS, I continued a broad but regionally focused field program that, in Colorado, has included quantitative collection, stratigraphic analysis, and paleoecological interpretation of fossil floras from the Jurassic Morrison Formation at Temple Canyon, the Maastrichtian through Eocene Denver Basin rocks, the Paleocene Middle Park Formation, and the latest Eocene Florissant Formation. Outside of Colorado, I have focused on the middle Eocene Wind River flora, the Maastrichtian Fox Hills and Hell Creek formations, and the Campanian Kaiparowits, Fruitland and Kirkland floras. In 2012 and 2015, in collaboration with Joe Sertich, I conducted reconnaissance fieldwork in Madagascar and collected Late Cretaceous leaves and fossil wood. My major research projects at DMNS have included studying the uplift of the Colorado Front Range; quarrying, morphotyping, describing, and analyzing the plants of the Denver, Morrison, Fruitland, Kirkland, Wind River, Middle Park, and Kaiparowits formations; leading the Snowmastodon Project Team with Kirk Johnson; and finishing the taxonomic and paleoecological analysis of the Winthrop flora started during my PhD thesis.

Goals for the next 5 years
My goals and interests for the next five years reflect my training; my past work as a paleobotanist and tectonicist; my two primary research directions in 1) Late Cretaceous dinosaur ecosystems and 2) extinction at and recovery after the K-Pg boundary; my colleague’s research directions and expertise;
and the museum’s fieldwork, preparation, and curation facilities. I plan to continue to collaborate with colleagues in the Earth Sciences while utilizing our dedicated volunteer force and regional amateur collector/donor community to collect, prepare, curate, and research exceptional plant fossils from the American West. I will continue to promote involvement of scientists and volunteers alike in existing long-term, on-going paleobotanical research (e.g. Denver Basin Project, Laramidia Project, etc.). Fundamental to my goal of building and sustaining a diverse research and collecting program is an aggressive external private and public funding strategy. Fossil collecting will be targeted and project based.

I plan to continue my work in the Western Interior of North America focused on collecting and researching the exceptionally preserved Late Cretaceous floras in Utah and New Mexico, particularly those found on the Kaiparowits Plateau and in the San Juan Basin, respectively. The work is collaborative in nature, particularly as it pertains to joint fieldwork and funding, and it falls within the more inclusive research effort to reconstruct Late Cretaceous dinosaur ecosystems at DMNS led by Joe Sertich (The Laramidia Project).

In terms of fossil plants, my work seeks to combine historical collections, climate and faunal change records, and precise and accurate geochronology, with newly collected floras to form the foundation for an updated synthesis of plant ecosystems during the Late Cretaceous greenhouse. Currently, I maintain 3-4 weeks of annual fieldwork in the Fruitland and Kirkland Formations in the San Juan Basin, and the Kaiparowits Formation on the Kaiparowits Plateau in the Grand-Staircase Escalante National Monument. I am also the external advisor for a PhD student (Sarah “Gussie” Maccraken) at the University of Maryland working on insect herbivory on fossil leaves from this time period.

In the next five years, I plan to expand my research to the contemporaneous Aguja and Wahweap formations in Texas and Utah, respectively. This research progression mirrors that of Joe Sertich and his efforts to expand the Laramidia Project footprint. As a result, it takes advantage of joint fieldwork opportunities and our ongoing internal research and funding collaboration. Finally, as opportunity arises and time allows, I also plan to conduct reconnaissance fieldwork in contemporaneous formations in Wyoming, Montana, and Mexico to prepare for the next five year phase of this research.

I plan to continue my work in the Denver Basin in west-central Colorado, which focuses on ecosystem change immediately before and after the K-Pg boundary. This project is a continuation of the 22 year-long Denver Basin Project that was initiated by Kirk Johnson and Bob Raynolds at DMNS in 1996. Currently, I co-lead this project with Tyler Lyson, who is focused on collecting and describing the early Paleocene vertebrate fossils from and the basin and interpreting the recovery of animals following the K-Pg extinction. In addition to Tyler, James Hagadorn (geology, taphonomy), David Krause (mammals), and Joe Sertich (dinosaurs, crocodiles) work on aspects of this project. While recent efforts have included fieldwork in the Corral Bluffs region to build new fossil leaf collections to answer specific questions related to vertebrate paleoecology following the K-Pg, the primary research aim for the next five years will focus on the analysis of the large and existing fossil leaf collections from the basin. This work will be complimented by targeted collection of specific and exceptionally preserved floras in the basin that may additionally help elucidate biotic patterns before and after the K-Pg. Presently, my research on the K-Pg involves serving as the external advisor to two PhD students (Christine Edwards at the Stevens Institute of Technology, and Vikki Crystal and the University of Colorado). These student’s work focuses on modeling extinction tipping points and investigating geochemical patterns across the K-Pg in Western Interior basins.

In conjunction with work on the Denver Basin flora, I plan to further develop my K-Pg research by continuing my work in contemporaneous rocks in the Williston Basin in North Dakota, South Dakota,
Wyoming and Montana (Fox Hills and Hell Creek Formations), and the Powder River Basin in Wyoming (Lance Formation). Collectively, these formations form the best continental record of ecosystems immediately leading up to and following the K-Pg extinction. As a result, research in these rocks are one of the best approaches to gaining insight into the current, anthropogenically-driven mass extinction. Finally, this research track takes advantage of joint fieldwork opportunities with Tyler Lyson including an ongoing internal research and funding collaboration.

I plan to continue to compliment my two main research and collecting efforts listed above (Campanian-aged floras in the context of the Laramidia Project; Maastrichtian/Paleocene floras and plant extinction and recovery before and after the K-Pg) with three additional research tracks that require comparatively minor collecting efforts. First, I plan to continue the long-term and opportunistic research and collecting efforts related to the Eocene lacustrine lagerstätten (Florissant, Republic and Green River) and associated floodplain floras (Wind River) at DMNS. I have been working in these areas for more than 10 years and I plan to continue this research with collaborators and volunteers. Second, I plan to continue my work to decipher the uplift history of the Colorado Front Range. This research combines temperature proxies including leaf physiognomy, isotopes, carbon chain lengths in leaf and archael bacterial lipids, and thermochronology. I started this work during my postdoctoral position at DMNS and am currently focused on analyzing herbarium collections to refine leaf physiognomic proxies to advance this research. Third, I plan to finish research related to the taxonomy and paleoecology of the Early Cretaceous Winthrop flora that was the focus of my PhD thesis. This will require collections work at DMNS and Yale University. In the context of this work, I plan reconnaissance fieldwork in contemporary formations in Nevada and Wyoming with collaborators. The fieldwork will determine if this area of research will be part of my next five year plan.

Over the next five years, I plan to remain scientifically nimble and take advantage of unanticipated fieldwork, collections, and research opportunities as they arise. One of the hallmarks of a successful and diverse research program that produces high profile science is being prepared to opportunistically pursue “high-risk and high-reward” local and international fieldwork, collections research, and scientific collaborations. The Earth Sciences Department at DMNS and its team of scientists with diverse expertise who operate on flexible, non-academic schedules, combined with lab and collections facilities and support staff, a core of trained field and lab volunteers, internal museum partnerships with Programs and Exhibits, and an aggressive private and public funding strategy, is uniquely suited to tackle “once-in-a-lifetime” research and collections acquisition opportunities. Examples of our ability to engage in this kind of research and collections acquisition include the Snowmastodon Project, the Colorado Springs Project, the Smokey Hawk King acquisition, and the *Torosaurus* discovery. In the future, I anticipate unexpected opportunities to arise and I plan to be prepared to take advantage of them as appropriate.

3.2.2. James Hagadorn, Senior Curator of Geology

**Nature of Research**

I am a broadly trained geologist whose research focuses on understanding ancient environments. My scholarship is centered in the subdisciplines of paleontology, sedimentology, and geochemistry. Through a combination of fieldwork, laboratory analyses, and collections-based work, I seek to understand how animals and microbes first colonized land, what prevegetated landscapes were like, and how the interplay of tectonics and climate influences evolution and landscapes. As a deep-time earth scientist who is also concerned about human impacts on our planet’s surface envelope, I also seek to better understand surficial earth processes and to leverage examples from earth history to facilitate informed decision-making about our future. As an interpreter of ancient earth, my research is aligned with the museum’s mission – to archive, understand, and explain our past, to communicate the relevance.
of science to the general public, and to leverage the thrill of curiosity-driven discovery to inspire an informed public and the next generation of scientific thinkers.

Personal Research History
My past and anticipated research is divided into four realms of inquiry, all of which I hope to pursue in the coming five years. Key questions I am involved in addressing are:

1) What triggered the appearance of animals and the onset of biomineralization? Some 500-550 million years ago, each of the major groups of shell-building animals appears in an ocean-scale bloom, and then goes extinct. This pattern suggests that a genetic, ecological, or environmental mechanism may be triggering their abrupt appearance and disappearance. In tandem with field-based environmental and geochronological analyses of sedimentary rocks that house these fossils, I have used X-ray CT and petrography to understand the growth and chemical evolution of these fossils. Preliminary work suggests that perturbations in ocean chemistry did not cause these biomineralization events.

2) Why & how did animals colonize land?: Marine animals appear to have colonized land shortly after they appeared in the oceans, yet we do not know what anatomical or behavioral strategies they employed to withstand the vicissitudes of subaerial exposure, and why they made their initial forays across tidal flats and coastal dunes. Initial work suggests that the first terrestrial pioneers were scorpion-like and slug-like animals that grazed microbial mats in protected, low-energy, low-relief episodically emergent sand flats and associated tidepools.

3) What did prevegetated coastal systems look like and what processes controlled their development? These sandy coastal systems are common in Earth history during times of high sea level, and produce thick packages of sediment that are important oil, natural gas, and water reservoirs. Yet we know very little about what these coastal systems looked like, how they were impacted by tides, waves, and wind, and what processes facilitate their lateral and vertical migration such that they build wedges of sediment thick enough to become substantial rock reservoirs.

4) How do microbes affect landscapes?: Although there has been much progress made on identifying microbial structures in ancient sandstones and identifying modern analogues for these structures, no one has produced any of them in the lab. Thus, we have no idea what suite(s) of conditions control the formation of these structures. Moreover, most of the basic experimental sedimentology work that all geologists use to estimate flow velocities is flawed because it was conducted on sterile sediments. Yet microbes are ubiquitous in every wet environment on Earth – today and in the past – and they secrete sticky substances that dramatically affect the way grains of sand can be moved by physical transport processes. My pilot studies done in a microbe-inoculated laboratory flume confirmed this supposition, and suggests that microbes have the potential to control the evolution of entire landscapes – including not only ancient marine landscapes but modern terrestrial settings like those in Colorado.

Goals for the next 5 years
My research goals for the next five years center on completing three regionally-relevant projects aimed at deciphering the geologic history of ancient western North America. The first project involves studying Ediacaran-Cambrian basalts of western North America to test the hypothesis that rifting of the western Laurentian continent facilitated animal diversification during the Cambrian explosion. The second project leverages Late Devonian outcrops of western Colorado to determine if and/or how regional reef systems were affected by the Famennian mass extinction event. The third project aims to leverage subsurface outcrops of the little-studied Lykins Formation of the Front Range region to determine if the record of the Permian-Triassic mass extinction is preserved in Colorado and if so, how the region changed through this biotic pinch-point. Sufficient pilot data exists to suggest these goals are accomplishable, and over the next five years I intend to continue work with our team of community scientists and collaborators to address these knowledge gaps.
3.2.3 David Krause, Senior Curator of Vertebrate Paleontology

Nature of Research

I have long believed that the greatest impacts in my chosen discipline — paleontology — can be made through discoveries in the field, largely because only a tiny fraction of past life is represented in known fossil collections and because so many places remain unexplored and so many past time intervals remain unsampled. In essence, my field- and specimen-based research has been driven by two primary factors: questions and opportunities. The early part of my professional career was focused on documenting changes in the composition of mammalian faunas during the Paleocene, after the devastating K-Pg mass extinction, in an attempt to determine the drivers of such changes. To that end, in the early 1980’s, I seized upon the opportunity to resurrect a long-dormant field program in the Crazy Mountains Basin of south-central Montana, following in the large footsteps of George Gaylord Simpson’s work in the 1930’s. Then, in 1993, came the opportunity to conduct fieldwork in Madagascar, a massive island (more than twice the size of Colorado) off the southeast coast of Africa that fascinated me because of its unique biota, which contains an overwhelming majority of plants and animals unknown from anywhere else in the world. When and how did the terrestrial and freshwater animals and plants get there? From where did they come? Was there evidence of progressive isolation of the biota that matched the physical isolation of the island as the southern supercontinent Gondwana fragmented into the major landmasses we know today? These were questions that I felt could be addressed through the discovery of fossils. Here again, I seized upon the opportunity of the island being more open to scientific exploration as it transitioned from authoritarian rule to an admittedly unstable democracy in the early 1990’s. Not in my wildest dreams did I envision the successes we would have there . . . . even though we did not find direct evidence to conclusively resolve some of my initial questions. Such is the exciting, serendipitous nature of paleontology (and, oftentimes, science in general)!

My research program over the last 25+ years has focused heavily on the biogeographic and plate tectonic history of Gondwana through the window afforded by discoveries made in the Late Cretaceous of Madagascar. Although primarily a mammalian paleontologist, I have taken the opportunities provided by our discoveries to also work on fishes, frogs, turtles, lizards, snakes, crocodyliforms, non-avian dinosaurs, and birds. Much effort has been placed on recruiting experts from around the world in this work and on training students, both American and Malagasy. My field research programs have been conducted on large scales, with large field teams and for extended durations. In an effort to comprehensively reconstruct aspects of paleoenvironment and paleoecology, we have collected all identifiable fossils through a variety of methods (surface collecting, quarrying, scree ning [both wet and dry]) and amassed data that allows us to place fossils in appropriate geological context. Lab work includes complementing traditional approaches by maximizing the advantages of recently developed 3D imaging techniques to reveal anatomical structure, work that is now conducted here in the DMNS Digital Research Lab.

Personal Research History

As a young child, and even as a teenager, I assumed I would be a cattle rancher. I grew up on a ranch in southeastern Alberta, Canada, in the middle of nowhere, and started my education in a one-room schoolhouse that my four brothers, my sister, and I got to in a horse and buggy. I was pretty oblivious to anything at all in the world of paleontology — I doubt I even knew what the word “fossil” meant — until one Sunday, when I was maybe 10, the grain elevator operator from the closest small town came by and asked my father if he could take me to look for dinosaur bones on our land, in the breaks of the South Saskatchewan River. I found a cervical vertebra of a hadrosaur that day (which I still have) and must admit that it intrigued me to no end. It opened up a new world to me. But the possibility of
embarking on a paleontological career didn’t really enter my head until the summer after my freshman year in college, at the University of Alberta, when a young professor by the name of Richard Fox took me on as a field hand, something for which I will be forever grateful. I was hooked. The opportunity to live and work in the great outdoors coupled with the thrill of discovering animals long extinct seemed like an unbeatable combination. It still does today and I’m as "pumped" about it now as I was then, perhaps even more so.

My journey took me through Bachelors (1971) and Masters (1976) degrees in Zoology at the University of Alberta, with a couple of gap years (teaching at the University of Alberta and doing fossil preparation at the Manitoba Museum), and a Ph.D. (1982) in Geology at the University of Michigan under the supervision of Philip D. Gingerich and, along the way, fieldwork in Alberta, Saskatchewan, Manitoba, Wyoming, Montana, Kansas, and Pakistan. Fresh out of grad school, I landed a job as Assistant Professor in the Department of Anatomical Sciences at Stony Brook University in Long Island, New York, where I remain a Distinguished Service Professor Emeritus. While teaching human anatomy to medical and dental students there for 34 years, I also had the opportunity to develop two field research programs, first in the Paleocene of the Crazy Mountains Basin in Montana and then, beginning in 1993, in the Late Cretaceous of Madagascar. I also had the good fortune of being able to train a number of outstanding graduate students, many of whom have gone on to highly successful academic careers and one of whom, Joe Sertich, is now the Curator of Dinosaurs here at the DMNS.

In 2016, I joined the DMNS Department of Earth Sciences, excited to become a part of such a strong and dynamic research team with similar approaches and strategies to scientific discovery. With the groundwork laid by Curator Joe Sertich, I brought the massive collection of Late Cretaceous vertebrate fossils from Madagascar with me. This collection continues to be the primary focus of my current research and that of researchers from around the world. Several of the fossils in the collection have already also served a prominent role in DMNS exhibitions (e.g., the temporary exhibit "Ultimate Dinosaurs").

Goals for the next 5 years
We have only begun to reveal the fossil riches of Madagascar. My primary goal is to lead the long-term Madagascar Paleontology Project into the future, along with my departmental colleague Joe Sertich and other researchers at other institutions (e.g., Patrick O’Connor, Ohio University; Ray Rogers and Kristi Curry Rogers, Macalester College; Alan Turner, Stony Brook University). This will entail publication in leading science journals and continued pursuit of extramural funding. The Madagascar collections made over the last 25+ years, which includes approximately 20,000 specimens, many of which are beautifully preserved skulls and skeletons of everything from giant frogs to both tiny and massive dinosaurs to bizarre crocodyliforms, birds, and mammals, are now here at the DMNS. By agreement with the Malagasy government, half of these collections have been accessioned into the DMNS collections while the other half will be returned to Madagascar after the specimens have been prepared and studied. My goal over the next five years, in addition to continuing to conduct targeted research on this collection along with colleagues, staff, and students, is to fully curate it.

I also plan to revitalize my earlier work and stimulate interest from other researchers, including my departmental colleagues Ian Miller and Tyler Lyson, in the Crazy Mountains Basin of Montana. This work, focused on the middle and late Paleocene, will also involve non-DMNS colleagues at Duke University (Doug Boyer), the University of Florida (Jon Bloch), and the University of North Alabama (Greg Buckley). A related goal in analyzing the recovery after the K-Pg mass extinction is to assist my colleagues Tyler Lyson and Ian Miller in uncovering the mysteries of early Paleocene mammalian evolution as revealed by their Denver Basin Project. This will largely entail providing expertise on certain
mammalian taxa (e.g., multituberculates) on which I have conducted research in the past (including as part of my graduate work).

I also will strive to ensure the long-term success of the DMNS Digital Research Lab, which I founded in 2017. Digital imaging and visualization from microCT and other scanning modalities have become commonplace in paleontological research and we are fortunate to have developed a state-of-the-art facility here at the DMNS, headed up by lead technician Lindsay Dougan. This facility has already contributed fundamentally to research in the Research and Collections Division but, in particular, to investigation of anatomical structure in fossils.

Finally, my overarching goal is to be recognized as a team player by continuing to work collaboratively with my departmental colleagues in conducting research and curating collections, as well as contributing to outreach efforts, and, in the process, building even stronger relationships with my fellow employees throughout the DMNS. I am committed to helping to raise the profile of the DMNS as a whole and the Department of Earth Sciences in particular into a top-tier research institution. I firmly believe that it is well positioned for this goal because of the outstanding abilities and dedication of the curators, the exceptional fossil preparation (both mechanical and digital) and collections management staff, and the strong community of support in the form of volunteers, interns, and teen science scholars. It is a unique institution with unlimited potential.

3.2.4 Tyler Lyson, Associate Curator of Vertebrate Paleontology

Nature of research
Broadly speaking, in terms of scholarship I am interested in specimen-based research in evolutionary vertebrate biology that integrates detailed descriptions of vertebrates, hypothesis driven fieldwork (neontological and paleontological), and phylogenetic analyses that incorporate both morphological and molecular data from several biological sources (e.g. soft tissue, osteological, developmental, microRNAs, genomes, etc.) with geochronologic and sedimentology data. The greatest natural history scientists (e.g. Charles Darwin, Louis Agassiz, etc.) were trained in several disciplines, and I have followed their lead by striving to become a broadly trained scientist. As a museum curator and research scientist, a primary goal of my research is to publish papers in peer reviewed journals while building a carefully curated collection of vertebrates complete with detailed sedimentologic and geochronologic data that will be useful for future generations of scientists.

My research can be broadly categorized into three major themes: 1) phylogenetic origin of turtles and the evolutionary history of their unique body plan, particularly their shell, shoulder girdle, and anapsid skull; 2) radiation of modern turtles from the early Jurassic to present; and 3) analysis of the timing and tempo of the Cretaceous/Paleogene (K/Pg) extinction and subsequent recovery (~first 1 million years post-extinction). All of my research relies on museum-based collections and as a result I actively promote field programs, particularly those in the Western Interior of North America, which help me address my research questions.

Personal Research History
Some of my earliest childhood memories include hiking through the Hell Creek badlands in search of vertebrate fossils. When I was 12 years old I started working for various visiting scientists, including Drs. Kirk Johnson, William Garstka, Robert Deaton, etc.), during my summer vacations. My love for paleontology led me to Swarthmore College where I majored in Biology (class of 2006), as paleontology is at the intersection of biology and geology. Here I worked with Dr. Scott Gilbert on developmental biology questions, particularly those related to the developmental origin of the turtle shell. In addition, my first year at Swarthmore College (2003) I created the 501c3 not for profit Marmarth
Research Foundation to continue to promote scientific research, public outreach, and to continue to collect scientifically important vertebrate fossils from the Hell Creek and Fort Union formations of southwestern North Dakota and eastern Montana. This collection was permanently transferred to the DMNS in 2015 and has resulted in 19 peer-reviewed publications (18 of which I authored or coauthored), two undergraduate theses, and one master's thesis, and these data continue to play a significant role in my ability to address research questions 2 and 3 (listed above).

In 2006 I began graduate school at Yale University where I studied vertebrate paleontology, comparative anatomy, and phylogenetic systematics with Dr. Jacques Gauthier. After graduating in 2012 (Geology and Geophysics) I worked with Dr. Kevin de Quieroz in the Department of Zoology as a Peter Buck postdoctoral researcher at the Smithsonian Institution. Throughout my training I believe that the integration of diverse datasets allows progress on recalcitrant problems to be made. Much of my past research focused on such difficult questions.

Much of my earlier work involved detailed descriptions of extinct turtles and understanding their phylogenetic history with the broad goal of elucidating turtle diversity in the very latest Cretaceous and earliest Paleocene, as a means of understanding the response of turtles to the K-Pg extinction event – the extinction that wiped out non-avian dinosaurs 66.021 mya. The meteorite impact, thought to be the cause of this extinction event, caused extreme environmental disturbance, but turtles remained relatively unaffected. In fact, throughout the long history (270 Ma) of this group, turtles have persisted through multiple extinction events (Permian/Triassic, Triassic/Jurassic, Cretaceous/Paleocene, Paleocene/Eocene, etc.) when other major groups suffered huge losses or became extinct. That is, until now turtles have thrived. It is not commonly known that turtles have been around longer than dinosaurs, flourished across major extinctions caused by asteroid impact or extreme global warming, yet are currently being driven to extinction by the pet trade and human consumption. The International Union for Conservation of Nature lists 47% of turtle species as endangered, while 27% are listed as critically endangered. The strategy of showing the longevity and success of turtles throughout the last 270 million years compared with how the group is doing today effectively conveys the severity of our current environmental disturbance. I have recently made this a focal point of a number of public talks, and will continue to do so in the future.

During the course of my graduate and postdoctoral career, observations made during my earlier turtle diversity studies matured into questions surrounding the origin of turtles and the evolutionary origin of their unique body plan. Prior to my work, very little was known about the evolutionary history of some of the bones that makeup the complex turtle shell, when the initial transformations of the shell occurred, the order in which various components of the shell were assembled, and how and when the novel abdominal muscle based lung ventilation mechanism found in extant turtles evolved. Turtle evolution is now a hot research topic and full of intriguing and unanswered questions. My current research addresses each of these questions by integrating a wide array of data sets including developmental and molecular data, soft tissue, histology, and osteology, with data from the fossil record. While I have contributed to each of my research questions by publishing five or more scholarly articles on each topic, I plan to continue my collaborative and multidisciplinary research to better understand these complex problems.

Goals for the next 5 years
My goals are ultimately to become a well-respected paleontologist worldwide, while also being regarded as a good teammate and useful colleague to the broader DMNS team. Over the course of the next five years I will strive to balance building the most useful vertebrate collections (in collaboration with other DMNS curators) centered around my research questions listed above, publishing papers on
my three research questions, and having a presence here at the DMNS where I can continue to build relationships across departments and divisions.

Collections: I plan to work with other DMNS curators/staff to systematically build a large comprehensive collection. I believe strongly in fieldwork oriented research and would like the collection I help build be one of my lasting legacies. Over the course of the next five years I plan to continue to carefully build collections around research questions 2 and 3. I will focus on two different field areas: Hell Creek and Fort Union formations of southwestern North Dakota and eastern Montana (Williston Basin) and the Denver Basin in Colorado. The rocks in these two research areas are the best place in the world for studying earth’s last major extinction event, the Cretaceous/Paleogene (K/Pg) extinction, and subsequent recovery. In addition, the DMNS currently has a strong paleobotany collection from these field areas, thanks to the work of former DMNS curator Dr. Kirk Johnson and Dr. Ian Miller. I plan to integrate the vertebrates with the plant fossil record, all within a tight chronostratigraphic framework to look at the tempo and cause of the extinction, as well as the timing of the subsequent recovery. Combined, these collections will be the most robust dataset for addressing extinction and recovery patterns on land, questions that are broadly interesting and relevant today, considering many scientists believe we are currently entering into earth’s 6th mass extinction.

I plan to complement my two main research efforts listed above with an additional research area: Powder River Basin, Lance formation in Wyoming. Like the other research areas, the Powder River Basin preserves the K/Pg boundary and one of the best fossil assemblages during the very end of the Mesozoic Era. While most museums have fossils from the Lance Formation, very little research and professional collecting has been conducted in this area over the past century. I plan to work with Research Associates, John Hankla and Dr. Antoine Bercovici, to collect vertebrates within a tight stratigraphic framework to look at patterns of extinction. In addition, this collecting effort will build off a recent major donation from Mr. Hankla of fossil Edmontosaurus bones from the Powder River Basin. By placing this collection, as well as all other fossils collected, within a stratigraphic framework I hope to help build a third complementary dataset to the Williston and Denver Basins in which to study patterns of K/Pg extinction and recovery.

Throughout my collections work I will collaborate with colleagues in the Earth Sciences while utilizing our dedicated volunteer force to collect, prepare, curate, and help research the vertebrate fossils from the American West. In addition, I will continue to promote involvement of a diverse and international group of scientists and students in the fieldwork, collections, and research. Presently, my research on the K/Pg involves serving as the external advisor to one PhD student (Vikki Crystal at the University of Colorado, Boulder) and two Master’s students (Anthony Fuentes at the University of New Hampshire and Yann Rollot at the University of Fribourg, Switzerland).

Research: I plan to continue my research in the Permian/Triassic rocks of the Karoo Basin in South Africa looking at the early evolution of reptiles. Molecular studies suggest that modern lepidosaurs, turtles, and archosaurs diverged in the middle Permian to early Triassic and South Africa has the best fossil reptile record in the world from this important interval of time. Here over the past 10 years I have developed collaborations with scientists throughout South Africa (Drs. Bruce Rubidge, University of Witswatersrand; Roger Smith, South African Museum; Jennifer Botha-Brink, State Museum of Bloemfontein) where we have looked at the origin of turtles and evolution of their boney shell and unique respiratory system. I plan to continue these collaborations and expand my studies to the origin of other reptiles, including lepidosaurs and archosaurs. I plan to CT scan important fossil reptiles housed in South African museums and analyze them, in collaboration with Dr. Gaberiel Bever (Johns Hopkins University School of Medicine) and his students, in a broad phylogenetic context. By doing so I hope to continue
to make important contributions on the phylogenetic relationships of reptiles and the origin of their body plans (research question 1 above).

Additionally and in order to address research question 1, I plan to continue to collaborate with molecular systematists in order to synthesize the extant/fossil morphologic and molecular datasets that currently disagree on the phylogenetic placement of turtles. I will continue to critically analyze the morphological data (in collaboration with Dr. Bever) and develop new datasets, such as the cardiovascular system (in collaboration with Dr. Emma Schachner, Louisiana State University), to determine if synapomorphies exist for a turtle-archosaur clade as hypothesized by robust molecular data. I will also work with molecular systematists (in collaboration with Dr. Allison Hsiang, Lund University) to use phylogenetic models employing rarely used (but important) parameters to further test the turtle-archosaur hypothesis. I am confident that by continuing to operate in a collaborative multidisciplinary framework and continuing fieldwork in the Middle/Late Permian to early Triassic (Karoo Basin, South Africa), I will continue to make important strides in resolving the origin of the turtle body plan and the placement of turtles among amniotes.

Regarding research questions 2-3, I plan to analyze North American fossil turtles, clade by clade, and integrate data from under studied basins (Denver, Powder River, etc.) to get a broader understanding of the evolution of North American turtles. I am particularly interested in tracking turtle biodiversity through the late Cretaceous to end Eocene of North America and placing each species within a phylogenetic context (in collaboration with Dr. Walter Joyce, University of Fribourg) to determine the response of turtles to the K/Pg boundary and the Paleocene/Eocene thermal maximum. Prior investigations did not take phylogeny into account, ignoring “ghost” lineages, used fragmentary material, and were often limited to the Williston Basin with a focus on eastern Montana.

Throughout my research I will balance broad synthetic papers with more nuts and bolts alpha taxonomy papers. While the latter is not as splashy, I strongly believe as a museum scientist it is important to publish well-illustrated papers on the alpha taxonomy and systematics of the fossils we collect. Such papers generally have a much longer impact than most theoretical papers (e.g. the descriptions and illustrations of specimens described 50+ years ago are generally much more useful than their theoretical considerations). Thus in addition to one larger synthetic paper, I will strive to publish 2-3 alpha taxonomic/systematics papers each year.

3.2.5 Joseph Sertich, Associate Curator of Dinosaurs

Nature of Research

I am a broadly trained vertebrate paleontologist focused on global- and continental-scale patterns of terrestrial macroevolution during the Mesozoic through the application of a wide variety of approaches including systematics, paleoecology, tectonics, and sedimentology. Generally, I seek to understand how vertebrate evolution has been influenced by deep-time factors including tectonics, climate, and sea-level fluctuation. Specifically, I employ a combination of fieldwork and specimen/collections-based work to elucidate patterns of morphological and evolutionary change in a variety of terrestrial vertebrate clades with particular emphasis on archosaurs (e.g., dinosaurs, crocodyliforms, and pterosaurs). In order to accomplish this, I employ a number of methodological approaches including morphometric analysis, phylogenetic systematics, biogeographic analysis, 3D morphological approaches, and classical anatomical description.

My current research focuses on the evolution of Cretaceous terrestrial ecosystems and can be divided into two primary areas: (1) understanding patterns of vertebrate distribution and the influence of climate and sea-level on ecosystems in western North America (Laramidia) during the Upper Cretaceous
(Turonian-Maastrichtian), and 2) understanding the influence of the Cretaceous breakup of Gondwanan landmasses on the evolution of terrestrial vertebrates.

Personal Research History
My paleontological research experience began at Colorado State University, where I majored in Biological Sciences, Zoology, and Geology. Prior to graduating, I conducted a paleontological survey of the Eocene Green River Formation in the area around Flaming Gorge Reservoir, Wyoming on behalf of the USDA Forest Service. The fossil fauna and flora recovered during this survey ignited my passion for fossils, and solidified my desire to pursue a career in paleontology.

In 2004, I began my graduate studies at the University of Utah/Natural History Museum of Utah where I studied vertebrate paleontology and taphonomy under Scott D. Sampson. Immediately prior to enrolling, I was fortunate to join a brief reconnaissance expedition to dinosaur-bearing sediments in northern Turkana, Kenya. The diverse but fragmentary vertebrate fossils recovered on this expedition became the subject of my Master’s thesis and fostered my interest in Gondwanan plate tectonics and terrestrial evolution during the Cretaceous. While at Utah, I also became extensively involved in fieldwork and research in the Kaiparowits and Wahweap formations of Grand Staircase-Escalante National Monument and in fieldwork investigating the Late Cretaceous of Madagascar.

In 2006, I began my PhD research at Stony Brook University as part of the then newly formed Turkana Basin Institute and under the supervision of David Krause. While at Stony Brook, my research focus shifted substantially toward understanding crocodyliform systematics and applying vertebrate paleontology to historical biogeography. Recent vertebrate finds, particularly from Madagascar, had thrown into question the timing and sequence of Gondwanan fragmentation. However, substantial gaps in the terrestrial fossil record of Gondwana made hypotheses surrounding this question impossible to address. In order to begin filling some of these gaps, I continued my field research in Kenya and began additional collaborative field research. This included the search for older fossil-bearing Cretaceous deposits in Madagascar, assisting with fieldwork in the Cretaceous of Tanzania in collaboration with Patrick O’Connor (Ohio University), the initiation of collaborative fieldwork in the Cretaceous of Egypt with Hesham Sallam (Mansoura University), and participating in Cretaceous research in Antarctica. Presently, both the Madagascar and Kenya endeavors continue to be the focus of my work in the southern Hemisphere targeting global-scale biogeographic patterns related to plate tectonics.

I also became interested in questions surrounding continental-scale controls on biogeography through my early work in the Kaiparowits Formation of Grand Staircase-Escalante National Monument, southern Utah. The Western Interior of North America preserves an unparalleled record of terrestrial evolution through much of the Upper Cretaceous, a record largely influenced by orogenic events and fluctuations in sea-level, culminating with the terminal Cretaceous mass extinction. The response of terrestrial ecosystems to orogenic and sea-level driven perturbations, and their effect on the evolution of many archosaur groups including dinosaurs and crocodyliforms, is currently my primary area of interest.

I joined the DMNS in 2011 as Curator of Vertebrate Paleontology with the intent of pursuing these same research questions and expanding my research into the Western Interior of North America. While at DMNS, I initiated the Laramidia Project, a large-scale field research effort focusing on the Campanian of western North America primarily focused on the Kaiparowits and Wahweap formations of southern Utah and the Fruitland and Kirtland formations of northwestern New Mexico. I have also continued my international research and collaborations, including fieldwork and research in the Cretaceous of Madagascar.
I have overseen significant growth in the DMNS vertebrate paleontology collections through my own field collecting and also through relationships with external researchers and field collectors. This includes acquisitions of several significant and large vertebrate collections through donations (e.g., the Hankla Family Collection of Lance Creek Fm dinosaurs), transfers of unaccessioned collections (e.g., Madagascar Cretaceous Collection, Rose-Willwood Collection), and partnerships with field collectors (e.g., Sandy Site Hell Creek Fm collection-Triebold Paleontology Inc., Kaycee Morrison Fm dinosaur collections-Chris Weege and David Schmude). These important collections will be preserved in perpetuity for researchers and students, and many are appropriate for future exhibition.

Goals for the next 5 years
In the next five years, I intend to focus my research objectives in the western United States and Madagascar to maintain a top-tier paleontology program at the DMNS. In particular, I plan to utilize the strong DMNS volunteer program and exceptional preparation and curation facilities to acquire, process, and conduct research on remarkable vertebrate fossils. Aggressive and creative pursuit of external funding will be utilized to sustain and expand existing and future research endeavors. In addition, I plan to continue to collaborate with colleagues in the Earth Sciences Department and beyond to pursue well-rounded, cutting-edge research into fossil ecosystems. Fundamental to my goal of building and sustaining a strong dinosaur paleontology program is to establish DMNS as the premier field and collections-based institution in western North America. Fieldwork will be research driven and project/funding based, and will focus on:

- Continuation of the long-term, collaborative Laramidia Project, investigating the evolution of terrestrial ecosystems during the Upper Cretaceous (Turonian-late Campanian) of western North America, a period of isolation on the hothouse landmass of Laramidia. This project will focus on the exceptional fossil record of the Kaiparowits Plateau of southern Utah and the San Juan Basin of northwestern New Mexico, but may also expand to include fossiliferous Cretaceous localities from elsewhere in Colorado, Utah, and Texas, and potentially as far afield as Mexico.
- Continue collaborative work in Cretaceous deposits of Gondwana to address biogeographic and phylogenetic questions. This includes the systematic exploration for, and collection of, Cretaceous vertebrates from Madagascar as part of the long-term Madagascar Paleontology Project.

I will continue to foster relationships with non-academic paleontologists including “commercial” paleontologists, field collectors, and avocational paleontologists to explore mutually beneficial and creative ways to bring significant specimens to DMNS for research and permanent preservation. I will also continue my support for the unequaled DMNS volunteer paleontology program with emphasis in fieldwork, preparation, collections, and research efforts.

Over the next five years I will also support the reorganization and rehousing of fossil vertebrate collections in the Avenir Collections Center. This will include overseeing specimen preparation, rehousing/cradling, specimen identifications, and cataloging. I will also continue to support temporary exhibitions, modifications to content in permanent exhibitions, and DMNS Initiatives requiring paleontological insight and expertise.
3.3. Health Sciences

3.3.1. Nicole Garneau, Department Chair & Associate Curator of Human Health

Nature of Research
Evolution has led to genetic variation in flavor-related genes, specifically in genes that may have played a role in natural selection such as the ability to taste bitter and sweet substances. The variations we see in genetic profiles are likely associated with where ancient ancestors lived, as the availability of flora and fauna differs throughout the world. As flavor continues to be the number one reason for food selection, taste also is a key variable in the health of individuals and populations in the 21st century. My research utilizes crowdsourcing to 1) document taste variability across the population 2) identify if there is a genetic underpinning from the observed variation (heredity) 3) assess the single nucleotide polymorphisms in specific genes found to be associated with variation.

Personal Research History
The idea of genetics was fascinating to me at an early age, and a career that I set forth to pursue beginning at Rutgers College, where I completed my B.A. in genetics. I also conducted four years of undergraduate research in the genetics laboratory of Dr. Stuart Peltz at the University of Medicine and Dentistry of New Jersey. My work centered on yeast genetics and determining how post-transcriptional control at the level of messenger RNA decay played a role in the highly regulated process of gene expression. For these studies, we used the eukaryotic model system of Saccharomyces cerevisiae, commonly known as brewer’s yeast. My undergraduate research culminated in a second-author publication, which showed that post-transcriptional control greatly affects final gene expression in the form of active cellular proteins. Additionally, my experience in post-transcriptional gene control led to a year of industry experience at the biotech company, PTC Therapeutics. There I worked within translational research, on a project centered testing the effect of small molecules on regulating aberrant post-transcriptional control—the cause of certain genetic diseases such as cystic fibrosis and hemophilia. This experience heightened my awareness of the bioscience industry, and introduced me to the business and communication side of science and health-related research.

My positive experience as an undergraduate in both academia and in industry in the field of RNA research led to my decision to attend graduate school. To stay within the field of translational research, I completed my dissertation in the sub-discipline of RNA virus genetics. Specifically, I sought to understand the role that messenger RNA decay plays in the ability of a host cell to defend itself against infection by an RNA virus. As this was a hitherto unstudied arena, I developed assays to specifically answer the questions posed in my graduate work, namely how to track the rate of RNA decay of RNA viruses in vivo. My research became interdisciplinary as it brought together the fields of RNA decay and virology, and my work was well received from both sides opening up a new genre of RNA research. Working with a pathogenic virus and host interactions made me revisit my original desire to work in human genetics, and influenced my decision to join the Museum in 2009, to lead the newly built Genetics of Taste Lab.

Since that time, nearly a decade now, I have taken the proposal of community science from an idea to a reality. Our pilot test ran 4 years as we explored if it was even possible for a non-medical, and informal science education setting, to compete with academics in sensory and population genetics research. With the success of our seminal publication in 2014, both in citations and in domestic and international media coverage, we knew that we had a model that would work. A series of studies followed. In each we tweaked our model to best serve both the research aims and our community commitment (including our community scientists, previously called citizen scientists, and our crowdsourced guests as human participants).
Briefly, these studies included:

- **2013-2015 Fatty Acid Taste Study** (2 years, 1K samples) providing population data to support the hypothesis that fat is the 6th taste.

- **2015-2016 Sweet-tasting Study** (9 mo., n= 1K) to assess the role of the oral microbiome in sweet detection and preference; The **2016-2017 Science of Sour Study** (9 mo., n= 1.7K) data collected and need to fundraise 100K for GWAS to determine associated genes with sour taste; The **savory and Sour Study** (9 mo., est. 1.5K).

- **2018-2019 Genes and Grains** (9mo, est. 1.5K) in planning.

- **2019-2020 TBD** in planning, will follow same model of open RFP to possible collaborators, applications open through Dec. 31, 2018. Curator to assess for scientifically sound and aligned with lab mission NS research goals. Feasibility team of community scientist led by the research manager to review applications and score. Community scientists as a whole to vote on which project to bring in for that year’s annual study. Community Scientist design team to draft script and mock up props for marketing and exhibits work orders and ultimately IRB submission. Study will begin week of Thanksgiving 2019, and run through August 2020.

In addition to the longer-term lab based studies, the team has begun piloting crowdtasting research events (through partnership with Museum Program and the Beer & Food Working Group). These sessions include scientific based design, approval from IRB to collect data from human subjects, and serves to begin to assess the complexity of flavor interactions in complex matrices (like food and drink) and how this affects taste perception and food choice. The impetus for this model is the lack of connectivity between high controlled lab studies on the flavor assessment of specific molecules to real life setting. The model was first prototyped in 2016 as a proof of principle. The model was changed for logistics and to introduce tighter control over variables and then piloted with IRB approval in 2017, with analysis currently in progress.

**Goals for the next 5 years**

With proven community research models in both the lab and in the crowdtasting events, the team has a strong foundation for continuing to conduct research. The challenges to be addressed in the next 5 years include:

- Ethically releasing data that is complete for open access
- Expanding/franchising the model of the lab to other community research organizations both domestically and internationally in order to both collect bigger and more diverse data sets and to expand community participation in authentic research that is applicable to people’s everyday lives.

**3.4. Space Science**

**3.4.1. Ka Chun Yu, Department Chair & Assistant Curator of Space Sciences**

**Nature of Research**

My research interests have turned back towards star formation in recent years. Following work with a collaborator on near-infrared spectroscopy of massive young stars at the heart of the W40 cloud, I have been characterizing the extended W40 star cluster by using wide-field, near-infrared surveys for finding young stars. I used photometry from the UKIDSS Galactic Plane Survey to create extinction maps of the region, and found clumps of sources away from the main cluster core by looking at K-band excess above a theoretical stellar background. I am extending this technique further east of W40, to a band just north of and parallel with the galactic plane, where we are seeing hints of isolated, previously unknown locations of star formation.
Personal research history
Although trained as an observational astrophysicist who studied outflows from young stars in star forming regions, I was hired at DMNS as a scientific visualization interpreter and developer, helping to write real-time visualization software for the Gates Planetarium, which was undergoing renovation at the time. This experience gave me the opportunity to develop a realistic virtual simulation of the solar system and galaxy. After moving into the Research & Collections Division, I wanted to continue to use these skills not only to improve the types of outreach that is possible with digital domes, but also to study how to use this relatively young medium to impact audiences.

My first research project at DMNS looked at how computer-generated immersive virtual environments could be used to teach astronomy. The long-term study involved 975 students from 17 undergraduate classes at Metropolitan State University of Denver from 2006-2010. The project activities included categorization and identification of astronomical misconceptions from student interviews; and the development of new curriculum materials for the digital planetarium. Our team has published on student misconceptions of orbits and Kepler’s Laws, as well as how immersive visualizations shown in the digital planetarium are more effective than classroom visualizations for the topics of seasons, moons in the solar system, and scale of the solar system.

Goals for the next 5 years
The Aquila Rift is a large region of the sky encompassing several constellations that hug the plane of the Milky Way, including Aquila, Serpens, and eastern Ophiuchus. Although the dark clouds in the Rift appear similar to other clouds elsewhere close to the galactic plane, there are only two significant star forming regions, Serpens and W40. Both these clusters are located close to each other at the western end of the Rift, and both have been and continue to be subjects of investigation by multiple groups. However, it is a mystery as to why there is a paucity of star formation within the larger Rift, with only a handful of known locations with young stars at the eastern end of the Rift.

My current investigation of W40 and neighboring star forming regions just to its east offers a follow-up opportunity to examine the larger Aquila Rift region for star formation activity. Using newer, deep, large-scale archival surveys in the near-, mid-, and far-infrared, we can look for star formation that has been missed by earlier researchers. Coupling the infrared observations with mapping at millimeter wavelength CO (carbon monoxide) lines, we can try to understand the structure and dynamics of the cold molecular gas in these regions. Follow-up high-resolution imaging and low-resolution spectroscopy of newly identified young stellar objects will allow us to characterize individual members of young clusters, including their radial velocity motions. Aggregating imaging and spectral data together for the region as a whole will give us insight into the relationships between the bulk gas and young stars, and perhaps give us a better understanding of how and why the Aquila Rift clouds have the level of star-forming activity that they currently possess.

3.5. Zoology

3.5.1. John Demboski, Director of the Zoology & Health Sciences Branch, Department Chair & Senior Curator of Mammals

Nature of Research
I am an evolutionary biologist and more specifically, a field biologist/molecular phylogeneticist that studies small mammals. My research program is firmly grounded in fieldwork conducted primarily in the western North America and relies heavily upon museum research collections, including DMNS and other museums. Fieldwork is combined with molecular approaches (more recently genomics),
morphological data, and informatics to address questions concerning evolutionary relationships, phylogeography (genetic variation over geography) and mechanisms of speciation and divergence in small mammals. More recently, I have also moved into molecular studies of mammalian parasites addressing questions of codivergence between hosts and parasites.

My research program follows in the footsteps of traditional museum-based evolutionary biologists such as Joseph Grinnell and Ernst Mayr in that I use natural history collections for research, education, and solving biodiversity problems. In addition, recent advances in genomics and informatics have spurred a wealth of new, innovative uses for museum collections and my research program is in step with these advances. My emphasis on research questions based in western North America compliments the DMNS focus on the Rocky Mountain region, and thus has relevance to biodiversity issues in Colorado and surrounding states.

**Personal Research History**

The broad questions that I have been addressing over the past 20 years are: 1) What can be inferred about the role of historical or contemporary processes, such as climate and geological change, in shaping genetic, geographic, and ecological diversity? 2) When closely related species meet what kind of interactions come into play, reproductive isolation? hybridization? 3) Are different species responding in an individual or concerted manner? and 4) Does current taxonomy accurately reflect underlying evolutionary relationships? In addition, I am also interested in how this knowledge can inform conservation issues. My research efforts have focused primarily upon small mammals such as chipmunks (*Tamias*), shrews (*Sorex*), and their associated parasites. My research program has always been specimen based and will continue to build upon this framework.

The basic framework for my research has been to use phylogenetic frameworks to address the broader questions stated above. Without an understanding of evolutionary relationships, a comprehensive understanding of biodiversity and the processes that generate diversity is missing. For many of the groups I study, this framework has been traditionally difficult to estimate using traditional, non-molecular methodology and thus, application of new techniques has resulted in a better understanding of evolutionary relationships. This has allowed me to erect new hypotheses concerning taxonomic relationships, biogeographic history, and ideas about speciation in many of these groups. In some cases, my research has uncovered cryptic species and lineages. Much of this work, particularly with shrews and chipmunks now provides the framework for other researchers that are asking different or expanded questions about the species I have studied.

**Goals for the next 5 years**

I will continue to build on the major steps that I have made over the last 20 years, which has been primarily focused on chipmunks, and other small mammals. The projects have relied heavily on my joint collaborations with researchers at other universities including the University of Idaho, University of Montana, and the Los Angeles County Museum of Natural History, as well as leveraging their graduate students to develop projects around these faunal groups. The major goals over the next 5 years are: 1) continued resolution of western North America chipmunk and shrew evolutionary relationships increasingly applying phylogenomic techniques, 2) phylogeographic research on select species (including those in Colorado) and, 3) in-depth examination of interspecific zones of hybridization in both the northern and southern Rockies. In addition, newer side projects examining co-divergence of hosts and parasites will continue to be developed as in the past. This research will be supported by fieldwork in the western states that will also continue to contribute to the DMNS mammal and parasite collections as well as offer a better understanding of large-scale patterns of biodiversity. Western chipmunks represent an excellent model system since they occur in a wide variety of habitats including sage plains;
pinyon-juniper forests, coniferous forests and sub-alpine areas, and thus provides both historical and contemporary information about the establishment and health of the animal communities associated with these habitats. Over the next five years, I will be focused on expanding the above objectives and will be seeking new avenues of funding (e.g., NSF).

Because the DMNS serves as such a highly visible conduit of scientific knowledge/education to the general public, I will be in an excellent position to disseminate results of my research through formal and informal curator lectures, by providing scientific support for museum exhibits and programs, and electronically via the on-line collections database. Although my research is focused on small mammals, they provide an excellent segue into a myriad of educational and outreach directions that have a firm basis in evolutionary biology, biodiversity, and the overall importance of museum collections.

3.5.2. Paula E. Cushing, Senior Curator of Invertebrate Zoology

Nature of Research
I am an evolutionary biologist whose research focus is on arachnids (spiders and their relatives). The three most active areas of current research focus are in 1) Solifugae diversity, taxonomy, and phylogeny (research funded through the National Science Foundation; 2) spider biodiversity in the Rocky Mountain / Great Plains Ecoregion (e.g., Colorado Spider Survey, or CSS); and 3) the evolutionary ecology of spider-ant symbiotic relationships.

My research program extensively utilizes museum research collections. I also am a strong advocate of citizen science and engaging volunteers, students, and lay researchers in my research program extensively. I have an active cadre of volunteers who have taken my Colorado Spider Survey training workshops or Spider Biology classes who are now helping to curate the arachnology collections, assisting with field work, and/or working on their own research projects.

Personal Research History
I have been researching arachnids since my undergraduate days. My research history is reflected in my publication record. Early in my career, my focus was on the behavioral ecology of spiders; specifically, predator prey relationships and predator avoidance strategies among spiders. For my doctoral research, I focused on the evolutionary ecology of a spider commensal that lives in the nests of the Florida harvester ant. I explored the adaptations that enabled the spider to live inside the ant nests. When I began my research at the DMNS in 1998, I initiated a regional biodiversity program, the Colorado Spider Survey. The goals of this research were to establish baseline data about the species diversity of Araneae in the Rocky Mountain / Great Plans region and to engage citizen scientists in all aspects of this research. I also began an active research program in solifuge taxonomy with my research associate, Jack Brookhart. This research continues to this day and formed the basis for two large NSF Solifugae grants. The solifuge project has resulted in thousands of additional arachnid specimens added to the arachnology collection and has resulted in 14 scientific publications.

In the last five years over 10,000 arachnid records have been added to the database; many from specimens collected by CSS participants. The arachnology volunteer force has also grown with more people taking my CSS training workshop or Spider Biology class. These volunteers identify and database specimens collected by CSS participants or acquired during fieldwork. They have also been primary or co-authors on five scientific publications. The arachnology collection has grown from fewer than 50 vials prior to my hiring in 1998 to over 39,000 databased and identified records (lots) published in an online database with another 20,000 vials (lots) remaining in the backlog.
Goals for the next 5 years
From 2018 - 2023, I will be focusing on a recently funded four year NSF project: “Collaborative Research: ARTS: North American camel spiders (Arachnida, Solifugae, Eremobatidae): systemic revision and biogeography of an understudied taxon.” My co-PI on this grant is Matt Graham from Eastern Connecticut State University. The over $1M grant supports one postdoctoral scholar, a doctoral student, a master’s student, and several undergraduate students. The graduate students will be supported in my lab.
This project addresses the systematic and taxonomic impediments in the study of camel spiders by using existing expertise to train students in cutting-edge phylogenomic, biogeographic, and taxonomic methodology. Extensive fieldwork carried out as part of this project, particularly in the Chihuahuan Desert, Baja California peninsula, and California Coast Ranges, will undoubtedly reveal many new species in this family, greatly enhancing the understanding of arachnid diversity present in these underexplored arid ecosystems.

In the next five years, I will continue the Colorado Spider Survey project and will continue to add to the arachnid collection, particularly the spiders, and will accept donations from colleagues, primarily donations focusing on this region of North America.

I also hope to work with colleagues to re-initiate a project focused on spider myrmecophiles (symbionts inside ant colonies). My colleague in Wisconsin, Dr. Mike Draney, and my colleague in Denver, Dr. Mike Greene, and I will focus on spiders in the genus Masoncus, species of which are found associated with ants in the genera Pogonomyrmex, Aphaenogaster, and Formica. We will also explore the biogeography of the spiders and the ants to determine if historical biogeographic patterns can explain the distribution and ant-associations of these spiders and will describe new species.

The research projects carried out in my lab will be presented at public lectures, highlighted in one Science News exhibit, and used to build an online Guide to Camel Spiders of North America. I will continue to be the point person for arachnid-related questions from the public. And I will continue to give public presentations to groups about spider biology and spiders of medical importance. In addition, my lab will present current research every year at regional, national, and international scientific conferences.

I will also continue to be actively engaged in my scientific discipline. I am the lead person for the revision of the primary resource for identification of North American Spiders: Spiders of North America: an identification manual and will work with colleagues from the American Arachnological Society to revise this book. I am currently the President of the International Society of Arachnology and will continue to be active with that society after my term ends. I am also the Secretary and Press Officer for the American Arachnological Society and will continue my work with that scientific society. I also serve on the board of the Colorado Mountain Club Foundation and lead a committee soliciting and reviewing graduate research grants through that organization. I expect to continue this role during the next five years.

3.5.3. Frank Krell, Senior Curator of Entomology
Nature of Research
Sub-discipline: Natural history of beetles, particularly scarab beetles (organismic taxonomy, phylogeny, paleontology, ecology, and biogeography). I am an expert on world scarab beetles with a leading role in nomenclature and fossil scarabs. My research is primarily taxon-oriented with solid taxonomy being the foundation of all my projects. Taxon-oriented, collection-based research is the traditional domain of Museums. I maintain my world-wide taxonomic orientation, but have shifted my focus to the beetle fauna.
of Colorado, their species distribution, temporal and ecological patterns (habitat preferences; effects of anthropogenic and climatic change). Determining the effects of anthropogenic habitat change on beetle communities has been one of my central research topics for almost two decades. Beyond natural history, I have published on research evaluation, particularly the journal impact factor, and, as chair of the ICZN ZooBank Committee, am involved in development and implementation of ZooBank, the official register for scientific animal names.

**Personal Research History**

I have been working with collections and building collections for over thirty-five years. All my research either creates or is based on collections. I have written the scarab chapters for the standard works on the beetles of Central Europe and the Palaeartic beetle catalogue, a catalogue of fossil Scarabaeoidea and of Scarabaeoidea of Colorado, and many contributions to the taxonomy, distribution and natural history of scarab beetles, totaling 225 papers.

During nine years of projects on ecology of and influence of human land use on dung beetle communities in tropical Africa, I developed expertise in field ecology and leadership of teams of students and technicians. Establishing a similar projects here in Colorado is long-term goal, but might be facilitated by my collaborative DungWebs grant if funded. Anthropogenic effects on animal groups, be they regional or global, will stay in the public interest and provide the opportunity to present original DMNS research to the public. My Bison Beetle Project, an 8-year study of the influence of re-introduction of bison on the dung beetle fauna in Colorado, is currently at the stage of data evaluation. This project had integrated Teen Science Scholars for several years.

Having worked for years on fossil scarab faunas, monographic papers on the scarabs of Eocene Messel and Baltic and Mesozoic amber will be finalized soon. The long-term goal is a comparative review of fossil scarab faunas and their ecological and taphonomic implications for the paleohabitats.

With a functional morphology of the genitalic sclerites and muscles of the European cockchafer Melolontha, I made a novel highly complex character system accessible for phylogenetic analysis as my PhD project, but have never had the time to follow up. Establishing a comparative mycology of scarab beetles and using it for phylogenetic analyses is a long-term goal.

Dr. Thomas Schmitt in Freiburg and I are the leading team working on the question “Why is dung so attractive” to dung feeding organisms? Several papers on the chemical ecology of scarabs are published and the projects continue in Europe and in Colorado.

**Goals for the next 5 years**

My central goal is further developing my reputation as a world scarab expert and the collection as a relevant national and international research resource. As a long-term, but certainly over-ambitious goal, I would like to be capable of identifying any beetle species occurring in Colorado, with the help of a comprehensive reference collection that we are building.

Colorado Scarab Survey: After publishing a couple of papers about new and interesting scarab species for Colorado, I will prepare a monographic volume on the scarab and stag beetles of Colorado and probably an abridged version as an illustrated field guide for citizen scientists.

Bison Beetle Project: In 2008, collaboration with the Plains Conservation Center, we started a long-term monitoring program on the beetle fauna of the dung of re-introduced bison on PCC land in Elbert County. We want to find out whether re-introduction of native mammals leads to a recovery of the
dependent insect fauna. As a control, in 2010, we started monitoring the beetle fauna of cattle dung at the Keen Ranch nearby. The results of this project will be available in the next few years.

Westcliffe Project: Theodore Cockerell comprehensively collected and published the beetle fauna of Custer County around Westcliffe from 1887 to 1890. This is likely to be the only published comprehensive beetle fauna from Colorado of the 19th century and is a suitable baseline for determining faunal change during the last 120 years. In 2012, we started a collecting program in Custer County to compare the current fauna with Cockerell’s records. Despite mining and ranching having certainly affected landscape and associated biota, Custer County’s historically low and even decreasing human population size and consequently limited development and degradation make Custer County a model for the study of climate driven faunal change. We will continue collecting in Custer County to gain comparable data of the present fauna.

Paleontology: Ongoing monographic projects on scarab fossils (amber, Messel) will be published.

African ecological projects: The results of major experiments will be published and a significant part of the specimens integrated in the collection.

Chemical ecology: The minimum attractive odor bouquets for major dung beetle groups will be identified and evolutionary pathways reconstructed; a synthetic attractant for standardized sampling might be developed.

3.5.4. Garth Spellman, Associate Curator of Ornithology

Nature of Research
I am an evolutionary biologist whose muse is birds. Birds possess many qualities that make them the ideal organismal system for studying evolutionary biology. They are ubiquitous (found on every continent and soaring over all Earth’s oceans), easily observed (conspicuous and generally diurnal), extremely diverse (the most speciose class of terrestrial Tetrapod) and exhibit a plethora of beautiful and complicated adaptations (from plumage color to song complexity). My work attempts to reveal the processes (from natural selection to genetic drift to gene flow) that have driven the evolution of avian diversity in the past and the processes that continue to drive evolution today. I explore these processes using genomics or molecular genetics combined with specimen-based field research and observational science. Questions concerning avian systematics, biogeography, phylogeography, speciation, conservation, ecology and host-parasite co-evolution are the focus of ongoing studies in my research lab.

Personal Research History
For the last 15 years, I have primarily focused my attention on research questions that ask how past and current climatic changes have and are shaping avian diversity. Specific questions asked include: 1) How have the climatic oscillations of the Quaternary contributed to avian diversity in North American woodlands?; 2) In suture zones (areas where many species come into secondary contact and hybridize), do similar evolutionary processes act to keep species apart and conversely are similar processes working to allow once separate taxa to fuse and become one?; 3) What processes contribute to the maintenance or break down of avian hybrid zones?; and 4) How is genetic diversity and genetic structure affected as species shift their ranges in response to current rapid climate change? The taxonomic focus of the studies addressing these questions centers on Passeriform species (songbirds) and Piciform species (woodpeckers).
My ability to answer the above questions and my research interests have evolved over time in conjunction with changing DNA sequencing technology. I began my career using mitochondrial DNA sequences to explore the evolutionary history of birds. However, sequencing technology has progressed rapidly and it has now become easy to sequence large portions of the genome and whole genomes for a fraction of what it used to cost to sequence one gene. The opening of the genome to evolutionary biology enables us to get a more complete picture of the processes shaping biodiversity and has shifted the focus of many evolutionary studies. Prior to the genomic revolution, evolutionary biologists generally looked to eliminate competing evolutionary processes to identify the primary driver in a system. Now, we generally seek to explain how competing and sometimes complementary evolutionary processes, like natural selection and genetic (neutral drift), work synergistically and antagonistically to shape the evolution of species and populations. This incredible access to an ocean of data has reshaped my research program and led me to start exploring questions about genomic evolution as it relates to speciation, hybridization and a myriad of other evolutionary phenomena.

Since I began pursuing my Master’s degree, every research project I have pursued as an independent scientist or as part of a collaboration has been specimen-based and therefore museum dependent. I passionately believe in the work natural history museums perform, preserving a lasting and secure record of biodiversity and cultural diversity. The specimens we take and preserve in our collection today provide the scientific foundation for tomorrow’s greatest discoveries; thus, it is our duty to ensure they are cared for to the best of our abilities and made available and accessible to future generations.

**Goals for the next 5 years**

After arriving in Colorado a couple of years ago, I made it a priority to establish local and regional research collaborations and to make these collaborations productive in terms of scientific rigor and output. These efforts are just beginning to be fruitful and provide the foundation for one aspect of my research program for the next half decade. The first large collaborative project is focused on the imperiled Brown-capped Rosy Finch and involves researchers from CU-Boulder, The Bird Conservancy of the Rockies, UC Santa Cruz, US Fish and Wildlife Service and Colorado Parks and Wildlife. The Brown-capped Rosy Finch has not been extensively studied. What little census work has been done on the species, suggests that populations have declined by as much as 95% over the past 50 years. Brown-capped Rosy Finches are emblematic of the Rocky Mountain state. Colorado is the highest state (in terms of mean elevation) and Rosy Finches are the highest breeding bird in the state. They breed in rocky crevices, in talus slopes and occasionally in abandoned mines above tree-line and feed on insects and seeds on snowfields. Most birders in Colorado are perhaps more familiar with these charismatic finches during their occasional low elevation visits when winter storms force them from their preferred mountain top homes. Climate change research tells us that changes will first effect species in extreme environments, for example arctic and alpine species. Thus, it is not shocking that Rosy Finch populations have experienced declines. This research project hopes to uncover many answered questions about Rosy Finch evolution, natural history, ecology and conservation. The exact causes of their declines need to be ascertained if we are to entertain the hope of conserving the species. I, in conjunction with researchers at CU Boulder, have sequenced 68 Rosy Finch genomes and collected blood samples from populations at seven different Colorado Mountain ranges. The genomes and samples will provide preliminary data for planned grant proposals to several federal agencies to support the work.

My move a couple years ago into avian genomics has also fostered a collaboration with Dr. Lauryn Benedict’s lab at the University of Northern Colorado. Dr. Benedict is a behavioral ecologist. Her work focuses on vocal communication in birds and how signal variation evolves in relationship to ecology and in response to selection. Very few researchers are investigating behavioral traits in an evolutionary and genomic context and we are designing projects to help fill this scientific gap. We have begun by
investigating genomic variation and vocal variation across a latitudinal migratory divide in Rock Wrens. Migratory and non-migratory populations of Rock Wrens exhibit different vocal repertoires and we are trying to associate these differences with genomic variation to identify the regions of the genome that may be under selection in the different populations. The hope is to find evidence that a complex behavioral trait which evolves under strong cultural selection can have a lasting evolutionary impact on the genome. This has been found to be the case in humans, but it would be transformative to find it a non-human, non-primate species. We have preliminary genomic data from >100 birds across a transect in NM, CO, WY, and MT, which we plan to use in a proposal to the NSF in the upcoming years.

Over the next five years, I also plan to initiate studies into the evolutionary history of several extinct species and subspecies held in the DMNS Ornithology collection. These projects stem more from my innate scientific curiosity than from ideas I believe to be fundable by outside entities. The first project is a genomic investigation of the extinct San Benedicto Island Rock Wren and the work should be ready for publication within the next year. The research has revealed that the extinct wren was genetically unique, arrived on the island shortly before it emerged from the Pacific ocean, and had started to evolved characteristics similar to other oceanic island endemics (short round wings and longer legs). I plan to conduct a similar investigation of the extinct Guadalupe Island Ruby-crowned Kinglet and then turn my attention to subspecific variation in Carolina Parakeets using genomics.

In addition to the above, I plan to continue investigating the research questions I listed above in the Personal Research History. I conduct fieldwork annually in hybrid zones and various mountain ranges to support these research efforts, and a proposal to the NSF is currently being drafted to further support this work. This work is part of an ongoing collaboration with Dr. John Klicka, Burke Museum and University of Washington, and Dr. Joseph Manthey, Texas Tech University.
4. COLLECTION PLANS

4.1. Anthropology

4.1.1. World Ethnology
Curator: Chip Colwell
Plan author: Chip Colwell

Intellectual Framework
The Department of Anthropology aspires to curate the best understood and most ethically held anthropology collection in North America. The World Ethnology Collection is a central means of elucidating the world cultures that contextualize the Rocky Mountain’s history and diverse contemporary cultures.

For millennia, the Rocky Mountains have been a crossroads of cultures, from the ancient Paleoindian communities to the meeting of Navajo, Ute, and Pueblo peoples to the recent migrations of Hmong and Sudanese refugees. Today, Colorado residents drink coffee grown in Java and drive cars assembled in Japan. In a single day, we can travel half way across the globe; power plants in the Four Corners may contribute to the oceans rising in Polynesia. The World Ethnology Collection is thus important for situating the Rocky Mountain region in a global perspective. It is through authentic objects that the collection seeks to recognize the human experience in all its grand diversity.

This collection draws on one of ethnology’s disciplinary strengths, that is, comparative scholarship. The World Ethnology Collection not only provides the possibility of comparative research and exhibitions, but also inherently strengthens the American Ethnology Collection. However, as the world is a large place, it is unrealistic to cover every known culture. Rather, efforts will be made to focus on specific regions based on the identification of local connections, curatorial research agendas, or comparative dimensions with other parts of the DMNS’s holdings.

The historical legacy of colonialism which drove the collection of Native American objects also obtains to the collection of objects in Asia, Africa, Australia, and elsewhere. To hold the collection ethically thus entails directly addressing this legacy and seeking new, reparative ventures. As with the American Ethnology Collection, this one will also be guided by the principles of respect, reciprocity, justice, and dialogue. The ultimate aim for this collection is to use it to inspire intercultural dialogue that transcends ethnic or national boundaries. The World Ethnology Collection helps us to honor and understand Homo sapiens sapiens in our rich complexity—to recognize and critically examine our differences and similarities.

Scope of the Collection
The World Ethnology Collection of approximately 5,400 objects derives from cultures outside the Americas. The broad but thematically unified core collections of world ethnology have highest intrinsic potential for research and programming when field-collected and well documented by when, where, by whom, and under what circumstances collected. Included in world ethnology are the following classes of systematic anthropological research collections: (1) Culture Unit Collections (ethnographic culture units and culture areas); (2) Typological Collections (morphological and functional collections); and (3) Comparative Reference Collections (e.g., ethno-botanical and ethno-zoological collections). Inclusion of this variety of collections permits a specific-to-global range of idea development, cross-cultural, and applied objectives. Objects in the World Ethnology Collection come from every corner of the earth, although five sub-collections represent the most significant holdings.
African Collections: The 1,600 African objects center on Botswana, which was the DMNS’s zooological-ecological field collecting area in the late 1960s. Culture unit collections of some 400 objects represent a virtual cultural inventory of mid-20th century lifeways of Botswana’s San (best represented), Bantu, and Tswana, Herero, Hambukushu, Bayei, and Basubiya peoples. Systematically field-collected materials range from ethno-botanical specimens, tools, basketry, pottery, ostrich and turtle shell containers, weapons and clothing, jewelry, musical instruments, to art forms made for sale. Collections from neighboring regions include 129 field-collected objects from Zimbabwe’s Shona and Matabele people and 130 objects from South Africa’s Basuto, Kwazulu, Ndebele, and several other groups.

A secondary collecting focus is the Democratic Republic of the Congo with 187 objects from field collected objects from the Ndengese, Luba, Kuba, Songe, and several other cultures. Objects from the last half of the twentieth century include masks, drums, whistles, wooden figures, and copper pieces as well as the everyday cultural inventory. The material culture of other parts of Africa makes up the remainder of this sub-collection, which include typical utilitarian objects and arts made for sale in the mid-twentieth century as well as fine, old examples of bark cloth and other textiles, baskets, beadwork, metal, and leather craft, wooden figurines, and masks.

Asian Collections: The Southeast Asian collection of more than 1,500 objects is the most significant world ethnographic holding, outside the Native American collections. Collected during the last forty years, it represents a systematic, documented holding from the Hmong, Mien, Akha, Lahu, Lisu, and Karen Hill Tribes of the northern margins of Thailand, Laos, Burma, Vietnam, and southwestern China. The core is the Paul and Elaine Lewis Southeast Asian Collection, featuring clothing, domestic equipment, and beads that were field-collected primarily during the 1970s. Supplementary holdings were DMNS field-collected in 1987, collected by Anthropology Research Associates in the 1980s and 1990s, and contributed by original native owners, Hmong Americans in the Denver-Boulder area. The collection includes material systems of clothing, basketry, pottery, artworks, tools, weapons, objects of healing and religion, as well as other realms of human activity and creativity.

Small groups of Asian objects illustrate scattered peoples and traits of Han (China), aboriginal Taiwanese, Japanese, South Asian (India, Bangladesh), Indonesian, and Philippine Indigenous cultures. These collections vary from a few to 167 items and include a wide range of objects. One of the more important holdings is the collection made by William A. Phillips, donated in 1961, consisting of 50 Garo materials collected in Assam, India from 1922 to 1927, which relates well to the Burma tribal collections. The collection made by Charles Mantz, donated in 1972, includes 167 art objects collected mostly in Japan and north China in the 1950s. Field-collected from 1946-1951, by Ralph Covell, is a small Yi collection from Xichang, China; and collected between 1952-1966 is a group of 11 Takoko materials from Taiwan.

Oceanic and Australian Collections: About 700 objects make up this smallest and perhaps most diverse DMNS ethnology holding. It illustrates the main materials, technologies, forms, and designs used during the early to mid-20th century by the peoples of Pacific Ocean islands from Hawaii to Papua New Guinea and the continent of Australia. Oceania is represented by 254 Melanesian objects, primarily from New Guinea and the Admiralty Islands; 61 Polynesian objects, primarily from New Zealand; 216 objects are from Australia; 50 objects represent the New Zealand’s Maori; and a few Micronesian objects. A majority of these objects, poorly documented by miscellaneous donors, are best viewed as typological collections. Important in global comparisons are such specialized objects as outrigger canoes, tapa cloth, palm leaf clothing and mats, coconut utensils, tusk and shell ornaments, and ceremonial carvings.
Ethnological Art Collection: The Ethnological Art Collection draws attention to cultural life through aesthetic values. Consisting predominately of two-dimensional works from the Americas and beyond, many pieces document societies before the advent of photography. All the objects serve to inspire and excite curiosity through our sense of beauty and artistic expression. These art pieces, made by Indigenous peoples, are especially unique as ways of providing an “insider view” of culture. Because the DMNS is not an art museum, the objects in this collection must be evaluated on three key criteria: (1) the object should ethnographically document cultural lifeways or histories, (2) the object should inspire and excite people about the human experience through the work’s aesthetic qualities, and (3) the object should be created by early explorers, amateur ethnographers, or anthropologists, or by an Indigenous person visually representing their own culture. The collection currently consists of more than 800 objects, and includes pieces by important Native American artists such as Woody Crumbo (Pottawattomie) and Otis Polelonema (Hopi), as well as non-Native explorers such as George Catlin and Fredrick Catherwood.

History of the Collection
This collection was initially shaped to add scientifically valid cultural context to the DMNS’s natural history research and exhibition program. The southwestern Pacific region and Southern Africa, particularly the African cultural groups in Botswana, were first perceived as special collecting regions and then were placed in broad context with neighboring peoples’ objects. With ethnology established alongside archaeology in the Department of Anthropology in 1968, directed cultural content and response to audiences became important. Many of the objects in the World Ethnology Collection were donated or purchased from the 1960s onward. The collection began to illustrate a broad range of cultures as well as local community changes. Historically, and currently, the Department of Anthropology strives for in-depth systematic as well as comparative collections.

The earliest ethnographic collections outside of the Americas largely resulted from Museum expeditions. They were directed toward the development of cultural exhibits within diorama halls that presented each expedition’s flora and fauna. The first such collections derived from Director Alfred I. Bailey’s expedition to southwestern Pacific islands and Australia. Exchanges with the National Museum of Victoria, Australia, in 1955 and the Dominion Museum of Wellington, New Zealand, in 1958 netted 222 objects from Indigenous peoples, constituting a third of the present Oceanic and Australian collection. Although highly selective, field collected and scientifically valid, these objects were intended primarily for culturally specific exhibition. For nearly thirty years they remained in two cases adjacent to the dioramas resulting from the Pacific expedition.

The African collection consisted of only a few donated objects until systematic collecting began in 1969 when a four-month-long Museum expedition went to Zimbabwe and Botswana to gather faunal specimens and data for the Helen K. and Arthur E. Johnson Botswana Africa Hall. Expedition naturalists and participating trustees collected 65 ethnographic objects locally from the Kang and Okwa San, Mbugu, and Herero groups.

Responding to the DMNS’s directions toward growth in comparative global collections and regional opportunities for heritage preservation of older institutional holdings, in 1986 and 1987 the DMNS accepted “orphan” collections from Colorado College and University of Northern Colorado. Included were cross-cultural materials from Africa, China, India, the Philippines, and the Pacific region, as well as American Indians, ranging from the early 1900s to the 1970s. In 1998 the DMNS and donors purchased the Elaine T. Lewis Bead Collection, a typological collection of heirloom and contemporary beads collected in northern Thailand from 1975-1989. Ethnological art objects have been gradually
added through the years, most recently with the Alice Dodge Wallace and H. Toll collections, in 2005-2007.

Future of the Collection
In the next decade the World Ethnology Collection will be shaped into a portal through which researchers, artists, Indigenous peoples, and the public are exposed to material culture of the world’s major cultural groups. Ethnic groups residing in the Rocky Mountain region will be the focus of any new collecting. As the collection becomes more ethnologically honed, collecting will include folk material culture from the African diaspora to the Americas, similarly to the present inclusion of objects from Hmong Americans. Objects designed for sale to tourists also have their place in providing invaluable comparative data on change of style based on non-traditional use and markets. The Department of Anthropology’s endowments may be vital in bringing in new and important objects—especially new targets of opportunity as they arise.

As every society has culturally sensitive objects, the collection must be in tune with the goals of respect and dialogue. With anthropology’s tangled legacy, unethically and illegally held objects must be contended with. Special consideration should be given to international treaties such as the 1970 UNESCO Convention, as well as the fact that there is no equivalent to NAGPRA for human remains, sacred objects, and objects of cultural patrimony taken from Indigenous peoples outside the United States; for example, the vigango (memorial statues). Every effort should be made to work collaboratively with the communities that connect themselves to the objects held in the museum’s stewardship. The overall goal is to develop a collection that is in dialogue with the multiple audiences the museum is meant to serve, and one that delivers breadth and depth in understanding cultural variation, change, and persistence.

4.1.2. American Ethnology
Curator: Chip Colwell
Plan author: Chip Colwell

Intellectual Framework
The Department of Anthropology aspires to curate the best understood and most ethically held anthropology collection in North America. The American Ethnology Collection illuminates the cultures, mostly Indigenous, of North America.

In the late 1800s, as natural history museums were established, Native American communities faced tremendous social, political, and economic pressures. Tribal lands were rapidly disappearing through the Dawes Act of 1887, Native children were taken from their families and forced to forget their traditions, and tribal political sovereignty was undermined as treaty after treaty was broken. Even as millions of Indigenous peoples lived in North America when Columbus first set foot on what he believed was the outer edge of India, after more than four centuries of colonial turmoil a mere 250,000 Native Americans could be found in the United States.

At the close of the 19th century, the burgeoning field of anthropology found its calling to preserve the physical remnants of what was widely believed to be fast disappearing American Indian cultures. Anthropology, as a scientific field dedicated to the preservation of cultures, found an easy home in natural history museums, which sought to capture, categorize, and conserve every wondrous aspect of our world. With Native America threatened from every quarter, early museum anthropologists indeed were able to save many objects that otherwise would have been lost to time. And with its broad survey
of human societies and its celebration of cultural diversity, anthropology helped awaken the Western world to the multiplicity of the human experience.

But this progress came at a steep price. Often, the goal of cultural preservation in fact contradictorily led to the destruction of Native traditions and the rupture of communities. In the name of science, vast numbers of objects were taken without regard for their spiritual and cultural contexts. Human bodies were uprooted from their graves by the thousands. Sacred objects were secretly purchased, sometimes stolen. Situated within the natural history museum, Native Americans were regularly portrayed as “naturals,” akin to the extinct dinosaurs and dodos displayed nearby. Over time, these injurious aspects of natural history museums fanned the flames of resentment and anger across Native America.

Today, we know that early anthropologists were wrong: Native American societies did not wholly disappear. Rather, lifeways changed and adapted, often blending ancient wisdoms with modern practicalities. “We were here, we are here, we will always be here” is a statement that echoes loudly across Indian country. Still, there is no denying that there are fewer Native American languages spoken today than a century ago, that tribal sovereignty continues to be threatened, and that the general public still poorly understands Native American culture and history. These challenges can be met by natural history museums and museum anthropology, which, like Native communities have also changed through the years. Objects in collections are now recognized to have a range of values. Objects wrongly taken are returned to their rightful owners. Anthropologists have increasingly recognized that their work unfolds in a complex social and political milieu—and ethical scientific pursuits ought to positively benefit more than the scientific community. Indeed, since the release of the Belmont Report in 1979, *benevolence* has emerged as a key concept. That is, scientists should not merely seek to “do no harm” but should actively seek to do some good.

Today, cultural anthropologists study far more than just Native Americans. This shift in the discipline is paralleled in the demographic shifts in that Denver and the Rocky Mountains, which are increasingly home to diverse ethnic groups. For example, in Colorado today, 21% of our community is Hispanic. Immigrants from more than 60 countries make Denver their home. And, in the years ahead, our communities will become only more diverse. According to some studies, the Hispanic population across the United States is projected to triple by 2050. All of these cultures from across the Americas are a vital subject—and audience—for the Museum.

Anthropology at the DMNS serves to document, preserve, and understand the human communities of the Rocky Mountain region through their material cultures. This is important because human communities are a central part of the Rocky Mountain landscape: a frame to picture those who have come before us and to imagine our collective future. The objects of these communities have the unique ability to inspire curiosity and excite minds of all ages. As Native Americans have been in the region the longest they are fittingly the focus of the collections. However, the objects of more distant Indigenous communities (as from all over the world) play an important role for comparative study. Also, in today’s urban environment, Native peoples throughout the Americas are living in the Rocky Mountain region.

For decades, the guiding principles of anthropologists in natural history museums have been discovery, salvage, and preservation. These principles are not negative as such, but rather have sometimes been badly applied when they have served to elevate scientific institutions at the cost of Native American well-being. The new guiding principles of the ethnology collections at the DMNS will be respect, reciprocity, justice, and dialogue. *Respect* is honoring people and the things that make up their social lives and showing deep consideration of their personal autonomy and collective welfare. *Reciprocity* is creating relationships that are based on parity, the cooperative exchange of ideas and things. *Justice* is
to repair past wrongs and to treat all people fairly. *Dialogue* is a commitment to open, democratic, and sustained conversation. Applying these principles in practice with archives and other items should be guided by the “Protocols for Native American Archival Materials.”

These principles do not entail the abandonment of “traditional” anthropological research, but rather a new commitment to the ideal of benevolence—acknowledging anthropology’s complicated legacy—that the discipline can and should do social good. The scientific use and long-term preservation of the American Ethnology Collection will be pursued while embracing the respectful treatment of Native Americans, the mutual benefit for myriad stakeholders, and the evenhanded treatment of all people through open and sincere dialogue.

**Scope of the Collection**

The American Ethnology Collection dominates the anthropology collections with about 21,400 objects, centered on a nearly 12,000-piece collection, which Mary and Frances Crane donated to the Museum in 1968. The second largest private American collection ever founding a museum department, the Crane’s collection contains at least one, and often many, of the most representative objects tracing Native American ways of life. Objects from the entire collection range from made-for-sale to ceremonial, from the 2000s to the 1700s in date, from unidentified to maker-identified, and from hobbyist creations to artistic masterpieces. Important documented sub-groups include collections made by the Fred Harvey Company, Jessie H. Bratley, and Axel Rasmussen.

The presence of the collection donated by the Cranes has stimulated growth during its 44 years at the DMNS, and built upon the small number of ethnology objects previously in the collection. The region in and around Colorado is prime, representing 65% of the collection. Collecting by Curator Emerita Joyce Herald has expanded the Jicarilla Apache, Havasupai, Lakota, Ute, and Oklahoma Indian holdings. The remainder of the collection is derived about equally from Arctic, Northwest Coast, Plateau, California, Northeast Woodlands, and Southeast Woodlands cultures.

The Hispanic history of the Western Interior forms a contrasting tradition, which is increasingly renewed with fresh migrations from Mexico and Central America, forming new topics for the ethnographic collector-researcher-exhibitor. The ethnographic collections provide comparable range and representative cultural groupings and types of materials to those from North America but are much smaller, numbering about 8,000 objects. Strengths are Mexican Indian arts, Guatemalan and Andean textiles and utilitarian objects, and a variety of Amazonian objects. Several small documented holdings derive from travelers (e.g., Crane objects from the Jivaro) and government or business missions (e.g., the Shipibo pottery vessels).

Assemblages of objects should be broad but unified. Highest value for research and programming use is placed on objects that are field-collected and well documented, including when materials were collected, by whom, where, and under what circumstances collected. Systematic anthropological research collections also include objects of comparative significance that strengthen broad context and cross-cultural research, program, and outreach. Only those objects that have been collected ethically and legally should remain in the collections; the collections should be managed in concert with all relevant professional codes, national laws, and international conventions, including but not limited to NAGPRA, ARPA, the 1970 UNESCO Convention, and the AAA Code of Ethics.

Through acquisition and study of such cultural collections we provide meaningful encounters with a wide variety of Museum audiences, from Denver’s families to specialized Native communities, art circles, and world interest groups. The DMNS American Ethnology Collections contain an array of resources to
elucidate a cross section of the human world. The essential vitality of the objects will come through most clearly by re-linking the collections with the living peoples whose ancestors made and used these irreplaceable treasures.

History of the Collection
The Denver Art Museum, History Colorado, Taylor Museum of the Colorado Springs Fine Arts Center, University of Colorado Museum, and many smaller history and art museums join the DMNS in the preservation and public access of Native heritage, but by far the largest, broadest, and best documented holdings in Native American ethnology in the Rocky Mountain region have been held here since 1968 when the Cranes donated their collection to the DMNS. Joyce Herold joined the museum in 1968 to help oversee the ethnology collections and became the first Curator of Ethnology in 1989. Chip Colwell joined the DMNS faculty in 2007 and now curates the collections of living cultures. The value of these holdings to Western history, science, public education, and Native heritage is notable: it forms the raison d’etre and resource for the North American Indian Hall, dozens of changing exhibits since 1979, articles and other investigation by numerous researchers, and lectures and classes offered annually. Since its founding in the core anthropology collection, the holdings have about doubled through curatorial field collecting, selective donations, and transfers from other museums.

Future of the Collection
Although the American Ethnology Collections have been at the DMNS for 44 years, the main efforts to date have been the organization of the materials and the exhibiting of them in the North American Indian Hall. Prior to 2007, the collections received minimal scholarly research and publication. A continuing and primary goal is to increase scholarly access to the collections and to publish the collections in peer-reviewed venues as well as popular magazines and online outlets. The aim to increase the scholarly use of the collections goes hand-in-hand with the re-inventory, re-organization, and re-presentation of the objects.

With the new principles of the collections that focus on collaborative endeavors, some objects may need to be deaccessioned if they were unethically or illegally obtained. Objects subject to NAGPRA must be repatriated. In turn, with the establishment of new trusting relationships and partnerships, wholly new opportunities for building the collections will emerge. New collections will focus on the Rocky Mountain’s contemporary Indigenous communities as well as the relationship between Native Americans and the natural world. The Department of Anthropology’s endowments will be important to pursue targets of opportunity as they arise.

In the coming decade, the goal for the American Ethnology Collections—indeed for all the collections of living cultures—is to be the best understood and most ethically cared for anthropology collection in North America.

4.1.3. Archaeology
Curators: Stephen Nash & Michele Koons
Plan authors: Stephen Nash & Michele Koons

Intellectual Framework
The Department of Anthropology at the Denver Museum of Nature & Science (DMNS) aspires to curate the best understood and most ethically held anthropology collection in North America. The Archaeology Collection offers a central means of elucidating the histories and cultures of the Rocky Mountain region’s pre-Columbian Native peoples, in keeping with the broader DMNS mission to present and preserve the world’s unique treasures. The Archaeology Collection, with its vast potential for academic research and
public display, directly supports the DMNS mission to ignite our community’s passion for nature and science, whether that community is defined as museum visitors, students, academic researchers, or tribal and source communities.

The Department of Anthropology at the DMNS curates tens of thousands of archaeological artifacts and specimens from around the world. Over the last nine decades, the Archaeology Collection has arrived at the DMNS in myriad ways—through amateur collecting and subsequent donation, outright purchase from dealers, and controlled scientific excavation. As a result of these ad hoc origins, the Archaeology Collection constitutes a unique resource that must be considered on its own terms, for it is characterized by many unique opportunities as well as many challenges common to museum-based archaeology collections.

**Scope of the Collection**

The Archaeology Collection contains more than 72,000 objects, with primary focus on the Rocky Mountain and Plains regions. This collection helps us understand the region’s fascinating and complex past with astonishing time depth, while also serving to bring the far corners of the globe to modern-day Denver. The Archaeology Collection provides rich and continuing opportunities for humanistic, scientific, and multidisciplinary research. It provides a unique forum for examining the ethics and philosophy of museum collections and collecting activity in the context of new and truly collaborative relationships with Native American tribes and other source communities. The Archaeology Collection strengthens regional teaching opportunities, provides life-long learning possibilities through exhibitions, outreach, and volunteer activities, and serves as a gateway to 21st century multi-vocal curation and inclusive community relationships.

The most important archaeology collections at the DMNS were professionally acquired by scientists through controlled excavation and survey. Such materials have been received sporadically since the mid-1920s and constitute a small portion of the collection. Controlled collections are primarily from Paleoindian sites, including the Folsom Site (1926-1928), Dent Site (1932-1933), Lindenmeier Site (1935), Frazier Site (1965-1966), Jones-Miller Site (mid-1970s) and Kanorado Site (1976, 1981, and 2002-2007). Other important collections include those from Hannah Marie Wormington’s excavations at Archaic sites in western Colorado in the 1930s and 1940s, Steve Holen’s Arikaree River survey collection (2003-2004), Magic Mountain collections from Centennial Archaeology Inc. (1994-1996), Koons’ Magic Mountain collections (2017-2018), and Koons’ and Nash’s Reserve Area Archaeological Project collections from the Torriette Lakes Great Kiva (2018). All of these collections have significant research potential and continue to be the subject of ongoing study. In 2017, DMNS took legal control of the WS Ranch collection from southwestern New Mexico. It is a massive collection of Mogollon material culture excavated by the University of Texas at Austin that remains uncatalogued and unpublished; it is nevertheless one of the most important archaeological collections now owned by DMNS.

Archaeology collections of secondary importance include those donated from private collections, which are characterized by highly variable amounts of contextual information. The Southwestern collection, which includes the Stahlgren collection of Southwestern pottery, contains representative pottery types from across the American Southwest, including classic Mimbres black-on-white bowls from southwestern New Mexico, Salado Polychrome from east-central Arizona, and Casas Grandes Polychrome vessels from Paquimé, Chihuahua, Mexico. The collection includes rare organic materials, including exquisitely preserved yucca sandals from the Four Corners region and a split-twig figurine from southwestern Colorado, the earliest known example of this enigmatic artifact form. These collections continue to
provide research and educational opportunities; Koons and Nash rely on these collections as a vital resource for their ongoing work on Mogollon archaeology in the greater Reserve, New Mexico region. Another important North American collection is the Herfurth Collection of projectile points and “discoidals”, acquired in early 2017 from a private collector in Colorado. On a percentage basis, these constitute a small portion of the Archaeology Collection, although many of the exhibition-quality artifacts are represented.

The Mesoamerican collection contains 2,000 objects representing all major ancient cultural groups, including the Maya, Aztec, and Olmec. Highlights include an Olmec greenstone figurine, a stone mask from Teotihuacan, and Huastec shell armlet/anklets.

The South and Central American Collections include 900 objects representing the Inca, Nasca, and Moche, among others. Of particular importance are 133 whole ceramic vessels from Cochabamba, Bolivia, one of the largest such collections outside Bolivia.

The World Archaeology Collection is dominated by 2,000 artifacts from ancient Egypt, Rome, Greece, Babylonia, and Sumeria. They provide the greater Rocky Mountain region with a unique resource facilitating the examination of diverse cultural paths along the human evolutionary journey.

History of the Collection
From its founding until the discovery of the Folsom point in 1927, the Colorado Museum of Natural History (now DMNS) curated a few archaeological materials, but these tended to be curiosities rather than scientific specimens. Scientifically excavated archaeology collections began to be made in the 1920s when paleontologist Jesse Dade Figgins began searching for Pleistocene megafauna. As early as 1924, Figgins’ crews excavated artifacts found in association with extinct forms of bison at various locations, but in 1927 they made what is arguably the most important scientific discovery made by the museum—spear points embedded in the ribs of an extinct bison found near Folsom, New Mexico. In 1932, Museum staff working with Regis College discovered Clovis-style spear points embedded in mammoth specimens at the Dent Site near Greeley, Colorado.

In 1935, after nearly a decade of such excavations, the Museum hired Hannah Marie Wormington, a 21-year-old with a Bachelor’s degree in anthropology from the University of Denver, and the Department of Archaeology was formed. In 1936, Wormington was named Curator of Archaeology. Over the next three decades, Wormington made significant contributions to North American archaeology, particularly through the publication of textbooks and other contributions. Wormington’s fieldwork and collecting activity proved sporadic in the ensuing decades. In the late 1930s she conducted excavations at the Moore and Casebier rock shelters in western Colorado. In 1965 and 1966 she excavated the Frazier Site near Greeley, Colorado. Wormington left the Museum in 1968; the definitive analysis of her legacy remains to be written.

In 1968, the Museum acquired the Crane American Indian Collection, which at that time consisted of some 11,600 pieces of Native American material culture, including some poorly recorded archaeology collections. Upon receiving the Crane Collection, the Department changed its name to Department of Anthropology, and Joyce Herold, an archaeologist by training, was hired as Curator of Ethnology, a position she held until 2005. In 1985 Herold was joined by Jane Day, a Mesoamericanist who was hired as Curator of Archaeology in 1985. Day retired in 2003.

In 1997, the Jones/Miller-Hell Gap bison kill collection was donated to DMNS. Excavated by the Smithsonian Institution in the 1970s, this important collection includes more than 100 projectile points.
and the largest assemblage of bison skeletons ever found in one site. The Jones-Miller bison bone returned to the Museum in 2017 and is being cataloged as part of the NEH grant agenda; the excavation records, photographs, and other archives will come to the museum by the end of 2018.

In 2001, DMNS was designated the official repository for a professionally excavated 5,000 lot-cataloged collection from the Magic Mountain Site in Golden (numbering over 80,000 individual artifacts), which now supplements previously existing DMNS collections from that site.

Curator of Archaeology Steven Holen arrived at DMNS in 2001 and retired in 2012. He continued the Department’s tradition of Paleoindian research, and he made new collections with an emphasis on Paleoindian sites in the Great Plains.

Curator of Archaeology Stephen E. Nash joined the faculty in 2006 and has spent a career systematically addressing the needs of legacy collections in museums. His field research focuses on west-central New Mexico with Michele L. Koons.

Koons arrived at the Museum as a post-doc in 2012 and was promoted to a curator position in 2013. She conducts field research at the Magic Mountain site in Golden, Colorado, in west-central New Mexico with Nash, and may return in the future to Peru to conduct Moche research.

Future of the Collection
To achieve our aspiration of curating the best understood and most ethically held collection means ensuring intellectual and physical control over the collection. In 2017 we obtained an NEH grant for $300K to move, organize, and rehouse the Archaeology Collection. This move is supported by our Collections Manager and Assistant Collections Manager, two temporary Collections Assistants, Native American Science Interns, and a team of 40+ volunteers. Together, and with our oversight, they are constructing archival mounts, ensuring organization of archival records and legacy data, and maintaining inventory control as the Archaeology Collection moves from the Figgins Storage Area into the Avenir Collections Center, which opened in 2014.

The moving and rehousing project began in early 2018 and is estimated to last until late 2020. A major component of this move is the reorganization of collections by culture area. (In addition to overcrowding, collections in Figgins were organized by material type.) The reorganization effort will improve accessibility for scholars, students, source communities, and the general public that in turn will facilitate humanities projects and research, cultural resilience, and scientific discovery.

Because archaeological research is inherently consumptive, because the archaeological record is a priceless, irreplaceable, and finite resource, and because the DMNS holds archaeological collections in the public trust, we have a moral and legal responsibility to systematically review and critically evaluate the Department’s archaeology holdings. Over the next several years the curators of the Archaeology Collection will continue to engage in such a review and evaluation as part of the Department’s Anthropology Collections Synthesis Project—a massive and systematic effort to better understand the Anthropology collections. The synthesis project is occurring concurrently with the NEH rehousing and move.

We are working toward reconstructing archaeological contexts where possible, reconciling orphan collections with their sources, and repatriating specific objects or entire collections as necessary. We strive to make these collections increasingly available to scholars and the general public through research, exhibition, publication, and the Internet. We will continue to make controlled, scientific
collections as part of our research, and we will consider the acquisition of privately held collections only
when a reasonable degree of contextual information is present and the curators deem the collection
important enough to maintain in the public domain. Our ultimate goal builds on the Folsom tradition and
seeks to transform an ad hoc collection into one that is systematically understood through the creation of
intimate linkages between objects, their contexts, and salient scientific research questions.

Collections lacking provenience information, that have little or no research value, that are not exhibition-
quality, that are on permanent loan from other institutions, that belong to federal agencies, or that can
be claimed under NAGPRA, will be proposed for deaccession. We do not believe that any of these
collections should be kept for their own sake.

The acquisition of new collections will be driven by curatorial research. Such collections will include
artifacts as well as faunal remains, pollen and phytolith samples, botanical remains, and sediment
samples.

Private collections will be considered for acquisition only when a reasonable degree of contextual
information has been recorded and if the curators deem the collection important enough to maintain in
the public domain. Under no circumstances will collections that violate the 1970 UNESCO Convention
be considered for acquisition.

4.2. Earth Sciences

4.2.1. Micromount Minerals
Curator: James Hagadorn
Plan author: James Hagadorn, Kristen MacKenzie, Nicole Neu-Yagle

Intellectual Framework
Minerals are the building blocks of rocks, typically visible as discrete individual units at the hand
specimen, hand lens, or optical microscope scale. They are characterized as naturally occurring,
inorganic crystalline solids, and in some minerals, especially clay minerals, their crystalline structure
cannot be observed optically, but can be detected by their ability to create regular diffraction patterns
with X-rays. Over five thousand minerals have now been identified, and, because they are crystalline
solids, each mineral is defined by fixed physical properties (some minerals have a range of
compositions between two end-member minerals, in which case they have a fixed range of physical
properties). Three common mineral physical properties are crystal form, crystal habit, and cleavage. The
first two properties refer to the shape of crystals that the mineral will grow if free crystal growth is
possible, and the mutual relations of these crystals. The third property is the property of some crystals to
break along preferred planes of weakness; a mineral may have one, two, three or more cleavage
planes, and these planes are sometimes, but not always, parallel to crystal faces. Mineral physical
properties are defined at the molecular level, and are independent of sample size, but small mineral
crystals are much more common than large crystals, but have all the properties of large crystals.
Collections of small mineral samples are known as micromount collections.

A micromount collection is a mineral collection made up of small specimens that require a microscope to
identify the mineral species. They are often mounted in small cubic boxes no more than approximately
20 mm on a side. Micromount collections are built by field collection of samples, by purchase and by
exchange with the global community of mineral collectors. Because the specimens are small and easily
transported, the availability of material is extensive and acquisition is relatively easy. As a result, a
micromount collection can be very broad in geographic scope and mineral species, often including
many species that are rare and expensive in hand sample size. Micromount specimens often exhibit nearly perfect a habit of crystal form based on the mineral structure, rather than a habit based on environment at formation. The many variations in the crystal structure of a mineral are also more readily found in micromount specimens. In some minerals, the theoretical crystal expression can only be readily found in micromount specimens. For research, comparison, and study, crystal habit (naturally occurring shape) is an important parameter in constraining the crystal lattice structure. Therefore, as research and study collections micromount collections are very valuable, and a large collection can be stored in a more restricted space than a hand sample collection. A microscope is needed to study micromounts, and imaging is needed for the public display.

Scope of the Collection
The Denver Museum of Nature & Science micromount collection is the third largest cataloged collection in the country, after the Los Angeles County Museum and Smithsonian collections. It is organized numerically based on the order in which its parent/donated collection specimens were acquired. The collection is completely catalogued, inventoried, databased, and housed in archival mounts, with no backlog of unprepared, unidentified, or uncatalogued specimens. There are approximately 22,000 specimens in the collection stored in small- to mid-size cases that comprise the volume of approximately four Steel Fixture cabinets. These cabinets are currently in the B2 Earth Sciences collections workshop. Specimens are mounted on posts and stored in small plastic and cardboard boxes, with lids, that are arranged in shallow trays. The micromount collection is basic reference material, very useful for comparison and research. Within the collection are large quantities of diamonds from the Paul Seel donation, which in aggregate have a high value. The diamond collection is the most diverse and one of the largest collections in the world, perhaps only smaller in scope than the DeBeers and GIA collections.

History of the Collection
The bulk of the collection was acquired through donations from Paul Seel, Shorty Withers, Willet Willis, and others. The Seel donation is noteworthy for its broad scope. Paul Seel was an avid collector and traded with colleagues around the world, acquiring specimens of minerals that are rare or unobtainable in this country. In addition, his collection contains many specimens from localities in the eastern US that have been destroyed over the years by construction in the sample locations, and some of those mineral species can no longer be easily acquired. The Seel collection of diamonds is large, in excess of 3000, and derives from many friends Paul Seel had in South Africa.

The micromount collection does not have a Colorado/Rocky Mountain focus: it is global in coverage, with a large (~8%) subcollection of South African diamonds. However, as the third largest micromount collection in the United States, this is a nationally significant collection. It is an excellent resource for reference and research due to its wide coverage in mineral species, crystal expressions, and geographic origins. The collection has a primary audience of the knowledgeable visitor, particularly collectors of micromount specimens, who would be able to use the collection for reference. Geologists working on the crystal habit of rarer or more unusual specimens are an additional audience. Because the specimens are small and best viewed under magnification, the collection cannot be exhibited as hand samples.

Future of the Collection
Significant growth in this collection is not anticipated, but if historically relevant collections become available, particularly if they are rich in diamonds, they should be acquired. Two volunteers are presently working on cleaning up locality data within the micromount database and integrating the
micromount database into Emu. Substantial work remains to scan and integrate historic specimen drawings and images of the collection into the database.

The potential of the micromount collection as a public or research resource has never been realized, despite a recent paper (Kosman et al. 2016) and two loans grounded in the diamond collection. The micromount catalog is not publicly available, except by request, and images of most of the samples are not available. The result is that few in the earth science community know that this collection exists and few visitors come to use it. We are working on a book and catalogue-style report on the collection, which will hopefully improve awareness. Publication of the micromount catalogue on the web and/or its integration into larger-scale searchable external databases could substantially change awareness and use of this collection, should the Museum make this a priority.

4.2.2. Mineral Collection
Curator: James Hagadorn
Plan author: James Hagadorn, Kristen MacKenzie, Nicole Neu-Yagle

Intellectual Framework
Minerals are the building blocks of rocks and mineral collections have traditionally formed one of the pillars of natural history museums. Because mining was one of the primary driving factors in the opening of the mountain west, and a component of the environment and natural history of the interior west, minerals of Colorado and the southern Rocky Mountain region are part of the overall collections mission of the Denver Museum of Nature & Science.

The underlying context of the southern Rocky Mountain regional terrain and environment is the geologic materials and processes that formed and maintain the area. The minerals in these materials have a significant control on the rate and style of the geologic process and the resultant geomorphology. The minerals also had a major influence on the human history of the area through mining. A study and knowledge of the minerals present in the southern Rocky Mountains region provides insight into the geologic processes that have acted through time in this region by providing opportunities to study chemical, isotopic, and radiometric age relations. Minerals are of sufficient significance to the State of Colorado that the Legislature has designated a State Mineral, rhodochrosite, and a State Gemstone, aquamarine, both minerals for which Colorado is distinguished for producing fine specimens.

Scope of the Collection
The mineral collection comprises more than 20,000 cataloged specimens which are organized geographically by country, state/province, and within Colorado, by county. The collection is completely catalogued, inventoried, databased, and housed in archival mounts, and has no historic backlog of unprepared, unidentified, and uncatalogued specimens. The biggest component of the mineral collection are specimens from Colorado, numbering over 6,000 specimens from about 500 different mines or quarries from nearly every region of the state. The collection includes prepared, unprepared minerals in their host rock, as well as gems, cabochons, a small number of set stones, and related mounted pieces.

The collections are completely catalogued, inventoried, and archivally housed in padded trays or mounts, and are stored in 48 cabinets in the B1 Earth Sciences collections storage room in the Avenir Collections Facility. The high-value portion of the collection is stored in a secure subsection of this room. Approximately 96 specimens are housed on three pallet-style racks, also in this room. Approximately 1,100 specimens are on display in the Coors Mineral Hall.
Iconic specimens in the collection include the Alma King rhodochrosite and the Coors Pocket rhodochrosite wall from the Sweet Home mine; the Diane’s Pocket aquamarine slab; the gypsum/selenite cave deposits from the Naica and El Potosi mines in Chihuahua, Mexico which make up the Crystal Cave display in the mineral hall; gold specimens such as Tom’s Baby, the Campion Gold Collection, and the Summitville gold boulder; and the Smoky Hawk King amazonite. The Alma King rhodochrosite is the finest large rhodochrosite specimen in the world, and has been described as the best mineral specimen found in North America. The Diane’s Pocket aquamarine slab is the largest slab of aquamarine crystals found in North America. Tom’s Baby is the remaining 8.5 lb portion (5 lbs is missing) of the largest gold nugget ever found in Colorado. The Campion Gold Collection is a world-class gold collection donated to the Museum by John F. Campion, a founding father and first President of the Museum. The Smoky Hawk King is the largest plate of amazonite crystals in the world and awaits preparation and display. Specimens of high intrinsic value also include tourmalines donated by the Oreck family, a large mesolite specimen on display from the hills around Poona, India, and a 10,588 carat topaz once owned by Salvador Dali.

The Konovalenko gem carvings, on display on the third floor of the museum, are another iconic collection of DMNS. Although they are not considered mineral specimens and do not belong to the museum but to the DMNS Foundation, the Curator of Geology is charged with their care. These iconic folk-art carvings are composed entirely of rocks, minerals, fossils, and a minor amount of cloisonné and metal. They are of great historic and commercial value.

Samples in approximately 10% of the collection are of sufficient size and/or quality that they could be used in public exhibits. The remainder of the collection is research-grade minerals, mostly from quarries or mines in the southern Rocky Mountain region or synoptic reference materials. Some of the material in the collection is of historic value because the specimens come from sites that are no longer accessible or that no longer exist.

The Colorado minerals currently in the collection were not acquired as a directed project and there are significant gaps in geographic and mineralogical coverage. In the Rocky Mountain west the greatest diversity in mineral species comes from mining districts. Some mining districts are well covered in the collection, especially from well-located mineral claims, but others are only sparsely represented. Although the catalog information for most of the Colorado collection is relatively complete, provenance information for many closed mines is obscure because the locations of these mines are not given in the recorded data nor are they located on modern maps.

History of the Collection
The majority of the mineral specimens were acquired through donations. One of the early major donations to the collection was the John F. Campion Gold Collection. Subsequent major donors have been Henry Aarnes (1962), Thomas Addenbrooke (1986), John H. Alexander (1978), Florian Cajori (1977), E.W. Heinrich (1981-1982), Sadie House (1912), Verne Reckmeyer (1996), and Shorty Withers (1971-1984). Recently the Oreck family, particularly Bruce Oreck, have become significant donors. Other specimens were acquired via individual donations and purchase as specimens deemed necessary to fill gaps in the collections as they became available.

R.C. Hills was the first curator of the mineral collection (1911-1923), replaced by Frank Howland (1923-1937) and then Harvey C. Markman (1936-1955). The first curators added about 140 specimens to the mineral collection by collecting, being more process geologists or paleontologists than descriptive geologists. Jack Murphy became curator in 1968 and retired in 2004 and collected about 300 mineral specimens. Paul Morgan served as geology curator from 2006 to 2008. Logan Ivy
served as interim curator for the collection between Jack Murphy and Paul Morgan, followed by Ian Miller from 2008-2010. Curator of geology James Hagadorn currently shepherds the mineral collection.

**Future of the Collection**
Denver is one of the nation’s historic and present-day epicenters for minerals, whether as part mining or as part of the collectible industry. The DMNS collection is an excellent archive of the milestones of this history. Yet despite its scope and condition, little scholarly research has been conducted on the museum’s mineral collection in the last twenty years—principally because the database of the DMNS mineral collection is not available online to the global scientific and avocational communities, and because much of the collection is more of interest to the collector community than to the scholarly community. Publication of the mineral catalogue on the web and/or its integration into larger-scale searchable external databases could substantially change awareness and use of this collection, should the Museum make this a priority.

The DMNS mineral collection will likely grow modestly in the coming years, either through strategic acquisitions or opportunistic donations. Broadly speaking, the Museum ought to augment the collection when historically relevant or iconic display-caliber Rocky Mountain specimens become available. Acquisition of new specimens for research, for educational purposes, or to fill regional or geographic gaps in our collections ought to be done as well, but principally through opportunistic cultivation of donations of local collections. At present, specific targets for acquisition include the Centennial Diamond (or its ‘sister’ stone), a suite of representative historical jewelry containing Stateline District diamonds, a suite of jewelry containing Italian Mountain lapis, a suite of macroscopic (1 cm diameter or larger) euhedral Colorado zircons, a macroscopic sample of cahnite, and the molybdenite specimen on display in the offices of the soon-to-be-closed Henderson Mine.

**4.2.3. Rock Collection**
Curator: James Hagadorn
Plan authors: James Hagadorn, Kristen MacKenzie, Nicole Neu-Yagle

**Intellectual Framework**
A rock is an aggregate of one or more minerals or fossils. The composition and structure of a rock records its environment and history of its formation, as well as information about its history since formation. The geologic history of Colorado and the Rocky Mountain region is complex, including repeated episodes of marine and continental sedimentation and multiple events of orogeny and erosion. The physical evidence of that history is contained in the rocks found in the mountains and plains of the area. A thorough understanding of the history involves the study of these rocks. Interpretation of that history to the public audience of the museum requires these rocks as examples: tangible objects supporting the historical interpretation. Rocks are exposed in outcrop over much of Colorado and the Rocky Mountains, and in drill-core samples; knowledge of the rock types and their formational processes can lead to a better public understanding of the environment and the influence that geology has on that environment. Rocks also represent economic resources, such as energy and mineral resources, building materials, water resources, and aesthetically pleasing environmental settings.

The presently intended audience for the rock collection is the general public, with increasing growth of the research-focused and historically-focused portions of the collections.

**Scope of the Collection**
The rock collection consists of over 1,000 cataloged specimens stored in eight cabinets and on one shelf of a pallet rack in the B1 Earth Sciences collections storage room in the Avenir Collections Facility.
With the exception of specimens that are part of two recent large collections donations (described below), the rock collection is completely catalogued, inventoried, databased, and housed in archival mounts, and has no historic backlog of unprepared, unidentified, and uncatalogued specimens. The collection is organized by rock type (i.e., igneous, metamorphic and sedimentary); it largely consists of reference and historical specimens, with a growing suite of rocks from Colorado rock formations. The collection is anchored by suites of rocks from the Rocky Mountain region, a collection of building stones, by selected regional collections like a suite of kimberlite samples from the Stateline Diamond District, and a global suite of K-T boundary rocks from Glenn Izett.

History of the Collection
The origins of the rock collection are donations from various individuals, transfers from the National Park Service of Yellowstone material, targeted collections made by Jack Murphy, and donation of building stones from quarry owners. Major donors of various non-building stone rocks include Geoff Dunn, Wallace Hansen, and Henry M. Porter. About 22% of the rock collection has no donor or collector information, but these specimens were most likely collected in the course of museum field trips or were donated in the early days of the museum. Most of these specimens have provenience information, however, and are useful for that reason. The current rock collection is mostly from Colorado and the Rocky Mountain region.

Future of the Collection
The rock collection has potential for moderate to substantial growth in the coming years. Broadly speaking, the Museum ought to augment the collection when historically relevant or iconic display-caliber Rocky Mountain specimens become available, or when it is possible through donations or opportunistic collection to fill regional or geographic gaps in our collections. At present, specific targets for growth include a Silurian xenolith from the Stateline Diamond District, a diamond-bearing kimberlite from Ed Warner’s collection, a Morrison Formation stromatolite, and a piece of orbicular granite from south-central Colorado. Known sources of growth include recently acquired collections from Stew Hollingsworth and Lee Shropshire, together with incoming Cambrian, Devonian, Permian, Triassic, and Jurassic rocks being collected as part of James Hagadorn’s research, and Paleocene rocks that are part of the Colorado Springs Project.

No scholarly research has been conducted on the museum’s rock collection—principally because its catalogue is not available online to the global scientific communities. Publication of its catalogue on the web and/or its integration into larger-scale searchable external databases could substantially change awareness and use of this collection, should the Museum make this a priority.

4.2.4. Meteorites
Curator: James Hagadorn
Plan authors: James Hagadorn, Kristen MacKenzie, Nicole Neu-Yagle

Intellectual Framework
Meteorites are samples of solid material that have fallen to Earth through the atmosphere, originating from locations other than Earth. They are primarily materials that condensed and aggregated during the very early history of the Solar System but which did not aggregate to one of the final planetary bodies or their satellites. Most meteorites are believed to have formed from material in the inner Solar System and originate from bodies known as asteroids which orbit the Sun. The greatest concentration of asteroids is between the orbits of Mars and Jupiter; most of these asteroids have roughly circular orbits, but some have significantly elliptical orbits. Some of these elliptical orbits cross Earth’s path of travel, giving the potential for collision with Earth. When asteroids enter Earth’s atmosphere they become incandescent
through frictional heating. When transiting the atmosphere an asteroid is known as a meteor. Most asteroids with orbits that transect Earth’s orbit are very small and ablate in the atmosphere, leaving no remains. If a meteor is sufficiently large to survive transit through the atmosphere and impact with the surface of Earth, any remaining fragments are known as meteorites. Asteroid impact velocities with Earth are typically of the order of $10$ m/s ($22,500$ m.p.h.) and large asteroids (>30-50 m) are not significantly slowed in their transit through the atmosphere: they impact the ground at many times the speed of sound and explode in the subsurface, typically vaporizing the impacting body and some of the target material, leaving few remains of the impacting body. Thus, meteorites are derived from a limited size range of asteroids—those large enough to survive transit through the atmosphere, but not too large to self-destruct on impact. Meteors may start to break up in the atmosphere before impact, with smaller pieces slowing in the atmosphere much more than the main body. This is what occurred at Barringer (Meteor) Crater, Arizona, where there are many meteorite fragments (Canyon Diablo meteorites). Early attempts to locate the main nickel–iron meteorite beneath the crater by drilling and magnetic surveys were unsuccessful, and later calculations have concluded that the main body vaporized during the explosion that formed the crater.

A relatively small number of meteorites do not fit chemically or minerallogically into the main evolution sequence of the majority of meteorites. These meteorites do fall into distinct groups, however, and one group is mineralogically and chemically identical to the lunar samples returned by the Apollo missions. These meteorites are so similar to the Apollo samples that the only reasonable conclusion is that they came from the Moon. Most impact craters on the Moon are very circular, not because the impacts were formed by vertical impacts, but because very high-velocity impacts penetrate into the surface before the kinetic energy is released, and the result is more like an underground nuclear explosion than a slow-velocity angle-impact. At a few sites, however, very elongated craters are visible, evidence of impacts where the impacting body did not penetrate into the subsurface. At these sites, a fragment of the surface could have been ejected into space with sufficient velocity to escape the Moon’s gravity, and at some later time collide with Earth. These meteorites have significantly younger ages than the main sequence meteorites and are generally accepted to be lunar in origin.

A second group of younger meteorites have very different composition from the lunar meteorites and the main sequence meteorites. These meteorites have small bubbles of gas in them, whereas in most meteorites any holes are essentially void of gases. The composition of gases in these bubbles is identical, within experimental error, to the composition of the Martian atmosphere, as measured by the Mars Viking Mission landers in 1976. Thus, we conclude, that this group of meteorites probably originate from the surface of Mars by oblique impact ejection. Unfortunately, we do not know the site of their ejection and the surface of Mars is quite heterogeneous, but they are the only samples that we have of Mars to date. Other younger meteorites have unknown origins, but probably originate from the surface of some of the larger asteroids.

Studies of meteorites provide information about the origins, evolution, and present day composition of the solar system. Meteorites arrive on Earth with no discernable pattern, and in most areas are found by chance. When a large meteor (fireball) occurs, especially if there are sufficient sightings, the chance of discovery is increased and the area of impact can likely be determined. However, with the exception of Antarctica, no one area of Earth can be said to be a primary source for meteorites. The probability of meteorite material hitting Antarctica is no higher than any other area on Earth, but some Antarctic glaciers create a special discovery environment when, instead of calving into icebergs at the continental margin, they sublimate and recycle meteoritic material to the surface. In such areas of blue ice on zones of wind ablation of the glaciers, small meteoritic fragments are concentrated where they are relatively easy to identify. Elsewhere, meteorites on the earth’s surface are usually quite long lasting, so over time
there is a chance they will be found and can then be studied. However, there is a problem of their identification. Iron meteorites are the most readily identified as metallic iron is not a common natural earth material. Iron meteorites represent ~50% of general meteorite finds, but only represent 4% of Antarctic meteorites (which are thought to be an unbiased sample). Stony meteorites are less easy to distinguish, especially if a meteorite is not suspected in an area.

Meteorites have little intrinsic value, but are very important for research. They are often leveraged to explore questions about the solar system or deep-time questions about our planets. For outreach, the specimens have special value for audiences interested in planetary evolution, matters relating to space science, and the night time sky phenomena of meteor showers and fire balls. Meteorites also have high collectible value and are often sold as slices, with value dictated by their weight, composition, type, aesthetic, and historic provenance.

**Scope of the Collection**
The meteorite collection at DMNS consists of specimens from around the globe, with more emphasis, numerically, on those from North America. The collection is completely catalogued, inventoried, databased, and housed in archival mounts, with no backlog of unprepared, unidentified, or uncatalogued specimens. The collection is organized alphabetically based on the name of the meteorite or, if it is unnamed, based on the name of the location of where it fell. Of special interest are those meteorites that were found in Colorado. Most of the specimens are fragments of meteorites, including thin sections (which make up ~17% of the number of specimens in the collection). The majority of the collection is iron meteorites which are opaque and for which thin sections are inappropriate. There are 686 specimens in the meteorite collection that are housed in two cabinets in the B1 Earth Sciences collections storage room in the Avenir Collections Facility, as well as a suite of larger specimens stored on the bottom shelf of a pallet rack in that room.

Meteorites have formal names that are recognized and published the Natural History Museum in London. The formal names are based on geographic origin of the finds, designate discrete impacts or falls. The number of discrete fall events, or formally named meteorites, represented in the collection is 257. Some events are represented by many specimens, such as the Canyon Diablo meteorite from Barringer (or Meteor) Crater, Arizona, which is represented by 178 specimens.

Most of the meteorite collection consists of specimens of general interest, with some high interest specimens such as the Johnstown, the Zagami (two small sections of a Martian meteorite), and the Cotopaxi. The Canyon Diablo meteorite is mostly of iconic value, based primarily on length of display and publicity about the impact crater in Arizona. The collection contains no common specimens.

**History of the Collection**
DMNS has acquired meteorites for purposes of study and display from many sources and from many areas of the globe. Meteorites were first collected at the museum by H. H. Nininger in the 1930’s: he traveled the Rocky Mountain region collecting, buying, and accepting donations of meteorites. When Nininger left the museum he took most of his specimens with him to Tucson. The museum acquired a collection of 183 meteorite specimens, from 20 separate fall events from D. M. Gillespie in 1956. Over the time of the curatorial tenure of Jack Murphy, meteorites were acquired as specimens or funds became available. Starting in about 1995, Jack Murphy began to record fireball information gained from the public in an attempt to find meteorites whose location could be approximated. He also began to more actively acquire specimens through purchase, exchange, and donation, usually acquiring one specimen at a time. One multiple purchase was a series of thin sections of specimens of global distribution purchased from Blaine Reed in 1999.
The meteorite collection is of moderate size when compared to collections in many other institutions. The primary use of the meteorite collection at DMNS is educational and for exhibition purposes. The collection contains examples of most of the different meteorite species, and some of the specimens are very striking as display specimens. Meteorites are fundamental artifacts in demonstrating knowledge of the origin and composition of the Solar System, particularly the Inner Solar System, including Earth.

The collection includes a number of Colorado meteorites, but as the locations of meteorite impacts are chance events relative to state boundaries, these meteorites cannot be genetically related to any other Colorado earth science feature other than geography. However, in terms of spectacular, random, newsworthy celestial phenomena occasionally seen in Colorado meteors (fireballs) are probably the most prominent, and suspected meteorites dominate the geological samples brought DMNS for identification. There is therefore a continuing awareness of meteorites in Colorado through natural phenomena and high level of public interest in meteorite samples at the Museum. Thus, although a strong scientific argument cannot be made for a genetic connection among meteorites and Colorado or the southern Rocky Mountains, meteorites and related phenomena are of sufficient prominence in this region to demand a level of public interest that makes a meteorite collection at DMNS highly desirable.

Future of the Collection
The public has become cognizant of the importance and value of meteorites in recent years, with the result that the commercial value of specimens has increased dramatically and future donations are extremely unlikely. The museum has a sufficient number and range of meteorite specimens for education and exhibit purposes. No scholarly research has been conducted on DMNS meteorites in the last twenty years—principally because better repositories of meteorites exist at the Johnson Space Center and at Arizona State University, and because the database of the DMNS meteorite collection is not available online to the global scientific and avocational communities. Publication of the meteorite catalogue on the web and/or its integration into larger-scale searchable external databases could substantially change awareness and use of this collection, should the Museum make this a priority.

No major active growth of the meteorite collection is planned, but the museum should pursue any complete specimens of meteorites that fall in Colorado or vicinity, as well as any Venustian meteorites (should one be discovered and confirmed).

4.2.5. Vertebrate Paleontology
Curators: Joseph Sertich, Tyler Lyson, David Krause, and Richard Stucky (emeritus)
Plan authors: Joseph Sertich & Richard Stucky

Intellectual Framework
The Vertebrate Paleontology Collection was initiated in 1910 with the purchase of the R.C. Hills fossil collection of various fossil specimens on loan to the museum. The original impetus for the creation of this collection was exhibition and display, with fossils initially occupying three cases. The focus has since shifted to one of research and volunteer/student training, although display still remains important for high quality specimens. The collection has now grown to more than 292,477 cataloged specimens and lots, of which more than 280,000 have been collected from the Rocky Mountain Region since 1988. This significant growth has been accomplished using modern geological and paleontological field techniques as well as acquisition of established, catalogued collections. As a result, the collections are extremely well documented and of high value in addressing contemporary research questions related to the history of life, evolution, paleobiogeography, paleoclimate, and paleoecology.
The collection is divided into 1) exhibit specimens in Prehistoric Journey and elsewhere in the Museum, which target the museum visitor, and 2) research collections currently housed in two major storage spaces. The collection is used by scientists (both internal and external) and students in university (e.g., undergraduate research, Master’s, and PhD projects) and high school (e.g., Teen Science Scholars) programs. A number of high quality specimens, including articulated skeletons, are held within the scientific collections but are equally significant for their display potential.

The vertebrate paleontological collection preserves 74 holotypes, which serve as the morphological standards for various taxa. The holotypes are used by researchers, primarily for alpha systematics, although two biomechanical studies have been undertaken (e.g., Thalassomedon hanningtoni). About 125 real fossil bone specimens are displayed in Prehistoric Journey, where they illustrate the history of life. The research specimens, consisting of more than 2 million objects, have been used by both internal and external researchers, including curators, staff, professors, students, and volunteers. Since 1988, more than 500 books, scientific papers, abstracts and popular articles have been published on the vertebrate fossil collections.

Growth is currently focused on the research collection, with emphasis on Late Jurassic through Late Cretaceous vertebrates of western North America, Paleogene vertebrates of Wyoming and Colorado, Neogene vertebrates of Colorado, and Late Cretaceous vertebrates of Madagascar. These specimens form the core of active research by the curators, staff, research associates, students, and volunteers. Significant specimens discovered over the past 20 years include new vertebrate taxa and partly complete specimens that will be used as type specimens of new species, figured specimens for new anatomical detail, and for the analysis of morphological variation and function. The recent collections of fossil mammals and reptiles, in particular, have been documented in stratigraphic sections lending them to detailed analyses of patterns of evolution and systematics.

Scope of the Collection
The vertebrate collection contains more than 292,477 cataloged specimens and lots currently in the electronic database. As of the end of June 2018, our records show that the collection contained the following numbers of specimens of different classes of vertebrates:

<table>
<thead>
<tr>
<th>Class</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishes</td>
<td>17,410</td>
</tr>
<tr>
<td>Amphibia</td>
<td>8,578</td>
</tr>
<tr>
<td>Reptilia</td>
<td>13,564</td>
</tr>
<tr>
<td>Aves</td>
<td>187</td>
</tr>
<tr>
<td>Mammalia</td>
<td>159,519</td>
</tr>
</tbody>
</table>

In addition, some specimens have been cataloged in bulk, so that a number receive the same catalogue number (e.g., crocodyliform teeth from the Denver Basin) or consist of “lots” awaiting full curation. Thus, the total number of specimens in the collection exceeds 2 million objects. The collection also includes casts of holotype and significant specimens from other museum collections, used in research.

Five to ten thousand specimens are added to the research collection each year by curator-driven field work and collection acquisition. These specimens are accessioned during the year in which they are collected/acquired. The vertebrate fossil collection also contains several institutional icons. These include the skeletons of dinosaurs and large mammals, such as Diplodocus, Allosaurus, Stegosaurus, Torosaurus, Megacerops, Amebelodon phippsi, Thalassomedon, and numerous Mammut. It is fair to say that the general public associates these specimens with the Museum and, in the public’s eye, they are the specimens that are most commonly remembered. The collection contains 74 holotype specimens that serve as morphological standards for their respective species. In addition, some specimens in the
collections come from localities currently inaccessible (Kessler Stegosaurus locality; Carnegie Quarry, Dinosaur National Monument, Porcupine Cave, Ziegler Reservoir Snowmass, Thornton Torosaurus), thus providing greater historical/scientific value.

The vertebrate collection contains several large seminal collections from single quarries that are being used for demographic and paleoecological studies. Some of these include: Gastonia lorriemcwhinneyae from the Cedar Mountain Formation, Trigonias from two different Trigonias quarries, Megocerops from the Titanothere Quarry, mixed taxa from the Bones Galore locality, Mammuthus from the Dent Site, the faunal assemblage from the Pleistocene Snowmass site, and Eocene Buck Spring Quarries.

Because much of the collection has been acquired over the past 30 years, the majority of specimens have well-documented locality and geological information. These well-documented collections are especially valuable for future evolutionary, paleobiogeographical, paleoclimatological, and paleoecological studies. In the past, the Earth Sciences department deaccessioned collections of no educational, scientific, or display value. Currently, collections are only made/acquired that meet the highest of curatorial and data standards.

**History of the Collection**

Information regarding the history of the growth of the vertebrate collections is taken from the Annual Reports (1910–present) and the recently completed history of paleontology at DMNS by Richard Stucky and Kirk Johnson (DMNS Annals 4, 2013). Paleontological specimens associated with archeological sites are not included in this report (e.g., Folsom Bison and points—see Archaeology Collections).

The vertebrate fossil collection began with the purchase of a small collection in 1910 from Richard C. Hills, a prominent local geologist. The specimens included fishes and rays from the Green River Formation, mastodon teeth, jaws and tusks, and the skull of an oreodont mammal. The specimens were on loan to the museum for display prior to their purchase. To increase the number of specimens on display, the Museum’s director, J.D. Figgins, sent the museum’s first expedition to Florissant, Colorado in 1914. The following year, the museum acquired, through donation, a partial Diplodocus from the Morrison Formation north of Cañon City, Colorado. Following this donation, active collecting in Cenozoic and Cretaceous strata from neighboring states led to the discovery of numerous important specimens. Many of these specimens were described by external paleontologists (e.g., Osborn, Brown, Hay), many collaboratively, in the Museum’s scientific publication, the Proceedings of the Denver Museum of Natural History.

In 1920, the "Trigonias Quarry" became the first major vertebrate fossil quarry in Colorado, discovered in the White River Formation of Weld County. This and several other sites in adjoining counties were worked by the Museum sporadically over the next decade. Skulls and skeletons of titanotheres, rhinoceroses, and giant pig-like mammals (Archaeotherium) were collected from these sites and put on display or traded with other museums, including the American Museum of Natural History, Carnegie Museum of Natural History, Los Angeles County Museum, and the University of California Museum of Paleontology. In exchange, the Museum acquired some of its premier exhibit specimens: Diplodocus, Edmontosaurus, Rancho La Brea skeletons of Pleistocene mammals, and others.

Initially, specimens collected and acquired were displayed in Standley Hall. These exhibits were reinstalled in 1924, when the Fossil Mammal Hall opened. Featured specimens included those collected from the White River Formation of Weld County, Colorado and Mio-Pliocene mammals from the Ogallala Formation near the Kansas border. The Museum’s large Columbian Mammoth went on
display in 1931. Due to space constraints, the Museum’s first dinosaur specimen, the *Edmontosaurus*, did not go onto exhibit until 1935. In 1941, the Fossil Mammal Hall was renovated and specimens were arranged geochronologically.

Fieldwork slowed considerably in the late 1930s and basically stopped in 1939 due to the age of Philip Reinheimer, the Museum’s renowned preparator. After Reinheimer’s retirement, Robert Landberg took over as Head of the Paleontology Department, but departed after only a few years. The Paleontology Department was combined with the Geology Department in the early 1950s and Harvey Markman was appointed as dual curator of Geology and Paleontology. There was no growth of collections during this interval except for sporadic donations. Paleontology was reactivated in 1969 with the appointment of Charles Crockett as Curator. Crockett later became the Museum’s Assistant Director in 1971 and Don Lindsey was hired as Assistant Curator of Paleontology in the Geology Department. From 1971 to 1985, collections were made from various localities in Kansas, Colorado, Wyoming, Nebraska, and South Dakota. The collections grew minimally between 1971 and 1985.

Paleontology at the Denver Museum of Nature & Science ceased completely in 1985 but was quickly resumed in 1989 when plans were initiated to develop a new paleontology exhibit and paleontology program – Prehistoric Journey. Richard Stucky (1989-2014), Kenneth Carpenter (1990-2010), Bryan Small (1990-2012), Kirk Johnson (1991-2012), and Logan Ivy (1992-2016) were hired as part of this initiative. Following the completion of the exhibit, Russ Graham joined the Museum as Department Chair and Curator of Vertebrate Paleontology in 1996. Graham left the Museum in 2004 and Greg Wilson was hired as a paleontology Curator. Wilson and Carpenter left the Museum in 2006 and 2009, respectively. Stucky became the chief curator and vice president in 1996 and continued in this role until 2006 when he became the Curator of Paleoeocology and Evolution. Stucky retired in early 2013 but has maintained his relationship with DMNS as Emeritus Curator of Vertebrate Paleontology. All of these scientists have had active field collecting programs since then and added more than 60,000 specimens to the collections of vertebrates between 1988 and 2011.

In 2011, Joseph Sertich was hired to fill the role of Curator of Dinosaurs soon after the departure of Ken Carpenter and in the midst of the major Snowmass Pleistocene collecting effort. His arrival initiated a renewed effort to build upon the fieldwork and laboratory strengths of the vertebrate paleontology program, initiating campaign-style field efforts as part of the Laramidia Project (Campanian of Utah and New Mexico) and Madagascar Paleontology Project, among other efforts to expand collections through acquisitions and targeted fieldwork. Following the retirement of Richard Stucky, Tyler Lyson was hired in 2014 and contributed to the expansion of fieldwork and research through work in the Hell Creek/Fort Union formations (North Dakota and Montana) and expansion of Denver Basin fieldwork on Paleocene fossils in 2016. David Krause was hired into a term Senior Curator role in late 2016 to help shepherd the fossil mammal collections and assist in the transition of the Madagascar Paleontology Project to DMNS. This decade (2010-2020) has witnessed the most dramatic growth of the vertebrate paleontology collections through major projects (e.g., Snowmass, Laramidia, Hell Creek, Denver Basin, Madagascar) and acquisitions/transfers (e.g., Madagascar, Hankla Family Collection, Marmarth Research Foundation Collection, Triebold-Sandy Site, Rose-Willwood, Weege/Schmude-Morrison). During this period, many other staff were added, in part to assist with the dramatic influx of specimens including laboratory preparators Heather Finlayson (2010–2014), Adam Behlke (2015–2016), Mike Getty (2013–2017), Natalie Toth (2017–present), and Salvador Bastien (2018–present), and collections managers Kristen MacKenzie (2015–present) and Nicole You-Nagle (2018–present). The ability to conduct digital preparation of fossil vertebrate specimens was added to the DMNS through the initiation of the Digital Research Lab in 2017. This lab, headed by lead technician Lindsay Dougan
(2017–present), uses state-of-the-art imaging techniques to reveal the internal anatomical structure of fossil specimens, particularly skulls.

A portion of the fossil vertebrate collections belongs to DMNS through donations by private landowners or collectors including several major collections (e.g., Porcupine Cave Pleistocene). However, a significant portion are curated and maintained in trust for the State of Colorado, collected through regional efforts (e.g., Denver Basin Cretaceous/Paleocene) and major salvage (e.g., Snowmass Pleistocene). Most specimens held in trust by DMNS, collected from US Federal lands including the Department of the Interior Bureau of Land Management and USDA Forest Service, form the foundation of the research collection.

**Future of the Collection**

Growth of the Vertebrate Paleontology Collection is now based on various research projects and salvage projects that represent extraordinary opportunities for collections enhancement. Specimens are currently being collected from the Morrison Formation of Colorado; the Kaiparowits and Wahweap formations of Utah; the Fruitland and Kirtland formations of New Mexico; the Hell Creek and Fort Union formations of North Dakota, South Dakota, and Montana; the Lance Creek Formation of Wyoming; the Maevvarano Formation of Madagascar; the Laramie and Denver formations of Colorado; the Wind River, Willwood, and Bridger formations of Wyoming; and various Paleogene and Neogene localities in Colorado. Volunteers and interns in the field and the fossil preparation laboratory assist with the collection and preparation (both mechanical and digital) of these specimens. Future collecting will aim to develop a more comprehensive synoptic collection of vertebrates from the Mesozoic, Paleogene, and Neogene of the Rocky Mountain/Great Plains region to aid in future research and educational training. The strategy will employ both curator research projects as well as field projects directed by DMNS research associates and through strategic partnerships with external paleontologists/collectors.

Specimens are also acquired through donation, purchase, and as a result of repository/curatorial agreements with firms that conduct environmental impact statements. Specimens are accepted or purchased if they represent significant additions to the collections or contribute significantly to holdings from the Rocky Mountain and Great Plains regions. Clear title must be documented and collections must have precise locality data.

The growth of the vertebrate fossil collection has historically concentrated on the Rocky Mountain and western Great Plain regions, especially Colorado, Montana, New Mexico, North and South Dakota, Utah, and Wyoming. This strategy will be employed in the future, though research collections from international localities of high research value, such as the Cretaceous of Madagascar, will also be pursued.

4.2.6. **Paleobotany**

Curator: Ian Miller

Plan author: Ian Miller

**Intellectual Framework**

Plants are the basis of all terrestrial ecosystems and have been so since they first colonized land more than 400 million years ago. The fossil remains of plants provide a record not only of the evolution and extinction of plants and how our modern flora came to be, but also offer the best method to reconstruct ancient ecosystems and climates. The Rocky Mountain and Great Plains region contains an excellent fossil plant record that ranges from some of the earliest land plants found anywhere on earth (Early Devonian, 395 Ma), to the geologically recent record of the origin and spread of the grasslands (early
Miocene, 20 Ma), and to the “re-greening” of the Rocky Mountains after the last Ice Age (Late Pleistocene, 18 ka). For the period between 100 and 45 million years ago (Late Cretaceous, Paleocene and Eocene), this region contains the most abundant fossil floral record yet discovered on earth (measured in number, quality, density, and diversity of the fossil sites and the extensive exposures of rock with potential for the discovery of new sites). Research on fossils of this age provides detailed understanding of the evolution, palaeoecology, and paleoclimate of extinct ecosystems and forms a framework for understanding associated extinct terrestrial animals (e.g. dinosaurs, early placental mammals, early primates, etc.). Finally, plant fossils from the Rocky Mountain and Great Plains region give us the global standard by which we understand the nature of plant life during the most recent and sustained greenhouse climate (~90 to 50 Ma), and across the last great extinction in earth’s history (K-Pg). Ultimately, fossil plants from the Rocky Mountain and Great Plains provide compelling evidence that help us understand our current warming world and ongoing mass extinction. As such, the DMNS paleobotany collections support ongoing research, exhibits, and outreach focused on the fossils plants of the Rocky Mountain region.

The collection of fossil plants is the basis for the ancient ecosystem reconstructions presented in Prehistoric Journey exhibit and book, in the exhibit and integrated paleo-themed art at the Denver International Airport (DIA), in the Ancient Denver exhibit and book, in the Ancient Colorado installation at the Colorado Convention Center, and in the Digging Snowmastodon book and related materials. Fossil plants are literally the medium of time travel to lost worlds. DMNS has used fossil plants more effectively for this purpose than any other institution in the world. This strength is in part related to the institutions long history of creating place-specific dioramas, a methodology that was imported to the dioramas and enviroramas in Prehistoric Journey.

DMNS collects fossil plants because the Rocky Mountain region has a significant untapped resource of fossil plants that contains the answers to significant questions. No other institution in the American West presently maintains a large fossil plant collecting program. In addition to purposeful collecting, the rapidly growing population of the Colorado Front Range inadvertently presents fossil plant collecting opportunities through the creation of construction-related excavations. These salvage discoveries are one time opportunities and thus represent an obligation to prevent loss of scientific information.

**Scope of the Collection**

The paleobotany collections at DMNS are composed of fossilized plant remains spanning the history of plant life on land. The collection is closely focused on the Rocky Mountain and Great Plains region, arguably the most prolific fossil plant producing regions in the world. Fossil plant specimens include compression and impression fossils on stone matrix, petrified trunks and stems, palynological slides, and bulk samples and residues. The following sections are broken out into the megafloral collection (almost exclusively fossil leaf impression/compressions) and the palynological collection.

The paleobotany collection (megafloral and palynological) at DMNS is one of the four largest and best curated collections of Late Cretaceous and Paleogene plant fossils from the Rocky Mountain and Great Plains region. The Smithsonian collection is larger and contains most of the type specimens but much of it was collected more than 50 years ago, its provenance data is variable, and its current curation state is poor. The Yale Peabody collection contains the orphaned collections of Princeton University and the New York Botanical Garden as well as a number of significant recent collections, including those from the Hell Creek and Winthrop Formations that have counterparts in the DMNS collection. Finally, the University of Florida Museum has a strong representation of Cretaceous through Eocene plants and is continuing to grow. This collection is most comparable to the DMNS collection.
**Megafloral collection:**
The megafloral collection consists of an estimated 86,821 specimens as of 1/1/2018 from 1,475 discrete quarries in 129 geological formations from more than 20 US states, 4 Canadian Provinces, and 12 countries. A total of 24,669 specimens have been catalogued and the remaining collection is in process with a current effort by collections management to catalog the entire collection. Of the catalogued specimens, 1,390 are identified as holomorphotypes. The collection is particularly strong in fossils from Late Cretaceous (100-65.5 Ma) and Paleogene (65.5-25 Ma) rock units of the Rocky Mountain region.

The megafloral collection presently occupies 23 Delta Design RCD1a cabinets located on the northern half of the Earth Sciences collections space in B2 of the Avenir Collections Facility. Additional oversized specimens are housed on 8 pallet rack shelves at the southwest end of the facility. Specimens in process between the field and the collection space are stored in corrugated cardboard flats and larger cardboard boxes. Currently, there exists minimal preparation or curation backlog. In general, specimens are sorted by collection locality, which typically represents a 1-3 cubic meter hole in the ground. The number of specimens per locality ranges from 1 to more than 4,000. In many cases, quarries are collected in an unbiased manner in order to obtain an estimate of the relative abundance of various species in each quarry. These “census” collections typically contain more than 300 specimens and are subject to “high-grading” after scientific analysis. Given the present state of taxonomy in compression fossils, most DMNS specimens are identified at the species level using a parataxonomic morphotype method.

The most significant suites of specimens include:

**The Denver Basin collection.** A suite of approximately 20,000 specimens from Late Cretaceous, Early Paleocene, and Early Eocene strata collected at over 400 salvage sites and natural outcrops since 1991. This collection includes the 64 Ma Castle Rock Rainforest, which numbers nearly 10,000 specimens and represents the oldest known tropical rainforest, and the Corral Bluffs collection, a suite of about 5,000 specimens that compliments the exceptional vertebrate remains from the area.

**Fox Hills, Hell Creek and Fort Union collection.** A collection on more than 12,000 Late Cretaceous and Early Paleocene plants from over 100 localities in southwestern North Dakota and northwestern South Dakota. This is the most complete K-T boundary floral collection in the world.

**Green River collection.** A large suite of more than 4,000 specimens from nearly 50 localities in the middle Eocene oil shale deposits of Colorado, Utah, and Wyoming. This collection includes an intact census collection of over 1,000 specimens from Bonanza, Utah, a 4’ by 8’ Eocene palm frond from Kemmerer, Wyoming, and the Douglas Pass collection, which is arguably the largest collection of the Parachute Creek Member in Colorado of the formation. The latter collection was built through a 20+ year collaboration between museum professionals and the Western Interior Paleontology Society members.

**Kaiparowits Formation collection.** A large suite (>8,000) from nearly 100 localities in the Campanian Kaiparowits Formation. This collection is currently being utilized to study Late Cretaceous dinosaur ecosystems in Laramidia and is the focus of an ongoing PhD thesis on insect herbivory in the fossil record.

**University Montana collection.** An orphan collection that documents the career of Charles Miller and his students. Contains numerous localities from Montana including thesis collections for the Early Cretaceous
Kootenai Fm. (Tony LaPasha), Late Jurassic Morrison Formation (Brown) and Late Cretaceous Two Medicine Formation (Crabtree).

Republic collection. A censused suite of more than 3,500 fossil plants from the Early Eocene Republic Flora of northeastern Washington State. This is one of the best known and most diverse high elevation Eocene floras known.

Florissant Fossil Beds collection. Nearly 1,000 specimens collected by the museum in 1915 and more recent collections including a censuses collection of over 4,000 specimens from the Clare Quarry.

Wind River Basin collection. A suite of fossils from the Early Eocene (ca. 52-50 Ma) Wind River Formation that documents subtropical rainforest conditions and is the main comparative site to the Bighorn Basin, which is arguably the best collected fossil ecosystem of this age in the world.

Bison Basin collection. A suite of fossil plants from the mid-Paleocene Fort Union Formation in the Great Divide Basin, Wyoming. This collection was made from 10 quarries along a 0.6 km transect of the same horizon.

Puget Group collection. A suite of nearly 2,000 fossils from near 20 Paleocene and Eocene localities in the Puget lowlands of Washington State. Includes the superb Chuckanut Formation rainforest collection.

The Snowmastodon collection. A suite of more than 150+ anatomically preserved cones and pollen from the Late Pleistocene of the Rocky Mountains that helps document the significant climatic change between ~130-55 ka represented in the Ziegler Reservoir. This collection formally included more than 125 well-preserved logs. These specimens have been permanently transferred to the Laboratory of Tree-Ring Research in Tucson, Arizona.

Winthrop Flora collection. A large collection of Early Cretaceous fossil plants from eastern Washington that documents floral evidence for the Baja-BC hypothesis and early taxonomic radiation of angiosperms. This flora was collected by Ian Miller (Colorado College honors thesis), David Crabtree and Kirk Johnson (small surface collecting). A large companion collection exists at Yale University that was collected by Ian Miller during his PhD thesis.

The Madagascar collection. Two extended expeditions in 2013 and 2015 were mounted to prospect for fossil plants in Madagascar to compliment the incredible vertebrate faunas recovered from the island. The collection that was amassed and is now accessioned at DMNS consists of minor compression floras (<100 specimens) and significant fossil wood remains (representing approximately 75 individual trees) from the mid- and Early Cretaceous rocks in the Ampoly and Manamana regions, respectively.

A large (4’ by 8’) slab of *Alethopteris* from the St. Clair coal mine in Pennsylvania, kept on display within the DMNS Prehistoric Journey exhibit, ‘First Forests.’

Significant long term research loans represent one case of fossils from Yale Peabody Museum. The large Paleocene collection on loan from the New Zealand government listed in previous iterations of this plan has been returned.

Megafloral fossil plant collections are measured by their quality of preservation and preparation of the specimens, rarity of the sites or species represented, collection size, and quality of the provenance data. Since the vast majority of the DMNS collection was made since 1991 using modern techniques, the
quality of the specimens, preparation, and data are uniformly high making the collection suitable for extensive ancillary research.

**Palynology collection:**

The palynology collection is be divided into two categories, fossil and modern pollen. The fossil pollen collection consists of 2,777 microscopy slides which are housed in 43 slide cases. They are documented in an archival binder titled Pollen and Ash data, an Excel spreadsheet named Pollen Slide List Continued, and an Access database named Pollen. Additional microscopy slides will be added to the collection after the initial 2,777 slides are accessioned and the Access database is migrated to K-Emu.

The modern pollen collection consists of pollen slides donated to the DMNS by USGS emeritus scientist Tom Ager. The donation of this collection is ongoing, and presently includes 641 microscopy slides, with a total of 2,401 slides anticipated. The pollen slides consist of modern pollen reference material.

The practice of assigning DBP Numbers to microscopy slides began with the Denver Basin Project (DBP). Since 1999 most slides, and in recent years all slides put into the collection have received a DBP Number, even those that are not from the Denver Basin. The DBP Number is the primary reference used in numerous reports and papers. For these reasons, the formal accession numbers for the palynological slides in the collection will continue to be DBP Numbers. This mirrors the practice of the USGS wherein “D” numbers are assigned for originating from the Denver (Lakewood) offices of the USGS. The DBP Numbers are in the form DBP-2011-005, with DBP serving as the palynology collection designation, followed by the year the sample was processed, and finally, the chronological number for that year starting at 001 each year. All palynological slides accessioned into the DMNS palynology collection will receive DBP Numbers.

The fossil pollen collection consists of mounted palynomorph slides at a minimum. In many instances a reserve sample (split) of the original sediments that were processed to make the slide is retained in the collection. Each split is stored separately from the slide and is labeled with the same DBP number as the slide. These splits are in boxed, placed on pallets, and shrink wrapped. Also retained in the collection are the residues associated with producing the slides. Residues are a liquid suspension of the processed palynomorphs that can be used without further processing to make additional mounted slides. Each residue is stored separately from the slide and is labeled with the same DBP number as the slide. They are kept in the cabinets that house the slides. The modern pollen collection consists of mounted pollen slides. Since the slides are made from extant plants, no splits or residues are associated with these slides.

A primary concern in the long term conservation of the DMNS palynology collection is the stability of the mounting medium for both fossil and modern pollen slides. Most, if not all mounting mediums undergo degradation over time in the forms of desiccation, crystallization, color change, or a combination of these processes. Different mounting mediums have been used in the DMNS palynology collection over the years. The exact name, manufacturer, and chemical formulations of the mounting mediums used are not known in most cases, and obtaining this information presents a considerable challenge. Consideration must be given to the long term performance of mounting mediums and it is possible that no medium could be considered permanent. Therefore, it is important to retain and conserve the residues and splits so that a proxy of any degraded slides can be created. Other conservation concerns include verification that slide labels meet archival standards that splits are stored in a manner that prevents cross contamination, and that residues are monitored and maintained to prevent desiccation.
Documentation of the DMNS Palynology Collection is captured in three documents; an archival binder titled Pollen and Ash data, an Excel spreadsheet named Pollen Slide List Continued, and an Access database named Pollen. Each of these documents is discussed in the following sections. The Pollen and Ash data binder is a hard copy of collection data for each palynological sample. The information captured in this binder includes the DBP number, field number, latitude, longitude, locality name, collector name, formation, state, and the date the sample was sent for processing. Prior to 2007, latitude and longitude were not recorded, but USGS quadrant information was. The Pollen and Ash binder does not utilize acid free paper or archival inks, and is not archival quality.

The Pollen Slide List Continued is a Microsoft Excel spreadsheet that contains archival data on numerous fossil pollen slides. Thirty four pollen cases containing 2,777 microscopy slides have been entered into this spreadsheet. Of these, 1,593 of the slides (57%) have been assigned DBP numbers. The Pollen Slide List captures the DBP Number, collector’s name and field number, field data, and collections data. The field data includes the locality name, state, county, formation and member, and well depth information. The collections data includes additional processing numbers, notes, and the cabinet, draw, case, and slot numbers.

Pollen is a Microsoft Access database that contains archival data on 815 fossil pollen slides. The information in this database duplicates the information in the Pollen Slide List and additionally includes pollen species data. The slides in this database are mostly from the Denver Basin, and 338 (41%) of the slides contain pollen species data.

History of the Collection
Paleobotanical specimens were some of the first fossils collected by the Colorado Museum of Natural History when the museum purchased a plot of land near Florissant, Colorado in 1915, and opened a quarry that yielded several hundred specimens. A few hundred additional specimens were acquired from a variety of localities in the Rocky Mountain between 1916 and 1990. In 1990, paleobotanist Dr. Gary Upchurch was contracted to acquire collections and he added specimens from the Cretaceous of Kansas and the Triassic of Virginia. In 1991, paleobotanist Dr. Kirk Johnson became the museum’s first curator of paleobotany. More than 95% of the collection has been acquired since 1991. The collection was grown through large donations (Howard and Darlene Emry—Cretaceous-Miocene fossils from Colorado, Wyoming, Oregon, and Idaho; Donald Hopkins—Eocene-Miocene fossils from Washington; Mel and Norma Reeves—Eocene fossils from Utah), acceptance of orphan collections (primarily the University of Montana collection built during the career of Dr. Charles Miller—Jurassic and Cretaceous fossils from Montana), fieldwork associated with excavations for the Prehistoric Journey dioramas (Devonian of Wyoming; Pennsylvanian of Kansas; Cretaceous of North Dakota, Eocene of Wyoming), fieldwork associated with undergraduate and master’s theses (Kristian Benson & Ian Miller, Colorado College; Richard Barclay, Univ. of Florida; Regan Dunn, Univ. of Wyoming), and fieldwork associated with the research of the curator and their volunteers, students, and collaborators. Kirk Johnson has addressed the nature of Late Cretaceous and Paleogene flora with focused fieldwork in the Williston Basin of North and South Dakota and Montana and the Denver Basin of Colorado with additional survey collections from Washington, British Columbia, Saskatchewan, Wyoming, Utah, New Mexico, Colorado. His fieldwork in Mongolia, China, and Argentina has resulted in collections that, by law, are destined to remain in their country of origin. Many of the Denver Basin fossils were recovered from active construction sites that were subsequently destroyed or buried. Since 1994, a dedicated group of volunteers known as the Leaf Whackers has supported all aspects of the paleobotany program. In 2008, Ian Miller became the museum’s second curator of paleobotany. His work also addresses the nature of Late Cretaceous ecosystems, particularly in the context of dinosaurs, and the recovery of plants following the K-Pg boundary. He has focused his research and fieldwork on the Winthrop Flora, the
Wind River Flora, the Kaiparowits Flora, and associated Campanian floras, the Denver Basin Flora, and floras in Madagascar.

Future of the Collection
The paleobotany collection will continue to grow at a steady rate due to salvage paleontology opportunities in the Denver area and research activities focused on Jurassic-Eocene floras of the Rocky Mountain and Great Plains region and to a lesser extent, around the world. In 2007, the discipline of palynology was added to the collection with the acquisition of the D. J. Nichols collection of Rocky Mountain palynology slides. The move of the paleobotany collection to the Avenir Collections Facility was completed in 2017. We estimate that at current rates of collection, the cases in B2 of the Collections Facility will house approximately 20 years of growth. Cataloguing, curation, preparation, and culling of the collections continues.

In previous iterations of this plan, one significant orphan collection was identified (The Pioneer Trails Regional Museum 16 Lane cases of plants). This collection has been moved to the Heritage Museum in Bismarck, ND for permanent housing. Presently, no major orphan paleobotany collections are identified for acquisition. No major deaccessions are expected.

4.2.7. Invertebrate Paleontology
Curator: James Hagadorn
Plan author: James Hagadorn, Kristen MacKenzie, Nicole Neu-Yagle

Intellectual Framework
Fossil Invertebrates are common in sedimentary rocks deposited in marine and freshwater settings. Whereas the term “invertebrates” is somewhat artificial, for our purposes it includes all fossils that are not from vertebrate animals or plants. Invertebrates are the earliest macroscopic fossils and are abundant in rocks that are Cambrian or younger. They form the traditional basis of marine biostratigraphy and have been used extensively in the Rocky Mountain region to date rock layers as well as to make paleoecological interpretations. Many advances in the study of evolution and extinction have been based on invertebrate fossils because of their stratigraphic and geographic abundance. The Rocky Mountain region was intermittently flooded by seawater for most of the Paleozoic (542-251 million years), much of the Mesozoic (251-65.5 million years), and the first few million years of the Cenozoic (65.5 Ma to present). Freshwater ecosystems preserve both mollusks and arthropods and the latter are particularly well-represented by insects and arachnids. The Rocky Mountains contain a superb rock record that documents the region’s history for the last 500 million years, and the region is known for a host of invertebrate fossil localities spanning that time. Many of these sites are considered world class for the quality of the fossils in addition to the completeness of data derived from the extent of the deposits or their temporal continuity. Most notable of these regional suites are the Cambrian-Ordovician invertebrates (particularly trilobites) from Utah and Nevada; the fossils from the Cretaceous Interior seaway deposits (particularly ammonites) found in all of the Rocky Mountain states; and the insect faunas from Eocene lake deposits in Colorado, Wyoming, Utah, Idaho, Montana, and Washington.

Scope of the Collection
The invertebrate paleontology collections at DMNS consists of over 24,000 specimens that are housed in 16 cabinets and four pallet rack shelves in the B2 Earth Sciences collections storage room in the Avenir Collections Facility. The invertebrate paleontology collection shares a numbering system and string (EPI) with paleobotany and is housed in the same northwest row of cabinet ranges as the paleobotany collections. With the exception of two recent large donations, described below, the collection is completely catalogued, inventoried, databased, and housed in archival mounts, and has no
historic backlog of unprepared, unidentified, and uncatalogued specimens. The collection is organized time-stratigraphically, with fossils from the same rock unit grouped together. The collection spans the Ediacaran to present, and has strengths in the Eocene Green River, Creede, and Florissant formations (principally insects). Additional strengths of the invertebrate paleontology collection include an arthropod collection from the Pennsylvanian Hamilton Quarry of Kansas, large Placenticeras ammonites from the Cretaceous Pierre Shale near Kremmling, Colorado, and a recently assembled synoptic collection of Devonian (Famennian) invertebrates that pair with a suite of vertebrates from the same deposit. The collection includes some high profile specimens, all of which are on display in the Prehistoric Journey exhibit, including:

- A large Uintacrinus slab from the Mancos Shale near Grand Junction Colorado
- Pair of Didymoceras ammonites from the Pierre Shale of eastern Wyoming
- A meter wide inoceramid clam from the Cretaceous of Kansas
- Suite of premier three-dimensional trilobites from Morocco, New York, Nevada, and Oklahoma
- Slab with six eurypterids from the Silurian Bette Water Lime near Herkimer, New York
- Slab of Mississippian crinoids from the Indian Creek site in Indiana
- Glass Mountain chunk of silicified brachiopods from the Permian of Texas
- Giant Isotelus trilobite from the Ordovician of Cincinnati, Ohio

History of the Collection
DMNS has never had a dedicated curator of invertebrate paleontology. As a result, much of the collection was acquired by Volunteers (Karl Hirsch, Brian Cooney, Bill Bateman, Michael Graham, Wayne Itano, Steve Wagner), Research Associates (Reuben Ross, Allison Palmer, Emmett Evanoff, Karen Houck, Bill Cobban), and curators in other disciplines. Kirk Johnson led expeditions related to Prehistoric Journey to the Cambrian of Utah and Nevada (1991, 1994), the Precambrian of Australia (1990), the Silurian of Wisconsin and Illinois (1993), the Devonian of Wyoming (1993), and the Pennsylvanian of Kansas (1991). He also made the majority of the purchases to support the Prehistoric Journey exhibit. In 1998, he and Emmett Evanoff made a major excavation at the giant ammonite site near Kremmling, Colorado and retrieved nearly a dozen large Placenticeras ammonites. Volunteer Dena Meade-Hunter served as the collections manager of the fossil insect collection during the 1990s.

Future of the Collection
The invertebrate paleontology collection has potential for substantial growth in the coming years, in part through the recent donation of the Stew Hollingsworth and Lee Shropshire collection, and in part through field collections made by Earth Sciences Curator James Hagadorn and associated community scientists. The Hollingsworth Collection includes a world-class collection of trilobites, and the Shropshire Collection is dominated by invertebrates from the Midwest and west. A small amount of growth is anticipated from paleontological salvage work from our regional partners, and through opportunistic collecting by other curators in the Department of Earth Sciences, and through cultivation of donations that fill regionally or historically relevant gaps in the collection’s holdings.

Little scholarly research has been conducted on the museum’s invertebrate paleontology collection in the last twenty years—principally because its catalogue is not available online to the global scientific communities. Publication of the invertebrate paleontology catalogue on the web and/or its integration into larger-scale searchable external databases could substantially change awareness and use of this collection, should the Museum make this a priority.

4.3. Health Sciences
Curator: Nicole Garneau
Plan author: Nicole Garneau
Intellectual Framework
The DMNS Health Sciences Collection primarily focuses on human anatomy, physiology, and genetics. The collection has a minor focus on historically significant medical instruments and devices.

Scope of the Collection
The Health Sciences research collection’s scope includes authentic human anatomical specimens ranging from full-body plastinates to organs, as well as tissue, cellular and molecular specimens, and includes a small collection of historically significant medical instruments and devices. The subcollections are detailed below, including future growth.

Anatomy and Physiology: The Health Sciences collection covers human anatomical specimens including histopathological, fluid, desiccated, and plastinated anatomical specimens. A highlight of the collection is a complete fetal gestational development series, one of only a handful of complete collections in the world. These were originally collected by the American Medical Association, transferred to the Education Collection, and later transferred to the Health Sciences Collection. Growth of the collection will be minimal and will be primarily plastinated and/or wet specimens based on needs of Expedition Health and the research in the community-based genetics lab. The department currently has room for such growth in terms of storage (cabinet space). The logistics of this subcollection have specific local, Federal, and international guidelines and laws. As such, all human remains acquired comply with the United States of America Uniform Anatomical Gift Act (1968, revised 2006) and the European Union Human Tissue Directive (2004). Specimens are received under informed consent by the donor, and are acquired under the proviso of donor anonymity. Finally, the anatomical collection does not include specimens or remains whose significance and value are attributed to the provenance of the donor. We anticipate minimal growth to this subcollection.

Human Genetics: The nature of the department’s research, population genetics, has led to the curation of the museum world’s first human genetic collection. This subcollection currently includes DNA samples collected at an average rate of 1500 samples per year. In individual sample is approximately 50µL of pure DNA in a 1.5mL Eppendorf tube, stored at 20°C during active use, and then at -80°C for long term storage. This collection is considered a “destructive” collection, much like tissue samples collected by many zoologists, because as it is used for research it is depleted. In addition to DNA, this collection has the potential to include RNA and protein samples—pending future collaborations and the direction the population genetics lab takes. The use of the collection by external researchers is guided by the Institutional Review Board-approved informed consent and at the discretion of the department chair.

Medical Instruments: The health sciences collection aims to secure a small but historically significant medical instrument/devices collection. Highlights would include items that are currently housed in the Education Collection and the scientific instruments collection. We anticipate minimal growth in this subcollection.

History of the Collection
The Health Sciences Department was formally established in 2005 with the hiring of the Museum’s first Curator of Human Health, Bridget Coughlin. Prior to this time, all health-related collections were in the Education Collection and were used exclusively in classes, outreach programs, and exhibits. Since 2005 however, the department has worked closely with the Education Collections Manager to lay the groundwork for the transfer of specimens and artifacts that are better housed and cared for under the intellectual framework of the research collection. This includes the fetal gestation development collection, rare Jarvik hearts, and a growing pacemaker collection. External specimens that were accessioned
between 2005 and 2012 were all anatomical and physiological, and included many plastinated specimens from the Plastination Institute, and a small collection of wet specimens and bones from the Colorado Anatomical Board. Finally, in 2014, the Department received a large and historically important collection of histology and histopathology slides from retired pathologist, Dr. Robert Shikes. The intellectual and physical synthesis of this collection is ongoing.

4.4. Scientific Instruments
Curator: Ka Chun Yu
Plan authors: Ka Chun Yu, Evelyn Busch, Veronika Hall

Scope of the Collection
The DMNS Scientific Instrument Collection serves to preserve important aspects of the study of Earth and other natural sciences, as well as educate the public about the essential role of scientific instruments in advancing our understanding of the natural sciences. The instruments are excellent type-examples of particular instruments, or were part of historic experiments. The collection is maintained primarily for historical purposes, and is not intended for research use, although many of the items included have played important roles in past research programs. The Scientific Instruments Collection is distinct from that objects accessioned into the DMNS Archives, because the latter is meant for artifacts that have significant history with DMNS personnel or the institution itself. The Scientific Instruments Collection holds objects that do not have any intrinsic relationships with the Museum.

The instruments fall into the following categories:
- Microscopes with accessories and photomicrographs of microorganisms. Applied general microscopy, with accessories, and photomicrographs showing a range of applications to the natural sciences.
- Scientific instruments utilized in mineralogy, including petrographic microscopes and accessories used in determining properties of minerals, with suitable photomicrographs, mineralogical goniometers and other instruments intrinsically related to the study of minerals. Underground surveying instruments, with appropriate accessories and related underground photographs.
- Scientific measurement instruments, including balances, scales and weights.
- The original chemical glassware used in the famous Miller-Urey experiments on the synthesis of organic life-forming molecules from the gases and compounds that are thought to comprise the early Earth’s atmosphere and environment.

Most of the Scientific Instrument Collection is currently housed in a single steel cabinet in the Figgins collections hall. The Miller-Urey apparatus (ESI.1) has been put on public display in Prehistoric Journey. Other instruments (e.g., Zentmayer Histological Microscope ESI.10; Open Beam Balance, ESI.17; Bullseye Condenser, ESI.21) appear as decorative elements in the mining displays in the Coors Gems & Minerals Hall.

Recent History of the Collection
During the period of the last Long-Term Collections & Research Plan (2013-2017), the collection was re-evaluated in consultation with the Archivists, Image Archivist, Registrar, Education Collections Manager and the Curator of Geology. A number of key decisions were made in order to refine the collection to fit the redefined scope. This resulted in the deaccessioning of three pieces of furniture and two Spider Habitats, which were transferred either to the Archives or to the DMNS general furniture inventory when no significant DMNS history was associated. A few additional objects remain in the collection that do not appear to fit the collection scope. However, they will require additional research prior to deaccession.
In 2015, the Zentmayer “Centennial” binocular microscope was deaccessioned and transferred to the Leidy Microscopical Society following a challenge in ownership.

Future of the Collection
No current active research is being done with items from the Scientific Instrument Collection (nor is any future research expected). In addition, the Collection is not expected to grow in size. However, under special circumstances, and following further discussions and careful consideration by the Curator of the Scientific Instruments Collection and the Chief Curator, certain exceptions can be made to allow for limited acquisitions that will be added to the Collection. The current collection has historically been stored with several miscellaneous objects; including oculars, microscope slides, weight sets and filters. Minimal documentation was associated with these and the assumption is now being made that these were acquired with the Paul Seel collection between 1984 and 1986 and should be considered an accessioned part of this collection. The Education Collections Manager will be taking the lead on labelling and cataloguing these in the coming years.

4.5. Zoology

4.5.1. Arachnology
Curator: Paula Cushing
Plan author: Paula Cushing

Intellectual Framework
Over 100,000 species of arachnids have been described worldwide. This class includes the orders Acari, Amblypygi, Araneae, Opiliones, Palpigradi, Pseudoscorpiones, Ricinulei, Schizomida, Scorpionida, Solifugae, and Uropygi. Of these, the order Araneae ranks seventh in global species diversity amongst all organisms on earth with over 47,000 described species. Despite this diversity, arachnid taxonomy is poorly known. For example, the 47,000+ described species of spiders is thought to represent only half or less of the true species diversity of this taxonomic group. Arachnids are not only a diverse taxonomic group but, as top invertebrate predators in all terrestrial ecosystems, they also serve a critical function in maintaining the health and community structure of these terrestrial ecosystems.

In 1999, an aggressive program was begun to document the species diversity of Araneae in this region of the country. This project, the Colorado Spider Survey, or CSS, is a citizen science project that has taught over 1,000 members of the public about spiders, biodiversity, and the natural history of this taxonomic group. Over 100 of these CSS participants have become actively involved in the project collecting, identifying, and databasing spiders and other arachnids collected from nearly every ecosystem in the state (http://www.dmns.org/spiders/default.aspx). Every year since its inception, CSS participants have sent in, on average, 3,000 – 6,000 specimens (about 2,000 – 3,000 vials) of spiders including one species that represents a new regional family record and many species that represent species range extensions. CSS participants have also become involved in carrying out their own research projects on arachnid diversity, morphology, taxonomy and systematics. The CSS is an excellent example of how non-scientists, or citizen scientists, can become actively involved in every aspect of a research program.

Information about the arachnology program as well as collections data is available on the CSS section of the DMNS website (https://www.dmns.org/colorado-spider-survey). The arachnology collections data is published on a live online website through the Symbiota Collections of Arthropods Network, or SCAN (http://scan-bugs.org/portal/index.php). This website has become a model for providing electronic access to collections information. Collections data are also pushed out from SCAN to other
online portals such as the Global Biodiversity Information Facility (GBIF), https://www.gbif.org/. Currently there are over 38,000 records in the SCAN-DMNS arachnology database. The collection includes 40 – 60,000 vials of arachnids representing well over 1,000 species in all the arachnid orders.

Scope of the Collection
The current arachnid holdings at the DMNS include animals from 10 orders: Acari, Araneae, Amblypygi, Opiliones, Pseudoscorpiones, Ricinulei, Schizomida, Scorpiones, Solifugae, and Uropygi. The collection is housed in the Avenir Collections Center. The Arachnology lab has a central microscopy work area. Three closed rooms off this central work space house the arachnology collection in 18 ten-foot high fire-proof cabinets. Growth space for the next 10 – 20 years has been incorporated into these rooms and cabinets. The collection’s strength lies with the orders Araneae and Solifugae. The regional representation of the order Scorpiones is also strong. Eighty-four percent of the DMNS arachnology collection is from the Rocky Mountains / Great Plains eco-region including the states of CO, MT, UT, WY, KS, OK, ND, SD, and TX. The southwestern desert states of AZ and NM are also well represented. The data from identified and databased specimens have already been published online.

Prior to 1998, the DMNS had fewer than 50 vials of arachnids in its holdings. It now has over 60,000 representing 97 families and over 1,900 species. In the last five years, the arachnology collection at the DMNS has already become the largest such collection in the Rocky Mountain / Great Plains region and has become the sixth major arachnology collection in the U.S. curated by an arachnologist; the others being at the American Museum of Natural History, the Museum of Comparative Zoology, the National Museum of Natural History at the Smithsonian, the California Academy of Sciences, and the Field Museum of Natural History. Our knowledge of the arachnid diversity in the Rocky Mountain / Great Plains eco-region is poorly known and poorly represented in the other major arachnid collections. Although a relatively new collection, the arachnid collection at the DMNS already serves as the repository for over 85 type specimens (holotypes and paratypes) and a multitude of voucher specimens. It is expected that the number of deposited type specimens and vouchers will continue to increase as the arachnology research program expands.

History of the Collection
From 1950 to 1959, Walker Van Riper served as the Curator of Insects and Spiders at the DMNS. Van Riper established a modest research program in arachnology, particularly in the biology of black widow spiders in Colorado and spider diversity in the state. His collection, however, was deposited in the University of Colorado, Boulder Museum. From 1959 – 1998, Van Riper’s successors were entomologists, primarily lepidopterists, so the arachnology program lapsed. In 1998, Cushing was hired as the Curator of Entomology & Arachnology at the DMNS. Late that year, the arachnology collection was established with the donation of the private collection of Dr. Beatrice Vogel of Montana, one of the founders and the first president of the American Arachnological Society. In 1999, Cushing began an aggressive program, the CSS, to document the species diversity of Araneae in this region of the country. The collection has grown through active field collecting by DMNS staff and CSS volunteers as well as through major additional donations from Bea Vogel, Jack Brookhart, Daniel Jennings, Laurie Kerzicnik, Karl Stone, Rod Crawford, Candan Soykan, and Robert Fisher.

Future of the Collection:
The strengths of the collection are in Rocky Mountain / Great Plains material. The current weaknesses of the collection are in material from outside the eco-region and in non-spider/non-solifuge arachnids. Any taxonomic or systematic study of a taxon in the collection must also include species from outside the eco-region. For example, in order to carry out the current systematic, taxonomic, and morphological
research on Solifugae, we must borrow specimens held at other institutions. For the morphological research, we are limited in the degree to which we can dissect or examine certain morphological structures on specimens not from our holdings. We must, therefore, increase comparative material from outside the eco-region.

Collection growth will continue to occur largely through active field work by DMNS staff and volunteers. Such field work will be in conjunction with funded projects, such as the NSF funded Solifugae project. Collections growth will also occur through donations. Donations offered of material from within the eco-region will be accepted in order to further strengthen the taxonomic focus of the collection. Material offered for donation collected outside the eco-region will be accepted if it complements, enhances, or facilitates ongoing research projects. The curator has completed a collections manual for this DOZ collection. This manual outlines all procedures used to process, identify, and database specimens.

The establishment of the arachnid collection at the DMNS has already accomplished a great deal in increasing our knowledge of the taxonomic diversity of arachnids in this region of North America and in establishing an active arachnology research program. The DMNS leads the way worldwide in research on Solifugae taxonomy, systematics, and morphology and is serving as the primary regional repository for arachnids. It has become the largest such collection in the Rocky Mountain / Great Plains region and has become the sixth major arachnology collection in the U.S. curated by an arachnologist. Our knowledge of the arachnid diversity in the Rocky Mountain / Great Plains eco-region is poorly known and poorly represented in the other major arachnid collections.

4.5.2. Entomology
Curator: Frank Krell
Plan author: Frank Krell

Intellectual Framework
Insects the largest group of animals on earth with around 1,000,000 described species. They live in essentially every terrestrial habitat as well as many aquatic habitats, being absent only from the waters of the deep ocean. Insects are of critical importance in maintaining the health of ecosystems. Insects are also of enormous economic and health importance to humans, both as vectors agricultural pests, and providing ecological services: Two-thirds of all flowering plants rely on insects for pollination; they are an important component of the decomposer guild.

The entomology collection provides a reference for the diversity of the most species rich group on earth today. It documents and provides information about the diversity of insects in the Rocky Mountain / Great Plains ecoregions as well as data on exotic specimens from tropical regions of the world. In times of a global biodiversity crisis and climatic change, documenting baseline data of species occurrence and distribution is crucial to avoid irretrievably losing information about our natural heritage.

The insect collection at the DMNS, although still small in comparison to other national entomology collections, is increasingly used as an international research collection, and has long been serving as an important resource to the community, providing material for internal exhibits, artists and public tours. Due to its traditional global focus, it complements the two other major entomology collections in the State: Colorado State University and University of Colorado, Boulder Museum, which are mainly regionally focused.

Our collection is increasingly utilized by the research community, and use will grow as past and ongoing databasing projects raise visibility of our holdings. Once collection data is published online
and the collection occurs in the scientific literature more frequently, use of the collection will further increase.

**Scope of the Collection**

The DMNS entomology collection consists of 1,078,000 specimens (January 2019). At its current growth rate (~1.9% per year), we are adding an average of 20,000 specimens per year. The unprepared backlog is being processed at a rate of 20-30,000 specimens per year. The collection spans 1878–present. Holdings are worldwide in coverage and comprise all major insect orders, with a particular focus on Coleoptera (80%) and Lepidoptera (12%). About 10% of specimens (ca. 104,500) are currently cataloged and databased in our open access consortium database SCAN (Symbiota; http://scan-bugs.org/portal/collections/misc/collprofiles.php?collid=173).

The collection’s primary strength is its worldwide focus (60% of specimens from Africa, 25% regional, 15% from other regions), which distinguishes the DMNS entomology collection from other large insect collections in the region with mainly regional holdings. Nevertheless, the DMNS regional holdings are also strong, particularly in the Lepidoptera and in several families of Coleoptera (e.g., Scarabaeidae and Tenebrionidae). In 2008, Curator of Entomology Frank Krell initiated the creation of a Colorado State Reference Collection for Coleoptera, initially based on local holdings and then further developed with an aggressive collecting program across the state. Since its inception the reference collection has grown tenfold in size, but is still in need of thorough curation.

The entomology collection includes at least 13 name-bearing types and 185 paratypes described by museum staff and external researchers between 1882 and 2015 (Grote 1882; Aaron & Aaron 1885; French 1884; Cockerell 1905, 1906; Cross 1937a, b; Nonveiller 1960; Peigler 1992; and Peigler & Kendall 1993, for holo- or syntypes). An illustrated catalogue of the type specimens in the entomology collection is in preparation.

The Entomology collection continues to be an invaluable resource for exhibits and public programs. Insects are a wonderful model for the incredible diversity of life on earth. The collection is widely used for public programs such as lectures, behind-the-scenes tours, and school programs.

**History of the Collection**

The growth of the entomology collection began soon after the incorporation of the Museum in 1900 with the activity of the first entomology curator, Ernest J. Oslar (1908-1911). Oslar was a professional insect collector who collected around 10,000 specimens of mainly regional Lepidoptera for the Museum. Some material from Africa was also donated during his tenure. There appears to have been a disagreement with Museum leadership when Oslar presented an invoice for these specimens, and this led to his departure. Only a few Oslar specimens have been identified in the collections to date. A decade later, in 1918, John T. Mason, an avid collector with a wealth of contacts in the lepidopterist community and Museum manager from 1900-1910, donated a worldwide collection of 20,000 butterflies and moths to the Museum (Webb & Peigler 1990). His donation contained important historical material, type specimens, and many tropical species rare in collections. Specimens from the Mason collection first went on display in the Museum from 1929 to 1938. A more extensive exhibit was then constructed and the Colorado Butterflies and Moths Exhibit opened in 1940, funded by Mrs. Dora Porter Mason and presented in a hall named after this benefactress. This exhibit closed in 1986 during Museum expansion.

Mr. Frank Howland, Curator of Minerals and Geology, served as caretaker of the entomology collection from the late 1920s through 1935. From 1936 to 1938, Frank Clay Cross became the
Honorary Curator of Entomology. Together with his assistants, Robert Potts and Charles W. Dawson, he reorganized the collection and rediscovered several type specimens (Webb & Peigler 1990). **Walker Van Riper** served as Curator of Insects and Spiders from 1943 to 1959, with W.H. Tyenyar serving as Associate Curator in 1958. This period of moderate growth was followed by more than a decade of stagnation.

From 1972 to 1977, **Marc E. Epstein** was on contract, extensively collecting and curating butterflies. Epstein was at the Smithsonian for 15 years and is now a systematist at the California Department of Food and Agriculture. **Michael G. Pogue**, currently at the USDA/Smithsonian, was employed as Curatorial Assistant from 1975-1979, having been responsible for the curation of birds and insects. He donated his personal collection of butterflies, mostly from Colorado, when he left. Marc and Michael, with the help of volunteers, upgraded the collection significantly, particularly by transferring the Mason collection from cork-bottomed drawers to modern Cornell drawers. During the following decade, the insect collection again entered a stagnant period.

From 1990 to 1997, lepidopterist **Richard S. Peigler** worked at the Museum, first as Collections Manager, then as Curator of Entomology. The insect collection resumed moderate growth during his tenure. Peigler's rearing and hybridization experiments on wild silkmoths are well documented in the collection. Also during this period, many improvements were made to collection storage conditions, curation of the Lepidoptera collection (by Ray Stanford), and protocols that positively impacted the entomology collection. These included improvement of collections care by increased environmental monitoring and implementation of an Integrated Pest Management program in 1988.

From 1998 to 2006, arachnologist **Paula Cushing** was the curator responsible for the entomology collection. Her extensive Colorado Spider Survey resulted in thousands of non-target insects being collected in pitfall traps all over the Rocky Mountains and the western Great Plains. Cushing also accepted a donation of extraordinarily beautiful specimens (with collection data) collected over a century ago by **Clarence Riker** (inventor of the "Riker mount", a glass covered shallow box commonly used for displaying insects) and stored in Riker's original hand-made cabinet mounts. The Riker collection was accepted for its historical value as well as its outreach value for behind-the-scenes tours, art projects, and exhibits.

In January 2007, **Frank Krell** was hired as the Curator of Entomology responsible for both the entomology collection and the small herbarium. Krell has significantly increased the activity level of the entomology collection by hiring and training a substantial volunteer corps and starting regional collecting activities such as the Colorado Scarab Survey and the Colorado Beetle Reference Collection, hosting scientific meetings such as the 20th High Country Lepidopterists’ meeting in 2009 (Krell 2009) and the Combined Annual Meeting of the Lepidopterists’ Society and the Societas Europaea Lepidopterologica (Krell et al. 2012). Approximately 950,000 newly accessioned insect specimens have been added under his curatorship. This recent growth was achieved through intensified regional collecting (10-15,000 specimens/yr), accessioning a major unprocessed backlog material from 1990 to 2006, donation-funded projects, and large donated or transferred collections (e.g., B. Bartell, D. Bettman, E. Cano, T. Cekalovic, E. Eaton, D.M. Fanara, M. Fisher, C. Grinter, C. Harp, S.A. Johnson, F.-T. Krell, D. Matusik, A. Mudge, P. Moreto, S.M. Nelson, G. Opie, P. Tates, B. Vogel, I. Winkler, F.N. Zeiner, etc.).

Concurrent with this rapid growth, Krell has also instituted rigorous curatorial procedures; developed an entomology collections manual; developed focused accession policies; established a high-throughput team of trained volunteers that processes about 20-30,000 specimens per year from the unmounted
backlog; and attracted a team of department and research associates skilled in Lepidoptera taxonomy, namely Barbara Bartell, David Bettman, Todd Gilligan, Chuck Harp, Paul Opler, and Andrew Warren, who are re-curating the extensive butterfly and moth collection. The success with two grants funded by the National Science Foundation in 2012 helped transforming the entomology collection into a modern, accessible collection. The collection became a part of the Southwest Collections of Arthropods Network (SCAN), which will digitize the museum’s regional holdings of soil arthropods. A collections improvement grant (CSBR) provided new cabinetry for the collection’s move in September 2014 into a new, state-of-the-art collections preservation facility, the Avenir Collections Center (Krell & Stephenson 2014). Additionally, the grants provided funding for the hire of two curatorial assistants, David Bettman and Chris Grinter. A new grant, to be implemented in 2018, establishes the DMNS collection as part of LepNet (Lepidoptera of North America Network; Seltmann et al. 2017) and will help cataloguing, databasing, and photographing a part of the butterfly and moth collection. A temporary curatorial assistant, Eric Knutsen, will start in August 2018.

Future of the Collection
With hiring of Frank Krell as Curator of Entomology, the Entomology Collection has been transformed from a minor, unfocused and relatively unknown collection into one of the major insect research collections in the region. Krell has established five growth foci for the collection, in accordance with the DMNS mission and ongoing research.

Growth foci:

- Rocky Mountain/Great Plains insects: We run an active and growing collecting program in the region and will create the primary reference collection for Colorado insects (Colorado Insect Collection).
- United States beetles: Since the research of the Curator of Entomology and his collaborative networks focus on beetles, the collection will accept donations and samples of beetles from everywhere in the United States as reference and research material for projects on the Colorado beetle fauna with priority on material from the Rocky Mountain / Great Plains ecoregions.
- World scarab beetles: The Curator of Entomology is a world expert on scarab beetles and continues working on this group globally, which will result in research-driven growth in this area. World collections focused on a popular group raise international awareness of a collection among the scientific community and serve as sustainable scientific advertisement for the scientific relevance of a Museum. With Krell’s donation, the DMNS already houses one of the major scarab collections and the largest dung beetle collection in the country.
- World Lepidoptera: With an already comprehensive world Lepidoptera collection, we will generally not amass material beyond our regional focus, but will concentrate on filling gaps in our holdings. We will reconsider if we get offered scientifically exceptionally important material.
- Bees: With the arrival of our new Chief Curator, being a bee expert, we will increase the collecting efforts of our regional pollinator fauna.

We will explore the possibility of acquiring a large insect collection from a university in the region consisting of specimens mainly collected from our focal region. The university might consider transferring the collection to another institution in ten years time or so. This collection is generally well-curated and contains over 3,000,000 specimens in 2100 drawers (1200 sq ft) including 50 primary and 2500 secondary types, which would transform the DMNS insect collection into one of the most important entomological research collections in the United States, but could not be accommodated in our currently available collection space.
We will accept donations of entomology-related scientific instruments as they are useful in public programming and tours to show the history, techniques and methods of the discipline. Krell has completed and occasionally updated a collections manual for this DOZ collection. This manual outlines all procedures used to process, identify, and database specimens, but is in need of further updating.

In establishing a State reference collection for beetles, the holdings can be more efficiently used for regional research projects and outreach (reference for identification requests, tours). Specimen level databasing of material at least identified to family will continue. Publishing a collection database online and being a member of national or regional database consortia is crucial to publicize the collection and to increase its use by the research community. Also, major donations are being published on the Entomology web page and social media to raise awareness of the DMNS holdings, and a type catalogue will be prepared for the DMNS Annals. The collection may grow between 20 and 400% over the next 10 years, depending on the acquisition of orphaned collection and existing and potentially emerging storage space.

4.5.3. Marine Invertebrates
Curator: Paula Cushing
Plan author: Paula Cushing

Intellectual Framework
The marine invertebrate collection consists primarily of mollusk shells, plus corals, echinoderms, and sponges. This collection was previously known as the conchology collection but the name of this collection was changed in 2011 to better reflect our current and future holdings. There are about 100,000 different species of mollusks worldwide including marine, freshwater, land, and arboreal mollusks. Humans use mollusks for food, cultural icons, money, tools, artwork, and jewelry.

The DMNS marine invertebrate collection is a research collection for scientists but is also used by teachers, school groups, and artists. Specimens from the collection are very popular at museum member events and tours. An extensive group of shells and corals are displayed on the second floor in the South Pacific diorama. The Zoology Department frequently incorporates shells into its changing case exhibit and shells have been featured several times in the Catalyst to tie in to major exhibits such as Pompeii and Cuba.

Since Colorado is a landlocked state, the marine invertebrate collection in the Museum serves as an invaluable resource for members, shell collectors, researchers, educators, and the general public.

Scope of the Collection
The marine invertebrate collection currently contains approximately 45,000 lots of which 24,000 are fully catalogued and publicly available on Arctos (<http://arctos.database.museum/>). These 24,000 lots contain 80,000 individual specimens from micromollusks less than 0.25 inches (6 mm) to a giant clam more than 2 feet (0.6 m) long. Our collection is worldwide, but has particular strength in material from the Caribbean, western Mexico, and the Pacific (including Hawaii, the Philippines and Australia). The following families are particularly well represented in the collection: Cypraeidae, Muricidae, Conidae, Strombidae, Volutidae, Camaenidae, Veneridae, and Pectinidae. The collection contains fourteen paratypes. Endangered or CITES-protected species include queen conchs (*Lobatus gigas*), *Tridacna* species, *Achatinella* from Hawaii, and *Liguus* from Florida. Legacy collections include shells
from Trustees Henry Porter (collected by Trustee Mary Pratt) and John Evans, and corals from A. Bailey’s 1923 expedition to the Bahamas.

**History of the Collection**

The shell collection dates to 1904 but became most active when Pauline Morrison volunteered at the museum from 1970 – 1983 as the Honorary Curator in the Department of Conchology. She and her husband established the Morrison Trust and she donated many shells that became the basis of the expanded collection. The Morrison atria are named after Pauline and her husband George Morrison. Other major donations that increased the value of the collection include those of Charles Isle, Wayne Stacey, Louis Fletcher, J. E. Steadman, Jim Goddard (former DMNS staff member), Raymond Burr (the actor collected shells in Fiji), Irv Cone, Phyllis Sharp, Peter Warren, John Moore, and, most recently and significantly, Richard Schaake. Valuable books donated with the shells created a comprehensive reference library for research and shell identification.

**Future of the Collection**

CU-Boulder Museum is the only other large mollusk collection in the state. The collection at DMNS, strongest in marine species, complements the CU-Boulder Museum malacology collection, which is strongest in freshwater and terrestrial material.

The Marine Invertebrate Collection enhances the Department of Zoology as it includes the only marine organisms housed in the department. The other collections – ornithology, mammalogy, entomology and arachnology – are represented almost entirely by terrestrial species with a few freshwater or marine organisms. With the warming and acidification of the oceans and the loss of terrestrial habitats, preservation of these specimens is of increased importance.

Given the landlocked status of Colorado and the regional focus of the other Zoology collections, growth of the marine invertebrate collection will be limited. Only donations with significant collection information (i.e. locale, date collected, collector) linked to the specimens will be accepted. Specimens previously accepted into the collection without any collection information are continually deaccessioned to make room for specimens with scientific research value.

Currently, a dedicated group of volunteers devote their time and passion to maintaining the marine invertebrate collection. Irv Cone served as our volunteer marine invertebrate collection curator from the mid-1980s until his death in 2007. Phyllis Sharp and Bryan Johnson are the current Departmental Associates who oversee the day-to-day work in the collection.

Detailed procedures have been established for the curation of the marine invertebrate specimens and are annually updated in a procedural manual. In 2013, the marine invertebrate database transferred into Arctos, an online database, which immediately provided public access to all specimen records. At this time, over 50% of the lots have been entered into Arctos. Arctos enables us to geolocate lots and add images of significant specimens to the specimen record. Arctos uploads the DMNS data into multiple additional databases: InvertEBase, iDigBio, BISON, and GBIF. This has significantly increased the exposure of our collection to the public and has increased the number of inquiries about the collection.

As research technology advances, the value of such collections as the DMNS marine invertebrate collection will continually increase. For example, changes in the ion and mineral content of the world’s oceans may be detectable in historical collections of shells. Thus, collections such as ours may be used to detect the effects of climate change on the world’s oceans.
4.5.4. Mammals
Curator: John R. Demboski
Plan author: John R. Demboski

Intellectual Framework
Mammals, the evolutionary lineage to which humans belong, represent a diverse group of animals that are found across every continent on Earth. Because they have radiated into a staggering array of ecosystems, including marine and terrestrial, they represent excellent model organisms for exploring a wide range of questions addressing evolution, biodiversity, behavior, ecology, and the effects of global change. In addition, because of the large number of outdoor enthusiasts in Colorado and their familiarity with the more charismatic species, such as elk and bear, mammals serve as excellent tools for informal public education and outreach.

The DMNS mammal collection consists of 19,043 (August 2019) cataloged and databased specimens (~24,000 overall including backlog). It is an important regional and national resource and is used for a wide range of activities including research, education/outreach, artistic reference, and exhibit support. Research activities include studies of mammalian biodiversity, genetics, biochemistry, morphology, toxicology, and biological informatics by DMNS staff, associates, and increasingly more, the greater scientific community. The utilization and value of this collection has continued to increase with the application of new technologies to museum specimens including DNA sequencing, stable isotope analyses, and biological informatics. Educational and outreach utilization of the collection includes tours of the collections, workshops, artistic support, and support for DMNS programming, camps, events, and exhibits. Many of the collection’s taxidermy mounts (~400) are on permanent display in the Museum’s popular wildlife dioramas. The scientific and historic value of the collection is enhanced by the fact that many of the specimens, in addition to standard specimen data, have associated field notes, manuscripts, photographs, and correspondence from the collectors. These records are deposited in the DMNS Archives.

The scientific communities have utilized DMNS mammal specimens and data throughout the 118-year history of the Museum. The strong regional representation of the collection attracts researchers with a variety of questions focused on the Rocky Mountains and Great Plains. Based on increased collection activity over the last decade, there is a growing interest in the use of DMNS material and data spanning the overlapping disciplines of ecology, systematics, taxonomy, biogeography, parasitology, toxicology, climatology, and informatics. Given the accelerated growth of the collection since 2006 (see below) coupled with the ability since 2010 to disseminate DMNS mammal specimen records via the publically accessible database Arctos, and secondarily, through other data portals such as GBIF, iDigBio, VertNet, BISON, and GenBank, the use and value of the collection is only certain to grow. The value of the collection continues to grow with an increasing emphasis curation of the “holistic specimen”. That is, specimens that includes a voucher (e.g., study skin, skull, fluid, etc.), high quality specimen data, associated parasites, tissue samples, microbiomes, etc., and are linked to resulting publications and datasets.

Collection-use metrics from 2006 to July 2018 highlight the growing value of the DMNS mammal collection. Overall, metrics have increased since Curator John Demboski was hired in August 2006. The collection has grown from 10,921 (end of 2005) to ~24,000 specimens (120% increase), or about 1,090 new specimens annually. In addition, frozen tissues associated with 8000-plus mammal specimens and ecto/endoparasites (~6,000 specimen lots) have also been archived. Over this 12-year period, 174 loans have been processed, 470 researchers have visited the collection, and 128 publications (Google Scholar) have been produced using DMNS specimens and/or associated data.
Citations of publications using DMNS mammal specimens over this period number 5301 according to Google Scholar. Virtual visits and use of specimen records is reflected in query stats from Arctos and since 2010 there have been ~145,500 queries capturing 15,289,735 individual record instances. Professional visitors represent collection visits by researchers or state/federal agency staff, other professionals such as artists using the collections for artistic reference, and requests for information about holdings (e.g., e-mail inquiries). The number of peer-reviewed publications referencing the mammal collection is most likely underestimated given the lag between loans and subsequent publications, and reliance on researchers to inform DMNS about new publications.

Since 2014, the collection has been housed in the newly constructed and state-of-the-art Avenir Collections Center along with the Museum’s other 4.4M specimens and objects. The move allowed the collection to be reorganized, uncrowded, and housed in a climate-controlled facility ensuring best practices and growth into the distant future.

Collections Outreach and Education. As one of the largest natural history museums between Chicago and the West Coast, the DMNS has a long history of connecting with the general public through informal science education. There are a lot of opportunities to both learn about and view artifacts and specimens and in many instances, actually tour collections. A highly visible aspect of the mammal collection is its presence in the extensive wildlife dioramas (104 dioramas and 10 gallery halls on three floors) with accompanying interpretation. The mammal specimens, primarily body mounts, on long-term public display are curated by curator Demboski and cataloged in the DMNS mammal collection. Precise metrics for the number of visitors that view the dioramas are not available but given that approximately 1.6-1.8 M people visit the Museum on an annual basis, a significant number view the dioramas. The wildlife dioramas are a very popular and effective way of engaging the public across a wide range of topics covering evolution, ecology, wildlife issues, and human impacts on the environment. In addition, specimens from the mammal collections are routinely used to enhance temporary exhibits, touch carts, and special programs on the Museum floor.

The number of members of the public gaining access to the mammal collection via guided behind-the-scenes tours, education programs, open houses, special programming events (e.g., Museum Summer Camps, Science on the Spot, Museum Member Nights, etc.), lectures, workshops, and K-12 and university-level classes is truly amazing. As is readily apparent from this metric, 11,000+ visitors since 2006, the Museum is committed to allowing access to collections by as wide and varied an audience as possible. We view our role as a public repository for the earth’s biodiversity as an important function of natural history museums in general and the Museum in particular. Another significant outreach and educational outlet that leverages the research collections is the Museum’s extensive volunteer corps (1,800 plus); zoology volunteers (~121/yr) have donated 140,300 hours since 2006 including preparing specimens, working in the dermesterium, databasing, specimen inventory, data verification, and many other general collection tasks. Many of these volunteers work in the mammal collection.

The collection provides an irreplaceable geographic and temporal record of biodiversity in the region and abroad and this is evidenced by the both the professional and public use of the material, consistently producing among the highest use-metrics of any DMNS research collections.

Scope of the Collection

The DMNS mammal collection currently consists of approximately 24,000 specimens which includes 19,043 cataloged specimens (8/2019), and a backlog that is rapidly diminishing with the hiring of a full-time vertebrate preparator in 2018. The space dedicated to the mammal collection in the Avenir Collections Center can easily house a collection this size and depending on the nature of the
preparation, there is flexibility in areas of taxonomic growth. The collection spans 1870 to the present, is worldwide in coverage, and include specimens from the three major extant mammalian lineages (monotremes, marsupials, and placentals) distributed across 21 orders 265 genera, and 380 species. Specimens are cataloged and databased electronically in Arctos. The collection’s primary strength is its focus on the southern Rocky Mountains and Great Plains with approximately 82% of the collection from the western United States, with specimens from Colorado (73%) representing the largest percentage. Small mammals, such as shrews, rodents, lagomorphs, and bats, constitute the majority (84%) of specimens in the collection. The composition of the collection is primarily study skins with associated skeletal material or skull-only vouchers. Specimens preserved in ethanol are growing and mainly include shrews and bats. These are housed in 70-95% ethanol in the Zoology Wet Collections space on the main floor near the south loading dock. As mentioned above, high-quality specimen data, frozen tissues, and parasites are associated with most of the specimens archived since 2006.

The collection includes nine holotypes (one species, eight subspecies) and 20 paratypes all described by Museum staff between 1915 and 1933 (Figgins 1915, 1918, 1919, 1933; Miller 1925, 1928, 1930, 1933). Many of these have since been synonymized with other taxa. In addition, the collection also contains the other significant material:

- Type specimens for nine (seven from Colorado) holotypes described by Museum curators include (from Jones 1994): the hog-nosed skunk (Conopatus mesoleucus figginsi and C. m. fremontii), badger (Taxidea taxus phippsii), white-tailed deer (Odocoileus virginianus mcilhennyi), caribou (Rangifer mcguirei), bison (Bison bison haningtoni), yellow-bellied marmot (Marmota flaviventris campioni), northern pocket gopher (Thomomys talpoides macrotis), and wood rat (Neotoma albigula laplataensis). These specimens are of special historic significance in that they are an important record of some of the earliest mammalian studies conducted in Colorado.

- Specimens of mammals extirpated in Colorado include the black-footed ferret (23 specimens), wolf (9 specimens), bison (104 specimens, largest collection west of the Great Plains), and grizzly bear (11 specimens, including the last grizzly documented in the state 1979). In addition, the collection includes important holdings of threatened and endangered taxa such as the black-tailed prairie dog, wolverine, and Preble’s meadow jumping mouse.

- Carter Collection (a founding museum collection) – Originally 3,300 birds and mammals, unfortunately, all that remains of Carter’s original mammals is 26 mammal and ~200 bird specimens.

- Recent records of taxa previously unknown from Colorado include specimens of the first red bat (Lasiurus borealis; ZM.7849), Eastern pipistrelle (Perimyotis subflavus; ZM.7693), Mogollon vole (Microtus magallonesis; Frey et al. 2002), and a subspecies of meadow jumping mouse (Zapus hudsonius luteus; Jones 1999) that has been the focus of recent conservation concern.

- Large series of small mammals that are being actively studied both within DMNS and by external researchers: Tamias sp. (chipmunks; n=1490), Peromyscus maniculatus (deer mouse; n=2000), Cynomys ludovicianus (Black-tailed prairie dog; n=166), Zapus hudsonius preblei (Preble’s jumping mouse; n~150), and Ochotona princeps (pikas; n=208).

- Large series of Front Range mammals (n~1500) received from wildlife rehabilitation centers over the last decade. An important record of regional, urban biodiversity from Colorado.
Exotic mammals such as elephants, lemurs, Przewalski’s horse, okapi, African wild dog, cheetah, snow leopard, etc. from the Denver Zoo (and others).

Associated mammalian tissue samples and parasites (see above and below).

History of the Collection
The mammal collection’s history as part of the Museum’s greater history is documented in Denver’s Natural History Museum: A History (Johnson et al. 2013). The growth of the mammal collection can also be traced back to the incorporation of the Colorado Museum of Natural History (CMNH) in 1900 with the acquisition of Edwin Carter’s bird and mammal specimens. Mammal collection activity tracks different institutional foci and staffing over the last 118 years. The first period of real growth begins 1900-1910 and reflects collecting efforts in Colorado and New Mexico to document species occurrence and acquire specimens for public display in exhibits and dioramas. In 1910, mammalogist and ornithologist Jesse Figgins was hired as Museum director and initiated a period of growth centered on building the research collections and public exhibits. Expeditions in the North America (Rocky Mountain region; Alaska 1921) and abroad (South America 1926, 1928) supported this growth.

Following Figgins, Alfred Bailey was hired as director in 1936, where he remained until his retirement in 1969. Once again, collecting in the Rocky Mountain region continued in earnest, coupled with international expeditions to Central America (1931), Australia (1949), Campbell Island (1958), Galapagos Islands (1960), and Botswana (1969). As during the Figgins’s era, the fruits of these expeditions are still on display in the Museum’s diorama halls. During this time, Bailey also hired two mammal curators: Albert Rogers (1948-1958) and Henry Wichers (1959-1972).

From 1980-2003, a major spike in growth occurred under the direction of Carron Meaney (1985-1991, curator of mammals) and Cheri Jones (1992-2003, curator of mammals) with focused collecting trips in Colorado and Wyoming. During this period, many improvements were made to collection storage conditions and protocols that positively impacted the mammal collection. This included improvement of collections care by increased environmental monitoring and implementation of an Integrated Pest Management (IPM) program in 1988 followed by accreditation by the American Society of Mammalogists in 1989. In 1999-2001, funding from IMLS (IC-90-194-99) was used to improve storage conditions (cabinets, compactors and specialized storage mounts) for 600 large-bodied mammals stored in a 5,000-ft² shared collections area of the Museum.

In 2001, The University of Colorado Museum, Denver Botanic Gardens, and DMNS received NSF funding (DEB-0110133, Mountain and Plains Spatio-Temporal Database-Informatics Initiative, MaPSTeDI, 2001-2005) to convert their separate collections into one distributed biodiversity database and research toolkit for the southern/central Rockies and adjacent plains. Although the MaPSTeDI database is not currently active, the project supported initial geocoding of approximately 5,000 mammal records that were later migrated to Arctos.

In August 2006, Curator John Demboski was hired as the curator of vertebrate zoology responsible for both the mammal and bird (53,000 specimens) collections. PI Demboski began an aggressive program of growing both collections through mammal collecting (in part funded by NSF DEB-0716200) and salvage (including birds). This burst of activity has resulted in the greatest amount of growth (120%) in the mammal collection’s history (2006-2018), when compared to the previous 112 years. This recent growth has also benefitted from salvaged or collected mammals obtained from the Colorado Parks and Wildlife, United States Fish and Wildlife Service, Mesa Verde National Park, Denver Zoo, Colorado Natural Heritage Program, and wildlife rehabilitation centers among other agencies and groups.
Concurrent with this rapid growth over the last 12 years was the formation of an in-house frozen tissue collection; tissues have been archived from approximately 8,000 plus mammal specimens as of July 2018. The frozen tissue collection continues to grow as every incoming specimen is sampled. In addition, ecto- and endoparasites are now sampled from all incoming specimens and housed as a separate collection (~6000 specimen lots). Both the frozen tissue subcollection and the Parasite collections have substantially increased the overall value and utility of the mammal collection.

Demboski has also instituted rigorous curatorial procedures; development of a mammal collection manual, more discriminatory accession policies (e.g., only specimens with provenance), and processing a large backlog of accessioned specimens from the 1990’s. During fall 2009, the dry bird and mammal areas of the old Zoology Main Range were reorganized, by stacking cabinets higher to provide more efficient use of the restricted space, improve traffic flow through the collections, and to move many of the existing 287 cabinets off in-floor heated pipe chases. In 2010, the mammal specimen records were migrated to Arctos, and paper cataloging ceased. In spring 2011, a National Science Foundation grant ($498,417) was awarded to Demboski to support the purchase of new cabinetry (120 Delta Design cabinets with trays), inventory, reorganization, and databasing of the mammal collection in preparation for the 2014 move into the new facility. This funding also allowed a full-time collections technician, Meghan Truckey, to be hired for a 3-year term through 2014. In 2014 the collection was moved to the new Avenir Collections Center, and since then there have been ongoing projects around organizing the collection to make the best use of space in the new facility.

The ongoing growth of the mammal collection by Demboski has been spurred on by the need to better document mammalian diversity (including genetic diversity) in the southern Rocky Mountain region. This is important given the rapid influx of people into the region, particularly Colorado’s Front Range over the last 20 years coupled with a growing concern for the effects of rapid climate change. Given the 150-year span of the mammal collection, it provides an important, baseline resource from which to compare and contrast findings based on contemporary sampling of the mammalian fauna.

Future of the Collection
Future growth of the mammal collection will be primarily directed toward the acquisition of specimens with high quality data and associated tissue and parasites, etc., all centered around the “holistic specimen” philosophy. The primary source of new mammal material will be derived from regional collecting efforts by the curator, material from state and federal agencies (e.g., CPW), exotic mammals from the Denver Zoo, and acquisition of salvaged mammals from local wildlife rehabilitation centers. At its current growth rate (~1,090 specimens/yr since 2006), this collection is expected to reach ~37,000 specimens by the end of 2028. The bulk of new specimens will be small mammals (rodents and lagomorphs) and therefore will not adversely impact available Zoology collection space. Growth of this size for the collection was planned for in the design of the Avenir Collections Center. It is also anticipated that external loan activity will continue to increase as it already has, as a result of the rapidly expanding frozen tissue collection, given that tissue loans constitute a large % of loan activity.

Some of the growth outlined above in future years will be as a direct result of curator research projects focused on small mammals. For example, growth of the mammal collection has been influenced by Demboski’s research examining the systematics of western chipmunks. This project, with its strong Rocky Mountain field component has not only increased the mammal collection’s geographic and taxonomic holdings of chipmunks, but also that of other mammal species collected as part of the project (n= 1,400 mammals; 2006-2018). Other growth will come from local wildlife rehabilitation centers which
donated approximately 3,000 Front Range mammals over the last 10 years, and this is expected to continue into the future.

Concurrent with the acquisition of mammal specimens is the roughly 16,000-20,000 tissue cryotubes from about 8,000 specimens currently housed in a \(-87\)°C ultracold freezer, with records easily searchable in Arctos. This mammal sub-collection is very active with 10+ loans annually for tissue samples and this activity will continue to increase. By 2019, the tissue holdings (including birds) will also publish to the Global Genome Biodiversity Network (GGBN) portal through Arctos. This international online aggregator will most likely increase visibility, traffic, and loan activity for the tissue collection. With that in mind, curators Demboski and Spellman will be looking at logistics and funding in the next two years to move the bird and mammal tissues to a liquid nitrogen system. Such a system will allow for future expansion of the tissue sub-collections, allow better preservation at \(-190\)°C, reduce overall utility costs, and decrease risks associated with freezer failure.

Since the move to the Avenir Collections Center, there has been an ongoing effort to keep current with newly established taxonomic arrangements in mammals accepted by the greater scientific community. During the course of this project, many specimens and associated material have been moved, re-housed to increase storage space, and this will continue over the next 5 years. In addition, Zoology staff and volunteers are also in the process of coralling data from multiple paper records, verifying associated specimen data, inventorying specimens, improving or adding ancillary data associated with electronic records, and thus increasing the overall value of the collection. There are also associated imaging projects (macrodigital and GigaPan) to digitize more of the mammal collection and associate images with Arctos records for visibility. Given the large efforts to digitize (iDigBio) natural history collections, the future looks very bright for increasing visibility and research use of the collection.

Increased visibility and dissemination of the mammal collection’s holdings to both the scientific community and public has increased immensely in the last decade. This will continue over the next 5-10 years and will enhance the mammal collection’s value as an important regional resource for both the scientific community and the general public.

4.5.5. Ornithology
Curator: Garth Spellman
Plan authors: Garth Spellman & John Demboski

Intellectual Framework
Birds are the most diverse Class of terrestrial Tetrapods. Using divergent species concepts, Ornithologists have argued that the Class Aves includes somewhere between 11,000 and 18,000 species. Given their diversity, global distribution, beauty and ability to fly, birds easily captivate. They are the only surviving lineage of Dinosaurs, descending directly from a twig in the Theropod dinosaur tree, and represent an extremely successful, adaptive radiation and function as sensitive indicators of the health of ecosystems (as most species feed at the top of food chains). Birds are also often a gateway into community driven natural history research for citizen scientists. The majority of species are diurnal and conspicuous, which allows them to be easily observed and identified. These traits have been exploited by Ornithologists for centuries and are the drivers behind the modern birding movement, which continues to be the dominant and fastest growing recreational pastime around the globe.

The Ornithology Collection, with ca. 58,000 specimens, is an important regional, national and international resource for active specimen-based research and education. The majority of specimens in the collection (~75%) have been collected from the Rocky Mountains and Great Plains ecoregions.
There is also superb global representation and taxonomic coverage (see below under Scope). The collection is actively used for a wide range of activities including research, education, outreach, artistic reference, and exhibit support. Technology has transformed the importance of the Ornithology collection and given new life to the tens of thousands of specimens collected prior to 1950. Revolutions in genomics (allowing genomic data to be collected from old or historical specimens), isotope analysis, hormone analysis (getting diet information from feathers), and imaging technology (CT scans or microscopy) have reinvigorated collections-based research and are providing insights into the evolution and ecology of birds no one would have imagined was possible only five years ago. Examples from research projects using DMNS Ornithology specimens include: genomics of the Passenger Pigeon suggesting natural selection may have erased genetic variation in the species possibly leaving it susceptible to extinction (Murray et al., 2017); Feather hormones in Red-legged Kittiwakes link food availability to environmental changes in the Bering Sea over the last 100 years (Will AP, Kitaiskaia EV, & Kitaysky AS, 2018); Genomics reveal the extinct San Benedicto Island Rock Wren was genetically distinct and adapted to island life prior to being wiped out by a massive volcanic eruption (Spellman et al., in Prep). Each of these studies (and several more that are ongoing) would not have been possible to complete without the DMNS collection and the over a century of dedicated staff and curators ensuring the preservation and security of the specimens.

The transfer of the collection to the new Avenir Collections Center could not have come a better time. Although the old specimens will continue to age, the effects of that aging will be less severe with the new state of the art facility providing a controlled environment optimized for the preservation of natural history collections. New material coming into the collection (currently ~5% growth annually) will be housed under optimal conditions positioning the Ornithology Collection perfectly to serve the needs of the scientific, artistic, and educational communities today and well into the future.

Educational and outreach utilization of the collection includes tours, artistic support, classes/workshops offered by Zoology staff, and support for DMNS exhibits. The public sees the bird specimens daily since they are on permanent display in the 104 dioramas and display cases throughout the Museum.

The scientific and historic value of the collection is enhanced by the fact that the many of the specimens, in addition to standard specimen data, have associated field notes, manuscripts, and correspondence from the collectors. These records are stored in the DMNS Archives. The Archive also contains Edwin Carter’s original field notes from the late 1800’s, when he was building his private collection of specimens that would later became the catalyst for the founding of the Museum.
The specimens in the Ornithology Collection provide an irreplaceable geographic and temporal record of biodiversity in the Rocky Mountain/Great Plains region and abroad evidenced by loan activity of material to researchers, educators, and artists (53 loans in the last four years).

Scope of the Collection

The Ornithology Collection includes approximately 58,000 objects, including approximately 49,500 birds (study skins, mounts, and skeletal material), nearly 7,500 egg sets, and 1200 nests. Taxonomic coverage, geographic coverage and growth statistics are detailed in Table 1. The collection is worldwide in scope (6/7 continents represented) with excellent taxonomic coverage of class Aves (205/224 families represented). Ordinal representation is excellent; however, more than half of the birds in the collection belong to Passeriformes. Given Passeriformes includes more than 50% of all extant bird species, this is often the case for most large Ornithological collections. Other well-represented orders include Accipitriformes, Anseriformes, Charadriiformes, Columbiformes, Galliformes, Piciformes, and Strigiformes.

The geographic strength of the collection is regional. About 75% of the specimens are from the Rocky Mountains and Great Plains region with the majority of the specimens (69%) collected before 1950. The collection is the largest between the University of Kansas and West Coast collections. By comparison, other large, regional ornithology collections located at the University of Wyoming, University of Colorado Boulder, and University of New Mexico, have approximately 2,300, 11,000, and 40,000 specimens, respectively.

Significant specimens in the collection include eight holotypes: sharp-tailed grouse [Pedioecetes (Tympanuchus) phasianellus jamesi], northern bobwhite (Colinus virginianus taylori), Gunnison sage grouse (Centrocercus minimus), piculet (Picumnus arileucus), veery (Catharus fuscescens levy),

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### Table 1. Summary of taxonomic and geographic coverage. Growth statistics for the collection (Percentage growth in parentheses).

<table>
<thead>
<tr>
<th>Order (Clements 2004)</th>
<th>#</th>
<th>Region</th>
<th>#</th>
</tr>
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<tbody>
<tr>
<td>Accipitriformes</td>
<td>1809</td>
<td>Africa</td>
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<tr>
<td>Aepyornithiformes</td>
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<td>Antarctica</td>
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<td>Bucerotiformes</td>
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<td>Australia</td>
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<td>Central America</td>
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<tr>
<td>Casuariformes</td>
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<td>Eurasia</td>
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<td>611</td>
<td>2013-2015</td>
<td>51531(5%)</td>
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<td>3688(93%)</td>
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<tr>
<td>Trogoniformes</td>
<td>64</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Long-Term Collections & Research Plan 2019 - 2023*
saffron finch (*Sicalis pelzelni danisa*), savannah sparrow (*Passerculus sandwichensis bradburyi*), house finch (*Carpodacus mexicanus smithi*), and two lectotypes, the long-tailed ground dove (*Uropelia camppestris figginsi*) and house finch (*Carpodacus mexicanus sayi*). Twenty paratype specimens associated with the species/subspecies above are also housed in the collection. Phillips and Webb (1991) summarized the avian type material housed in the Ornithology Collection.

Other important specimens include those of twelve extinct taxa: the Passenger Pigeon (*Ectopistes migratorius*), Carolina Parakeet (*Conuropsis carolinensis*), Dusky Seaside Sparrow, (*Ammodramus maritimus nigriscens*), Eskimo Curlew (*Numenius borealis*), San Benedito Island Rock Wren (*Salpinctes obsoletus exsul*), Guadalupe Island Ruby-Crowned Kinglet (*Regulus calendula obscurus*), Heath Hen (*Tymanuchus cupido cupido*), Huia (*Heteralocha acutirostris*), Ivory-billed Woodpecker (*Campephilus principalis*), Imperial Woodpecker (*Campephilus imperialis*), Bachman’s Warbler (*Vermivora Bachmanii*), and eggs from the Elephant bird (*Aepyornis maximus*). Specimens of critically endangered or threatened species in the collection include the California condor (*Gymnogyps californianus*) and Kakapo parrot (*Strigops habroptilus*). In addition, the collection includes many large series of more common species (e.g., sparrows, blackbirds, robins, finches etc.) that provide important baseline population data for the Rocky Mountain and Great Plains regions.

All of the study skins, skeletal material, egg sets, nests and mounts are stored in cabinets in the main Zoology collections area on level B2 of the Avenir Collections Center. The egg set and nest collections, which were largely collected in the late 19th and early 20th centuries, are contained in specialized boxes with folded acrylic tops and lined with cotton. Avian frozen tissue samples, from approximately 6500 specimens, are stored in 2-ml cyrotubes in a Sanyo-86° C ultracold freezer that is located in the Zoology specimen preparation laboratory. The Ornithology Collection also includes approximately 200 fluid (EtOH) preserved specimens housed in specially designed fire proof cabinets in the 1st floor Zoology Fluid Collection facility.

**History of the Collection**

Birds collected and prepared by Edwin Carter in the 1870’s and 1880’s from the Breckenridge area formed the nucleus of the avian collection when the Colorado Museum of Natural History opened its doors in 1908. Systematic collecting in the early part of the 20th Century by the first Curator of Birds, Luman Hershey (1909-1913), Curator of Birds Frederick Lincoln (1914-1918), Curator of Oology W. C. Bradbury (1914-1925), Curator of Birds Alfred M. Bailey (1921-1926), and Museum Director Jesse Figgins (1910-1935) resulted in the establishment of an outstanding regional and burgeoning international collection with a strong emphasis on support for exhibits. Of note during this early period is the action by preparator Alexander Wetmore, who by failing to follow instructions in 1909 to discard specimens from the Edwin Carter Collection saved over 200+ valuable specimens, including several state records, and thus made a significant and lasting contribution to the collection. In addition, the Austin Paul Smith collection was added in 1916, which consisted of 732 bird specimens of 380 species and subspecies, including many rare specimens from type localities.

Perhaps the most important period of growth and notoriety for the Ornithology Collection was when Alfred M. Bailey returned to the Museum as its newly hired director in 1935, a position he held till 1969. Bailey, an extremely active ornithologist and collector, initiated and participated in many of the major international expeditions (e.g., Botswana, the Galapagos Islands, etc.) that expanded the research collections and public exhibits. Bailey also instituted many new innovations in curation and exhibitry. In addition, Bailey published many public and scientific works including the still very relevant *Birds of Colorado* (Bailey and Niedrach 1965). In close conjunction with the Curator of Birds Robert J. Niedrach (1935-1968), Bailey increased the visibility of the Museum and its educational role through
community outreach and in particular, through the upgrade and expansion of the world famous habitat dioramas. During Bailey’s tenure, the museum was renamed the Denver Museum of Natural History.

Following Bailey and Niedrach, Elizabeth A. Webb was hired as the Curator of Zoology in 1972. Webb rehoused, reorganized and consolidated the zoological collections (including Mammals and Entomology), which had been stored in boxes as the Museum moved towards a more pronounced public programming focus in the late 1960’s. Webb also initiated an integrated pest management program (Webb et al. 1989). During Webb’s tenure (1972-1992), ornithologist Allan R. Phillips was also contracted to serve as an avian taxonomy consultant.

In 1989, Chuck R. Preston was hired as the Curator of Ornithology and subsequently, Zoology Chairman. Over the course of his tenure (1989-1998), Preston incorporated approximately 2,000 specimens from the Rocky Mountain and Great Plains region, computerized all specimen records, increased the use of the collections by researchers and for outreach endeavors, and secured financial support for the Ornithology Collection through the Bouslog Fund, a bequest from the estate of John and Nina Bouslog. A more extensive history of the Ornithology Collection up to the year 2000 is presented in Preston and Haglund (2000).

From 2000-2005, Rob Roy Ramey III, was the Curator of Vertebrate Zoology and Zoology Chair. In early 2006, the DMNS Zoology and Conservation Departments were awarded an IMLS grant for arsenic testing and rehousing of the approximately 1000 mounted birds in the collection. The results from the testing indicate that majority of the mounts are arsenic positive and this information is being incorporated into curatorial procedures.

From August 2006-August 2015, John R. Demboski served as the Curator of Vertebrate Zoology. During this period, the collection grew and expanded at an average annual rate of ~3% through transfer and salvage programs fueled through relationships with local, state, and regional partners (i.e., Greenwood Wildlife Rehabilitation Center, Rocky Mountain Raptor Program, WILD Bird, Denver International Airport, Colorado Parks and Wildlife). Dr. Demboski oversaw a transformation of the collection by introducing new protocols that ensured incoming specimens could be utilized to their fullest potential, taking advantage of emerging technologies in science. This included preserving frozen tissues and associated parasite material from all specimens, and ground-truthing all specimen data for the migration to the multi-institutional web-accessible database Arctos (http://arctos.database.museum/dmns_bird). This allowed better visibility and dissemination of information to both the scientific community and public as Arctos automatically publishes to data portals such as GBIF, ORNIS, and VertNet. Loan growth exploded (~200% growth) following the migration to Arctos, likely due to the increased visibility of the collection, exemplified by the >65,000 web queries of the Ornithology collection between August 2013-August 2015. The full collection and all associated materials were transferred to the new state of the art Avenir Collections Center between 2014-2017 guaranteeing their future security and providing ample room for collections growth. The transfer of the collection began under Dr. Demboski’s supervision and was finished under the supervision of the newly hired Curator of Ornithology, Dr. Garth Spellman.

In August 2015, Dr. Garth M. Spellman was hired as the Curator of Ornithology and is pursuing the collections objectives detailed below.

**Future of the Collection**

The future direction of the Ornithology Collection is planned knowing the collection is secure and has room for expansion given the transition to the new Avenir Collections Center and its associated lab spaces. Growth continues to focus on the acquisition of research-grade specimens with associated tissue
and parasite samples. As during the period of 2012-2017, the primary source of new avian material will be transfer of specimens from state and federal agencies, birding groups, rehab programs, and continued acquisition of road/window kill specimens from the public. However, with the hiring of a new Curator of Ornithology, Dr. Spellman, specimens collected specifically for new and ongoing research projects will also be added to the collections annually, significantly increasing the diversity of species coming into the collection and expanding the geographic scope of the collection.

Growth of the Ornithology Collections was projected to be 1% annually when the previous five-year collections report was drafted. This was a slight miscalculation (see Table 1). Over the last five years, whole specimen (round skins, fluid preps, and skeletons) growth averaged 5% annually, which means that approximately 2700 specimens are added annually. Assuming this rate of growth continues (given Dr. Spellman’s active research program and the continuation of the Department’s salvage program this is a certainty), the Ornithology Collection will exceed 85,000 specimens by the year 2028. The new collections facilities should have more than adequate space to accommodate this growth, even if growth should exceed expectations by 1-2% annually.

All the new skin and skeletal specimens will have associated tissues and parasite material that will be properly preserved. Growth of the frozen tissue collection and parasite collections has exceeded 150% and 100% annually over the last five years and there is no sign that this growth will slow down (only with respect to the size of the collections). A new Ultracold freezer was purchased in 2018 to accommodate the expansion of the frozen tissue collection; however, given the current and expected annual growth rate of the collection, the frozen tissue collection will easily exceed 32,000 specimens by 2028. Our current freezer capacity is not large enough to accommodate these specimens and therefore a solution to address frozen tissue storage is a pressing need to secure the future of the bird and mammal frozen tissue collections. Dr. Spellman and Dr. Demboski are looking at grant opportunities and possible internal funding sources to acquire a large liquid nitrogen storage facility to safely and securely preserve the frozen tissue collections and to accommodate for the projected growth. The security and preservation of this material is imperative given that the majority of loan requests submitted to the Ornithology and Mammalogy collections are for frozen tissue samples. The same space constraints are on the horizon for the parasite collection, but these collections are stored in normal -20C freezers that are relatively cheap to purchase. The trick will be to find appropriate space for the freezers.

Over the last several years, the collection has been increasing its digital presence and visibility. This began with the ground truthing of the specimen data preceding the migration to the multi-institutional web-accessible database Arctos and continues today. The Zoology Department was able to purchase a gigapan imaging system using funds acquired through a generous donation. Collections staff and the curators have been developing a protocol for using this imaging system to scan entire trays of specimens. These images will be uploaded and linked to the specimen data allowing researchers around the world unprecedented access to DMNS collections. The images have the potential to seed new research projects without the need for those carrying out the research to visit DMNS. Digitization of the Ornithology Collection has resulted in an explosion of touches with our specimens. Since 2012, Arctos has recorded >198,000 web-queries of our bird collection, representing >22,000,000 individual specimens.

Never before in the history of the collection has it received so much visibility and the future digitization projects and growth of the collection will certainly increase this visibility over the next five years. All of the endeavors outlined above will ensure the Ornithology Collection continues to be a world-class resource for the scientific community and general public.
4.5.6. Amphibians and Reptiles
Curator: John R. Demboski
Plan author: John R. Demboski

Intellectual Framework
The amphibian and reptile collection is a small collection at DMNS that consists of amphibians and reptile specimens. Amphibians and reptiles represent large vertebrate groups with about 17,000 species worldwide, with approximately 74 species found in Colorado.

The collection is growing slowly but does get some visibility from the research community. Virtual visits and use of specimen records is reflected in query stats from Arctos since 05/2015 with 1663 queries capturing 19,067 individual record instances. The collection also publishes data to GBIF, iDigBio, VertNet, and BISON.

Scope of the Collection
The collection consists of approximately 600 specimens mostly housed 70%-95% ethanol and stored at room temperature in the Zoology Wet Collections space on the main floor near the south loading dock. There are also some dried specimens housed in the Avenir Collections Center in B2 Zoology. A small number of specimens are on display in the wildlife diorama halls. There is also a small frozen tissue collection associated with the collection (<20 specimens). To date, 102 (mostly small lizards) have been cataloged and are currently available in Arctos (July 2019). The geographic focus of the collection is primarily states in the American Southwest (Arizona, California, Colorado, Nevada, Wyoming, and Utah) or captive, exotic zoo herptiles. Some uncommon specimens include a Komodo dragon, iguanas, and tortoises from the Galapagos Islands, as well as bycatch herptiles collected during the first year of the National Ecological Observatory Network (NEON) project.

History of the Collection
The DMNS herpetology collection is a new collection that was established in May 2015 and has grown slowly, with the bulk of growth coming in the last 8 years. Historically, there was an assortment of reptiles from past collecting trips (e.g., 1960 Galapagos Islands, 1969 Botswana), some of which are on display in the wildlife diorama halls or behind-the-scenes (ACC B2), but these were never cataloged nor included as part of the greater DMNS collections. The collection was formally recognized in 2015 when specimen records began to be assigned catalog numbers (ZH.XXX) and uploaded to Arctos. The growth of the collection over the last 8 years has been primarily tied to salvage (e.g., roadkill), incidental bycatch (herptiles collected along with invertebrates that are cataloged in either the Museum’s entomology or arachnology collection), or exotic, captive herptiles from the Denver Zoo.

Future of the Collection
The collection will continue to grow slowly as it has over its short history. Over the next couple of years, volunteers will be specifically tasked to help sort, rehouse, and catalog specimens. In addition, preparation of backlogged herptiles will increase growth of the herpetology frozen tissue collection. By cataloging the growing backlog, specimens will be accessible via Arctos which will increase visibility of the collections, spur better identification, and support research projects.

4.5.7. Parasites
Curator: John R. Demboski
Plan author: John R. Demboski
**Intellectual Framework**
Parasites are a diverse group of organisms that live on or in a host (another organism) and use the host’s resources to survive. They span the animal kingdom and are routinely found in the vertebrates (birds and mammals) that are accessioned into the DMNS collections. Parasites are of importance from a biodiversity perspective, as well as a medical importance given their role sometimes as pathogen vectors.

The DMNS parasite collection is a new collection that was formally established in October 2016 and grew out of a concerted effort to survey and collect parasites from every vertebrate specimen accessioned and cataloged into the Museum’s bird, amphibian/reptile, and mammal collections over the last 12 years. The collection has grown rapidly along with its visibility and to date, multiple loans and nine publications ([Google Scholar](https://scholar.google.com)) have been produced based on DMNS parasites. Virtual visits and use of specimen records is reflected in query stats from [Arctos](https://arctoscollections.org) since 10/2016 with 1653 queries capturing 83,461 individual record instances. The collection also publishes data to [GBIF](https://www.gbif.org), [iDigBio](https://www.idigbio.org), [BISON](https://nrm.models.gov), and [GenBank](https://www.ncbi.nlm.nih.gov).

Although there are many parasite collections across the world, a strength of the DMNS collection is its strong ties to the vertebrate hosts deposited in the same institution, and also relationships among the different parasites collected from the same host. These host-parasite relationships are easily tracked in [Arctos](https://arctoscollections.org), and embody the philosophy of the “extended specimen”.

**Scope of the Collection**
The collection consists of about 7,500 specimens or specimen lots mostly housed in small vials (70%-95% ethanol) and stored in a -20°C freezer in the Vertebrate Prep Lab. Several hundred fleas and lice are mounted on slides and stored in a slide cabinet in the Avenir Collections Center. To date, approximately 1300 specimens or specimen lots have been cataloged, of which 940 are currently available in [Arctos](https://arctoscollections.org) (July 2019). The focus of the collection, like the vertebrate hosts, is on the Rocky Mountains and Great Plains regions. Taxonomic coverage includes ectoparasites such as insects (fleas, lice, streblid and oestrid flies), arachnids (ticks and mites), and endoparasites spanning Nematoda and Cestoda. Many of the sucking lice, fleas, and nematodes have been identified to species-level by experts and are captured in peer-reviewed publications.

**History of the Collection**
As mentioned above, the collection is new with the bulk of growth coming in the last 12 years when mammal curator John Demboski started to actively collect parasites from newly accessioned vertebrates. In addition, there was also a small collection of several dozen parasites that had been collected from birds and mammals dating back to the 1980’s and 1990’s. The collection was formally recognized in late 2016 when specimen records began to be assigned catalog numbers (ZP.XXX) and uploaded to [Arctos](https://arctoscollections.org). Growth of the collection has tracked the rapid expansion of the bird and mammal collections. Since its inception, there have several been projects centered on taxonomic identification led by external researchers interested in a particular group which has included sucking lice, fleas, ticks, and nematodes.

**Future of the Collection**
The collection will continue to grow in parallel with the growth of the vertebrate collections. Survey and collection of parasites from every vertebrate prepared is an integral step of the vertebrate prep workflow. Growth estimates for the bird and mammal collections point to approximately 37,000 vertebrate specimens being accessioned over the next decade and a large percentage will have parasites. There is storage in the Zoology Wet Collections space on the main floor near the south loading dock, and this is a prime candidate for long-term housing of the parasite fluid collection. Over
the next couple of years, volunteers will be specifically recruited to help sort, rehouse, and catalog specimens and specimen lots. By cataloging the parasites, they will be accessible via Arctos, which will increase visibility of the collections, spur better identification, and support research projects.

4.5.8. Botany
Curator: Frank Krell
Plan author: Frank Krell

Intellectual Framework
The DMNS houses about 4500 plant specimens (pressed plants mounted on sheets or in books, leaf litter samples, pine cones, seeds, wood samples) collected between the mid 19th century and today. The herbarium contains mostly material from the Rocky Mountain/Great Plains ecoregions, including material representing host plants for insects from the entomology collection and voucher specimens of plants used in the dioramas. Currently, the herbarium is mainly an auxiliary resource for non-botanical projects and exhibits, but currently gets integrated in the regional herbaria database consortium.

Scope of the Collection
The collection contains ca. 4000 mounted and databased specimens of ca. 240 families, but no type material, and ca. 500 unmounted or not yet databased specimens. The Kirk Johnson collection contains unmounted specimens (representations of leaf litter), and a donation from D. Miller contains pinecones (research vouchers). 2498 databased specimens are from the United States (1128 from Colorado). The majority of the material is well curated and identified to species. With the majority of specimens collected in North America the Herbarium fits well in the mission of the Museum.

History of the Collection
The herbarium collection was established by Ernest H. Brunquist, Honorary Curator of Botany from 1959 – 1978. The material was donated by many different collectors, with the oldest specimen collected in 1859. In 2014, we received Kirk Johnson’s herbarium as a substantial addition. The strength of the collection is that it provides a representative collection of plants from the Rocky Mountain/Great Plains ecoregions. The voucher material for the dioramas was collected when the dioramas were built.

Future of the Collection
Without a botanist on staff and being housed in the Zoology Department, the Herbarium serves mainly as repository for vouchers connected to activities and studies of this and other departments. The growth of the herbarium will be minor and will occur primarily as vouchers of host plants of insects are collected as well as representative plant species from major study sites. The herbarium will not grow independently, although we would accept scientific instruments related to botanical collecting since those would serve outreach activities such as behind-the-scenes tours. In collaboration with the Botanical Garden, our Colorado specimens were photographed, and the data and photographs are currently being uploaded into SEINet (Symbiota), where the DMNS Herbarium forms a part of the Rocky Mountain Regional Consortium at http://symbiota4.acis.ufl.edu/seinet/rockymt/portal/collections/misc/collprofiles.php?collid=429. This will raise awareness about its existence in the research community. The main task for the future will be mounting the unmounted specimens and date cleanup. Sheets with mounted plants will occasionally be used for temporary exhibits (Zoology changing case, travelling exhibits).
4.6. Education Collections
Director: Melissa Bechhoefer
Plan author: Evelyn Busch

Educational Merit and Impact of the Education Collections
Over the last 5 years, the Museum has oriented itself with the local community. Making efforts to “meet people where they are” and listening and responding to community feedback has become central to programs developed at DMNS. As such, programming here utilizes a “toolbox” approach when developing or revising programs. One of these tools is Object Based Inquiry.

Object Based Inquiry, or OBI, is a tool that combines two pedagogies: Object Based Learning, learning from an object that is in front of you – not a picture, video, or behind glass, but a real, tangible object in front of you. The second, is Inquiry Learning where individuals construct much of their understanding of the natural and human-designed worlds. Inquiry implies a “need or want to know” premise. Inquiry is not so much seeking the right answer - but rather seeking appropriate resolutions to questions and issues. For educators, inquiry implies emphasis on the development of inquiry skills and the nurturing of inquiring attitudes or habits of mind that will enable individuals to continue the quest for knowledge throughout life. Education Collections at DMNS brings these two pedagogies together and matches them with real museum objects for our community to interact with allowing our museum staff to fully deploy this tool in a manner that is unique to DMNS and within the museum community.

Community Impact of the Collections
As of January 2019, the DMNS Education Collections supports approximately 1,654 programs, as well as nearly all temporary exhibits reaching 576,795 people in 2018. A few examples of the programs that Education Collections supports are: Field Trip Adventures, Camp-Ins, Spring, Summer, Fall and Winter Camps, the Facilitated by Us and Delivered to You Programs, Science on the Spot, Science Lounge, Temporary Exhibit enhancements and Discovery Zone.

This diverse programmatic commitments Education Collections has to the institution necessitates that the department maintain its own tracking, scheduling, and cataloging system to maintain our legal responsibilities to a collection that held as a community resource in the public trust. As a Department we provide information to the public outreach departments who are seeking to acquire specimens for use in programs. The Education Collections Manager and Assistant Manager are well versed in both domestic and international collecting laws and regulations and ensure that the Museum is not put in a bad situation with an uninformed purchase or collection. We also make sure that all necessary reports to the Colorado Division of Wildlife and United States Fish and Wildlife Service are filed and accurate.

Different from our support of onsite programing, is the Education Collections Loan Program. After Education Collections meets its obligations to the DMNS programs we make available certain objects for loan out to schools, libraries, and other organizations that are doing educational public outreach in the natural sciences. We do not allow for the use of collections for things like dinner, or birthday parties. There needs to be a strong educational component present if we are going to provide a loan to an individual or organization. Education Collections Staff will work directly with teachers to match the best collections we can to their curriculum. Because of frequency, time involved and nature in which Education Collections receives requests, we maintain our own loan records. While we ardently conform to the RCD Collections Policy and Procedures Manual, we currently do about 80 loans, external to the Museum, per year.

Philosophy of the DMNS Education Collections
The DMNS Education Collections serves as a resource center for science programming at DMNS. As such, it is necessary to maintain a large breadth of high quality collections that represent all of the major study areas of our research departments – and even some that are not represented in DMNS research, but we offer programming around. Education Collection staff have competent knowledge in most of the sciences that are represented in our collection as well as fluency in education theory and science communication styles. As such, we can also act as content specialists when necessary for DMNS program and exhibit developers by merging these two characteristics of our roles.

Museum Collections versus Teaching Aids and Props
Historically, the DMNS Education Collections have not been responsible for things like posters, building materials like Legos or Kiva sticks. The department has assisted with some of the costumes and props that the Enactor Program utilizes. These items are usually high end costumes that need pest control and prevention, and reproductions that have a use long beyond a single “character”, in many cases we come back to their use time and time again as certain themes are popular with our visitors and characters can often draw upon the “props” that were used by a former character. What this looks like going forward, on a larger scale, if there is a larger scale, with the Education Collections and the Library living together is still unclear at this time. If we have a future together as more of a resource center than just a collection, then there may be opportunities to explore further here.

Care of Education Collections Objects
The Education Collections Managers, staff, interns and volunteers are challenged with a unique task, one that makes them leaders in the field of public access to collections: balancing access and audience engagement with preservation and conservation, which extends the longevity of the object’s lives. In addition to developing creative solutions to make objects, like extremely sharp Maasai spears, or fragile snake skulls, safe for people to interact with and still preserve the condition of the object along with ensuring visitor safety, Education Collections is also tasked with making programs like the Enactor Program as realistic as possible. The Enactor Program, for example, relies on the illusion of the authentic to communicate on the reality of the present. In many cases the enactors take on the persona of a person from the past. So, Education Collections is challenged with creating care strategies for specimens that look like the methods of the past, but still adhere to the Best Practices of today.

To achieve all of these, it is necessary to have and maintain a very close working relationship with Museum Educators and Curators and both of those parties need to have a respect for what Education Collections is trying to accomplish. On any given day, Education Collections networks with between five and ten different DMNS Departments and our ability to do this helps the Museum create meaningful visitor engagements and memorable learning experiences with the Education Collections and makes this Department a national model for teaching collections in other museums.

Scope of the Collection
As of the authoring of this plan there are approximately 23,300 objects and specimens cataloged in the DMNS Education Collections. There are most likely closer to 30,000 actual objects as this number includes lots and groups of items. These collections cover all of the major science disciplines represented at DMNS. Currently, the Education Collections are accessioned, cataloged and maintained following the Research and Collections Policies and Procedures Manual. However, in the coming months we will be evaluating this standard and update as necessary to modernize practices and facilitate the care and use of the collections more efficiently. The Education Collections are stored separately from the Research Collections because the use of these collections is magnitudes more than the research collections and that use isn’t always in pest and food free environments – we don’t want to introduce any agent of deterioration into the research collections. The DMNS understands that while the Research Collections

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maintained at this institution are entrusted to the museum for perpetuity, the same cannot be said for the Education Collections. With increased access to collections comes the risk of physical damage, chemical damage, biological damage, and theft. These are risks that the DMNS has chosen to accept in order to make science more accessible to our visitors and to our community. The Education Collections staff evaluates the individual level of access for each object that is put out in programming. The Education Collections recognizes that its job is to allow access and facilitate tangible learning moments, it also, simultaneously, has a responsibility to preserve and conserve the collections and work to increase their longevity; especially CITES listed species, species that are under federal regulation and fossils that are protected by US and international entities.

The Education Collections also retains a few institutional icons including a large Ponderosa Pine truck cross-section from a picnic area in the White River National Forest of Colorado (although current dendrochronologists believe it may have been growing further south towards the 4-Corners area), which sat unseen in storage for nearly a decade. It was refurbished by the University of Arizona’s Dendrochronology Lab and returned to the public floor in 2010 and today sits on the second floor in Edge of the Wild. Another well-recognized object is the full-scale model of a Mars Exploration Rover which is currently on display near the planetarium entrance and will be retained in the new version of Space Odyssey.

History of the Collection
In 1990, Jeff Stephenson, the first Education Collections Manager was hired with sole responsibility for establishing professional operations, consolidating storage, and maintaining the Education Collections. Under Stephenson, the Education Collections began to resemble what it is today. In 1997 the DMNS hired its first Registrar, Kelly Goulette, who established centralized registration within the Museum. This made the activity records in the Museum much more reliable than previously existed and more complete loan records and accession records exist in Education Collections after 2000. In 2001, the Education Collections were transferred from the Education Branch into the Research and Collections Division, with staff who reported to the Chief Curator. In 2006 the Education Collections was reorganized again report to the Deputy Chief Curator who served as the curator for these collections. In 2009, Education Collections was shifted into the Preservation and Documentary Resources Branch in RCD under now Director Kelly Goulette. Despite the shifting of Education Collections between supervisors, it has remained in the Research and Collections Division of the DMNS, which is important because of the support the Department gets from RCD collections staff and curators as well as the DMNS Registrar. In the summer of 2017, the Museum reorganized all the collections departments into one Integrative Collections Department. This has increased the Education Collections connection with other collections and collections staff. More importantly, it’s the first time in the history of the Education Collections that the department hasn’t been arbitrarily grouped into another branch or department, it has the support and colleagues it requires.

Future of the Collection
Collections move into Figgins Collections Range
As of the writing of this plan the department is still in the process of moving into and setting up the space in Figgins Collections Range. It is our plan to have a final arrangement that is more open and accessible to the DMNS Museum Programs Staff. As the DMNS Anthropology Department’s NEH grant is still active, we need to wait to make our space more open to the rest of DMNS. It is our hope to be able to provide an active brainstorm space, a space of wonder and delight as well as an information center to any DMNS staff member.
As part of the move out of the old spaces, we will also be reorganizing the zoological sub collections into phylogenetic categories so, for example, all Canids will be together, whether it’s a taxidermy mount or a skeleton or a hide, they will all be housed together to make working with our programs and exhibit staff more time efficient and effective.

Sharing Space with the Alfred M. Bailey Library
The future plan of the library is still in development at this time. However, we believe that there are some really strong possibilities for both the Education Collections and the Library inhabiting the same physical space. Being co-located, it makes the potential for an even stronger intuitional resource a possibility. The functions of both Education Collections and the Library are similar in that they are each lending and support centers for science communication. While they both have markedly different “best practices” we hope that we can work to create a strong partnership that empowers the entire institution.

New Policies and Procedures in 2018-2019
In the 3rd and 4th Quarter of 2018, RCD will be reviewing and revising our Polices and Procedures. This will offer us an opportunity to rethink and modernize the way we operate the education collections here at the Denver Museum of Nature & Science. Our goal is to remove unnecessary processes from collection activity where we can, since the education collections is not being held in “perpetuity” and yet preserve its leadership and best practices in the eyes of accrediting and governmental agencies.

Museum Programs and Exhibit Support
In June of 2018, the DMNS Exhibits Department and Museum Programs Department were brought together under the same division of the museum. From our perspective, this has already had positive effects concerning communication and project organization. While this is still a new restructuring, we are hopeful as time passes it will help with planning and organization across our work. Into the future, the DMNS Education Collections plans to continue to support – as appropriate – all DMNS programing and exhibits. Currently, there are a few temporary exhibits, such as PIXAR, in the near future where it may not be appropriate to inject the use of museum collections. We believe that the collections should be used where they most effectively enhance an experience or facilitate a learning objective, not shoe horned into a class or exhibit where they do not seem to fit well, or if a point can be better made using other demonstration, or hands on activities.

Future of Education Collections Object Acquisition:
Object acquisition in the DMNS Education Collections has slowed and become more focused since the end of the IMLS Grant 6 years ago. We will acquire, or help acquire, things primarily to support DMNS Programing and Exhibits. However, those objects and specimens need to be considered as being within the realm of “natural history” and reflect the content of the DMNS research collections. We do not randomly add objects and specimens to the collection. We also do not actively pursue donors or seek donations from private collections. When approached by an organization, or an individual seeking, without solicitation, to donate an item, or items, some of the criteria we consider are the following:

- Does the object fall within the wheel house of the natural sciences represented at the DMNS?
  - Categories of objects like works of art and pieces of industry are generally outside the scope of this collection.

- Is it likely to see use in programing within the next 5 years?
The Education Collections does not have finite space. It is an active department and the space should be filled with objects supporting the museum and its mission by being an active and effective resource.

- Is there an immediate or foreseen need for this object in programs?
  - If the department knows a need is coming or of a current need, it informs our decision when looking at objects and specimens being offered for transfer or donation.

- Is it a rare/regulated/endangered species, and are we unlikely to have another opportunity to have offered to the Education Collections?

- Does it, or is the probability high, that it contains arsenic or mercury?
  - Education Collections currently has specimens that have been treated with arsenic and mercury, these objects currently are not ideal as we have to build casework in order to use them in programing. We are making an active effort to replace these objects with non-heavy-metal-laden specimens. As such, we will not bring anything that is likely to have arsenic into the collections unless it is exceptionally rare or endangered.

- Is the object or specimen a higher quality than one we currently have in the collections that it could potentially replace?
  - In addition to evaluating the teaching points an object has, there is also an intangible “aesthetic” to an object as well that we consider – will it draw people to it and facilitate them asking questions?

- Does it fill a hole, or represent something that is not currently represented in the collections?
  - Does it complete or complement a series of objects or a family of animals?

- Does the individual/organization have legal possession and is that easily demonstrated?
  - Primarily a legal question. It’s more work to communicate with regulating agencies if the individual doesn’t have legal documentation of the object or specimen and at that point it’s a question of whether the extra work is worth having the item in the collections.

- Do we have physical space to store it appropriately?
  - We have finite space. And we don’t want to risk damaging collections in overcrowded storage units.

- Does the museum have any philosophical responsibility to take this object from a private collection into a public collection?
  - In their by-laws, the Society for Vertebrate Paleontology encourages museums to think about this. We have applied this in evaluating possible collections additions. There are also other institutions we can send people/organizations to if we feel like it isn’t a good fit for our collections/museum.

- Does the object have locality data?
  - Having some data is better than having no data when it comes to education. It’s a more meaningful and impactful education moment if you can tell someone that a projectile point came from Weld County, Colorado, rather than just “Earth”.

Things we do not generally bring into the collection:
- **Trophy/Shoulder Mounts**
  - These end up creating more questions than experiences in programing. They also give a “hunting lodge” feel to any space, which, with today’s wildlife conservation practices is at odds with the Museum’s mission. We will be retaining the ones we have – we have rare and endangered species, like a Gaur and lions, but we will not be seeking to expand that collection.

- **Dolls**
  - Unless they are made by the cultural group and they are representative of that group’s past or present culture.

- **Scientific Instruments**
  - There is a small group of historic medical and surveying equipment already in the collection, but it not a collection that is actively growing, nor do we foresee growing it in the near future.

- **Exhibit Components**
  - These are perhaps most appropriately evaluated and retained by the DMNS Archives Department. There was a time where the Education Collections maintained a large “Museology” Collection. These items are not used much anymore in programing, so that collection has been paired down and unless there is an exceptional piece of museum history that we can teach with.

- **Tourist Items**
  - These are often cheap and trite pieces that distill a culture down to a stereotype or overly general motif or idea.

4.7. **Bailey Library & Archives**

4.7.1. **Archives**

Curator: Sam Schiller  
Plan author: Sam Schiller

**Intellectual Framework**

The purpose of the Bailey Archives is to collect, preserve, and make available the intellectual and administrative history of the museum. The Archives provides information about the Museum’s core competency collections and its history to various audiences through on-site visits, and virtually through email, phone, and mail.

The primary collecting focus is records pertaining to Museum research and business, but under some circumstances we sometimes bring in collections from outside donors. Examples include materials related to one of our core competencies that might not have a suitable repository elsewhere, such as birding records. The Archives also houses the records of partner organizations that have had close relationships with the Museum, such as the Denver Field Ornithologists and the Egyptian Study Society.

**Scope of the Collection**

The official records of the Museum date from the Museum’s incorporation date of December 6, 1900 until the present. The Archives Collections contains over 34,000 cataloged objects, including correspondence, field notes, memos, policies, financial records, donor files, contracts, intellectual
property documentation, architectural drawings, oral histories, and three-dimensional objects that
document the institution’s history. Subject areas are drawn from across the museum’s divisions,
comprising papers from the President’s office, Research & Collections, Education, Exhibits, Finance,
Human Resources, attorneys, Marketing, and Building Operations. The retention and disposition of
DMNS records are governed by the Museum’s Records Retention Schedule.

History of the Collection
The Archives was formed at the urging and with the consent of the Museum’s Board of Trustees in
1977. The motivating concern at the time was the disposition of the papers, photographs, motion
picture films, and publications of museum Director Dr. Alfred M. Bailey. As Dr. Bailey neared retirement
in 1969, the Board and others began to recognize the value of the documentation he had created over
the course of his career. Their concern was underscored by the Colorado State Archivist, who had
previously urged the Museum administration as early as 1971 to respect the value of the Museum’s
records by developing a plan for their preservation. The focus was eventually broadened to encompass
the full scope of the museum’s history.

Future of the Collection
The collecting activities of the Archives will continue to document the Museum’s research, legal, and
administrative history. The most distinct change for the future of the Archives collection will not be the
subject matter of the materials collected, but the formats collected. The primary challenge moving
forward will be adapting the Archives’ model to accommodate the burgeoning amount of records that
are “born digital”. We have made advances towards being able to manage such records, and we will
continue to develop best practices for the entire life cycle of digital records, from creation to
preservation. Specific areas of born-digital records that will focus on are data sets and emails.

Regarding data sets, these include digital records that do not lend themselves towards traditional analog
archiving, or that would be useless outside of their native format. Long-term goals are to incorporate
security copies of catalog data stored on other portals as part of the collection.

Email presents one of the largest challenges for preserving the historic record. Historically, some of the
most valuable materials in the Archives have proven to be correspondence, insofar as these letters often
give context to past decisions or projects, since they tell the story behind the story. Yet the challenge of
acquiring, managing, indexing, and performing research with archived email accounts is significant.
We’ve had success with smaller pilot projects, and will continue to experiment with emerging
technologies and approaches as they develop.

4.7.2. Rare Books
Director: Melissa Bechhoefer
Plan author: René O’Connell

Intellectual Framework for the Rare Book Collection
The Museum’s Bailey Library exists to support and enhance the work of the Museum as a research
institution, as an exhibit venue, and as a vehicle for science education. Additions to the Library follow a
collection development plan which specifies which subject areas, and to what depth, we collect. This
plan focuses on the Museum’s core competencies and regional emphasis. Its audiences include
scholarly researchers, Museum staff, and college and university students by appointment.

Scope of the Collection
The collection contains early literature in all of the core competencies, with the exception of Health Sciences. It is strong in early works on Native American tribes, geology, paleontology, and zoology, especially ornithology and entomology. It also includes books associated with historical figures in the museum’s history and preservation copies of books published by the Museum and/or authored by its curators. In addition to overall library collection development guidelines, current criteria for inclusion in the Rare Book Collection include importance, scarcity, age, condition, physical and aesthetic properties, association, or subject matter, which give the publication an enhanced value.

The collection currently consists of 1826 titles, comprising 2791 volumes. The earliest publication date is 1773. Volumes are housed in the Archives collection under climate controlled conditions.

History of the Collection
The Museum has had a library since its founding. In the early years the library collection was stored in various curatorial offices and was not professionally cataloged. The Rare Book Collection was initiated in 1975 when Stephanie Stowe, a professional librarian, was hired to organize the libraries, particularly the books associated with the Crane Collection.

Once the collection was established, other rare, valuable or fragile materials were added from the existing library resources of the Museum. These included many books from the R. C. Hills collection, which was the founding collection of the geology library, and many books from Alfred M. Bailey’s collection of ornithology materials.

The collection has grown through donations and a few purchases over the years.

Future of the Collection
The collection will grow slowly in the future. Books are transferred from the circulating collection when they qualify for inclusion. Books will also be purchased upon the request of curators when they are important for research in our core competencies. Donations of rare books will only be accepted when they fit our collection development guidelines.

4.7.3. Library
Director: Melissa Bechhoefer
Plan Author: Melissa Bechhoefer

Intellectual Framework for the Library Collection
The Museum’s Bailey Library supports the Museum’s mission to ignite our community’s passion for nature and science. In order to help the Museum fulfill its mission, the Library has:
- Selectively collected, managed, and preserved literature supporting our core competencies and other Museum work.
- Collected and preserved publications that document the Museum’s work and collections.

History of the Collection
The Museum began purchasing publications for its library at least as early as 1907, to support research, exhibits, and other museum work. In 1908, the Museum opened to the public and in 1910 hired its first professional director Jesse Figgins. Figgins (1910-1935) and his successor Alfred M. Bailey (1936-1969) actively enlarged the library by purchasing publications from a library line-item budget, soliciting donations of publications from other museums, and carrying on a library exchange program with other organizations. Significant donations also added to the Library collection, such as the library of Richard Charles Hills, which was the founding library collection in Geology.
Through the years, various curatorial and other staff were assigned the responsibility for managing the library. Then in 1968, the donation of the Mary W.A. and Francis V. Crane collection prompted the hiring of the Museum’s first professional librarian, Stephanie Stowe, in 1975. She focused largely on cataloguing the rare books and then cataloguing the other library materials into the OCLC1 database. Ms. Stowe’s departure from the staff in 1983 coincided with a Museum staff down-sizing and resulted in the assignment of the library’s management to the Museum’s archivist, Kristine Haglund. Eloise Howerton, a former library volunteer, was hired on a half-time contract and cataloging was contracted.

In 1992, Katherine Gully was hired to fill the once again full-time librarian position. She retired the library’s card catalog and fully automated the library’s systems, making them web accessible. In 2006, the library moved into the former classroom 301, Ms. Gully retired in December 2011 and Brent Wagner was hired as librarian in December, 2012.

In July 2017, a reorganization of the Research and Collections Division resulted in the library becoming a part of the newly formed Integrative Collections Department. Also at this time, the staff librarian position was eliminated, requiring a revisioning of the library’s role—including holdings, functions, and services—in this new management structure. The library was temporarily closed mid-2018 with the intent of completing this revisioning process, intending to open early 2019. Due to Bond-funded construction projects, the closure was extended into 2019 and reopening of the library is anticipated in late 2020 or early 2021. The audience focus upon reopening will continue to be prioritized in the following way: museum scientists, other staff, and volunteers.

Scope of the Collection
The library has purchased materials to add to the library, including books, periodicals, and media, in accordance with the guidelines below. The library has also maintained subscriptions to online periodical databases BioOne and JSTOR2. Collecting guidelines and digital database subscriptions are currently in the process of being reviewed, and will be updated upon the reopening of the library in 2020-2021.

Donated books, journals, and other resources met the same criteria as purchased resources in terms of relevance to our core competencies; new collecting guidelines are being developed for donations as well.

The library collected as requested in the following areas, which are directly related to our core competencies:

1. Anthropology of the Southwest, Rocky Mountains, and Great Plains.
2. Archaeology of the Southwest, Rocky Mountains, Great Plains.
4. Paleontology of the western United States.
5. Zoology of the Rocky Mountains and Great Plains, including Ornithology, Mammalogy, and Entomology.
6. Mesoamerican archaeology
7. Publications by the Museum, authored by Museum staff, or using DMNS artifacts or images.

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1 Online Computer Library Center based in Dublin, Ohio.
2 BioOne and BioTwo include current biological and paleontological journals beginning in 2000 or later; JSTOR includes retrospective humanities, social science, biological land paleontological journals up to 3-5 years prior to the current issues.
The library collected selectively in the following areas to support Exhibits, Education, and other programming.

1. Children’s books covering our core competencies.
2. Current literature in museum studies.
3. Books required to support traveling exhibits, including popular and children’s materials.
4. Astronomy.
5. Archaeology in general.
7. Paleontology in general.
8. Egyptian archaeology.

Specialized materials acquired for a particular curator’s research were retained since they may relate to objects that are now in the collection. Some older literature was retained due to its historical value, e.g., museum studies materials. Some newsletter type publications are only retained for 1-5 years.

The collection currently consists of approximately 56,000 books (including 3,000 rare volumes), 60,000 issues of 1,100 different journals, and 400 recordings. The Museum’s library collection contains many works which are not available in any other library in Colorado, and in some cases, in the whole Rocky Mountain region or even in the world.

The composition of the library holdings closely matches to the composition of the Museum’s three-dimensional collections: General science (Books=11%, Journals=29%), Anthropology (B=45%, J=14%), Earth Sciences (B=15%, J=31%), Health Sciences (B=1%), Space Sciences (B=3%, J=2%), Zoology/Botany (B=23%, J=22%). Some of the more notable collections include Ornithology, a legacy of Alfred Bailey’s tenure (approx. 1800 titles); Native American studies, with many seminal works from the Crane Collection (approx. 3000 titles); an excellent reference collection on Native American and world basketry assembled by Joyce Herold, Curator Emerita of Ethnology (approx. 200 titles); and a reference collection on Lepidoptera assembled by Dr. Richard Peigler (approx. 400 titles). A collection of children’s books (approx. 1800 titles) serves staff who develop exhibits and educational programs.

Until recently, the Library collection was housed in the main Library space and in seven spaces behind dioramas, as well as in several small departmental collections. In early 2019 the main library reading room and an adjacent periodicals storage room has to be vacated due to construction activities. These collections, as well as those behind dioramas, are slated to be consolidated into the 2nd floor Figgins storage area, along with the Education Collection.

Because it is primarily a research library, the library has not generally “weeded” the collection, except for some popular and children’s books. Older books and periodical sets are retained due to the need for retrospective research in fields such as Zoology, Paleontology, and Archeology. However, moving forward, space and other resource constraints will require thoughtful assessment of existing collections and potential acquisitions. The library has not participated in interlibrary loan since 2015, requiring research staff to develop relationships with other academic institutions to fulfill their needs. Over the next few years as the library relocates to Figgins, continual assessment is needed in order to strike an appropriate balance of user needs and allocated resources.

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3 “Weeding” refers to the practice followed in public libraries of removing older, outdated publications in order to make room for new, more up-to-date ones.
Future of the Collection
The Library may continue to selectively acquire materials in support of the Museum’s research and other work, in accordance with the new policies and procedures to be determined upon the library’s reopening in 2020-2021.

Short Term Priorities for the next 1-5 years:
- Continued assessment to better understand and meet staff and volunteer information needs.
- Weeding and processing library collections in preparation for the move to Figgins
- Develop strong relationships with other research libraries in the metro area to avoid duplication of efforts and resources, and to better meet the needs of staff researchers
- Implement new procedures for running library in new location and without a librarian

4.7.4. Image Archives & Documentary Arts
Curator: René O’Connell
Plan author: René O’Connell

Intellectual Framework
The Image Archives is part of the Archives, which was created in 1977. It serves as the official central repository and manager of the Museum’s images. The Image Archives assists in meeting the Museum’s legal obligations and provides images to the Museum’s internal and external audiences. Central to the Image Archives’ mission is to ensure the creation and preservation of the most complete and appropriate documentation of the Museum, its work, its collections, and its core competencies. Images also come into the Museum’s possession through donation and purchase. Artwork created by Museum staff and/or for Museum projects is considered historical documentation and is part of the Image Archives collections. Artwork that documents the Museum’s core competencies is also part of the Image Archives collections.

The department continues to make great effort to publicize the image collections. An important method for making the collections more visible is through the Internet. Currently Image Archives uses a hosted application, Luna Imaging, to provide online access. Through Luna’s hosted environment, approximately 21,000 images are now available in digital format on the museum’s website at https://science.dmns.org/bailey-library-and-archives/. Uses of the images include publication, research, education, exhibit, lectures, marketing, Museum shop sales, and artistic reference.
Additionally, electronic finding aids at http://rmoa.unm.edu, a Google searchable website, help direct users to the Image Archives collections.

Scope of the Collection
Size of the collections: There are approximately 770,000 analog items and approximately 70,000 digital image files in the Image Archives and 1.49TB of digital movie and video files.

Subject matter: The major portion of the Image Archives consists of still and moving images taken by Museum staff in the course of their work. Images date from the late 1800s to the present, representing most of the Museum’s core competencies. Space Science is represented by slides created by the Planetarium staff for their shows prior to about 2001. Numerous images document the Museum building and its contents.

Strengths of the collection include: the history of the Museum; Native peoples and ethnographic subjects; Museum field work; documentation of the Museum’s exhibits; moving and still images of the Museum’s activities produced by the Museum’s photography department from the early 1900s to the
present. Outstanding items/collections include: Now extinct Laysan Island birds; Excavation of the Folsom Site (1926-1928); Film footage of Dent site excavation (1932); Jesse H. Bratley images of American Indians (1871-1941); Alfred M. Bailey images, especially his field work in Alaska (1921-1922); Roland Reed images of American Indians (1893-1934); Joseph Van Wormer images of birds and mammals (1946-1986); Kenneth Bigwood images of New Zealand birds (1947-1992); Ancient Denverers paintings (ca. 2000); illustrations for the Museum’s Prehistoric Journey Hall (1990-1995); DMNS dioramas; artwork for the Bailey-Niedrach publication Birds of Colorado; the African field sketches of Donald Leo Malick; photographs by William Henry Jackson; Edward S. Curtis photo, around 2,800 video recordings by David Baysinger (1979-present); hundreds of still images and extensive video footage of the Snowmass Pleistocene site excavation; and the only known 16mm copy of Walter Futter’s 1930 film Africa Speaks, which documents a 1928 photo-safari across the Belgian Congo.

Formats:
- Still images: Direct positive images (ambrotype and tintype); gelatin dry plate glass negatives; glass lantern slides (B&W and hand-colored); film negatives in B&W and color (nitrate and safety-based film in acetate and polyester); hand-colored positive images on canvas; positive images on mechanically printed gravures; positive prints on paper (B&W, sepia, color, and hand-colored, including albumen, cyanotype, silver gelatin, platinum, and resin-coated); postcards; stereo cards (B&W and hand-colored); large format color transparencies; 35mm color slides; and digital formats as TIFF, JPG,
- Moving images: Motion picture footage (positive and negative in nitrate, safety-based film, and polyester); video footage (raw and finished productions in 2”, 1”, ¾”, ½”, Beta. A small part of the collection has been digitized to formats AVI, MPG3, MPG4
- Artwork: Paintings, drawings, sculpture, and historical Museum artifacts.

History of the Collection
The motivating concern for the 1977 formation of the Archives lay in the disposition of the papers, photographs, motion picture films, and publications of Dr. Alfred M. Bailey. As Dr. Bailey neared retirement in 1969, the Board and others recognized the value of the documentation he had created over the course of his career (1912-1978). They did not want it to be lost, destroyed, or broken up. Their concern was further heightened by the Colorado State Archivist, who in 1971 urged the Museum administration to respect the value of the Museum’s records by developing a plan for their preservation.

The Museum’s first Image Archivist was Liz Clancy, who served in that position from 1985-2006. When the Archives began, the Bailey images were the top priority. Liz began organizing them on a part-time basis before her 1985 move from the Anthropology Department to the Archives. A major addition to the Image Archives came from the Photography Department, when that department was downsized in 1984. Other additions to the collection have come from in-house transfers from Museum staff, from external donors, and purchases of images for Museum use. Images produced by curators, collection managers, and volunteers have not routinely made their way into the Image Archives. For years the cost of reproduction of analog images (e.g., slides and prints) remained a significant barrier to providing copies of images to the Images Archives. With the proliferation of digital cameras, however, sharing is much easier and cheaper.

By the end of 2000, the Museum’s remaining professional still photographer was laid off and the photography department was closed due to shifting priorities, budget constraints, and an assumption that digital photography had somehow erased the need for a staff photographer. By the end of 2003, the photography researcher, who also took photographs as needed, was also gone. Since the fall of
2008, the Museum has employed a professional photographer to document and help promote the Museum’s collections and research. As a result of understaffing over the years, there exist some serious gaps in the Museum’s photographic record — gaps which can’t be filled retroactively. Copyrights and permissions for published images is granted and managed through the Image Archives.

Future of the Collection
It collects images created by and for the Museum and images that supplement the Museum’s core competencies. With the hiring of a permanent staff RCD photographer in 2014, the museum experienced a dramatic rise in the quantity and quality of photographic illustration of the Museum’s work. Under the supervision of the Image Archivist this position can be guaranteed to conduct proactive, high-quality, photo documentation with appropriate metadata. Further, as a working team, the photographer and Image Archivist can support a photographic training program for other staff members, manage the digital equipment budget, and expand the Museum’s capacity for photographic documentation.

With the growing need to make collections accessible to a wider audience, Image Archives embraces demands for making its collections digitally accessible. To date we have over 21k online and linked to the museum’s web page https://science.dmns.org/bailey-library-and-archives/ utilizing a part time volunteer workforce and a full time trained photographer, we are currently able to create ~4500 digital surrogates per year. With over one hundred years of archives to work from and ongoing need to photograph the collections, the work has barely begun. As the digital collection continues to grow through thoughtful curation and digital content creation, we can bring the museum’s treasures to thousands of end-users who may not otherwise know about our collections. The future of this program necessitates continued support from volunteers. Secondly, as our digital assets continue to grow exponentially, we must begin to address a trusted digital preservation plan. If we are to take the next step, Image Archives and Technology groups must work as collaborators to create and manage a permanent and sustainable digital preservation solution for both still and moving images. Image Archives has worked closely with IT to find a solution that meets both our needs for access and backup.

In order to preserve the important records of Research and Collections staff, the Museum needs to review, agree upon, and enforce a policy for the deposition of research and collections images with the Museum’s Image Archives. The Image Archives collects photo documentation related to current curator’s fieldwork by asking the curators to submit fieldwork schedules annually. The Image Archivist arranges the photographer’s schedule to capture any new work, significant sites, and highlights for museum publications. For any work deposited by curators to the Image Archives, we will work with each to establish standards for good digital imagery, acquire any associated metadata and rights for long term disposition.

The role of the Image Archives in the Museum will change to meet changing times, but at the core of its existence is its responsibility to document the Museum’s work for historical, administrative, operational, and legal purposes. The role of the Image Archivist is to take both the short-term and long-term views into consideration when determining what to acquire, what to preserve, and how to make it available. Since an important measure of the worth of collections is their usefulness, a major task of the Image Archivist is to encourage the fullest appropriate use of the valuable but underutilized image collections.
5. REFERENCES

ENTOMOLOGY

ORNITHOLOGY

6. APPENDICES

6.1 APPENDIX 1: Type Specimen Citations by Year

### Vertebrate Fossils

Scientific publications with Holotypes and Paratypes only

* = holotype; ** = paratypes (original designations only); † = figured specimen (non-types)

A complete list of all type, figured and referred specimens is available from the Department of Earth Sciences.

DMNH 92* Mastodon merriami

DMNH 310* Trilophodon hicksi; DMNH 311* Trilophodon paladentatus.


DMNH 486* Hyopsodus markmani

DMNH 495*, 496**, 529** Uintacolotherium blayneyi

DMNH 489* Manteoceras pratensis; DMNH 544* Telmatherium accola; DMNH 550* Telmatherium advocate; DMNH 541*, 542** Tanyorhinus blairi; DMNH 479*, 504**, 507**, 509** Tanyorhinus bridgeri; DMNH 487* Manteoceras foris; DMNH 552* Tanyorhinus harundivoras.

DMNH 823* Amphicyon reinheimeri.

DMNH 1078* Palaeocrex fax; DMNH 804* Phasmagyps patritus; DMNH 803 Palaeogyps prodromus; DMNH 805* Bathornis veredus
DMNH 304* Teleoceras hicksi

DMNH 1147* Bison chaneyi

DMNH 1261* Trilophodon phippsi

DMNH 897*, 422**, 881** Trigonias osborni figginsi; DMNH 884* Trigonias osborni secundus; DMNH 886* Trigonias hypostylus; DMNH 414* Trigonias precope; DMNH 1025* ?Caenops premits; DMNH 878* Trigonias preoccidentalis; DMNH 1029* Trigonias taylori

DMNH 574* BISON figginsi; DMNH 1236* BISON taylori; DMNH 629*, 631** BISON texanus;
DMNH 1057* Elephas haroldcook

DMNH 249* Aphelops malachorhinus longinaris; DMNH 732* ?Peraceras ponderis;

DMNH 1085* Equus achates. DMNH 574* Simobison figginsi; DMNH 1057 Elephas haroldcook; DMNH 1065*, 1066** Lama? hollomani; DMNH 1062* Gomphotherium priestleyi;

DMNH 1053* Trigonias cooki

DMNH 1359* Archidiskodon meridionalis nebrascensis

DMNH 1164*, 1364**, 1366** Bison angularis; DMNH 1363*, 1365** Stelabison occidentalis francisi; DMNH 1240* Bison oliverhayi; DMNH 1187* Bison rotundus; DMNH 1362* Bison bison septemtrionalis
DMNH 214* Yumaceras figginsi; DMNH* 219 ? Texoceras vaughani.

DMNH 469* Pachycephalosaurus reinheimeri.

DMNH 1588* Thalassomedon hannigtoni.

DMNH 468* Denversaurus schlesmani.

DMNH 21684* Kepadactylus inseratus

DMNS 5989*, 5996** Saurexallopus lovei.

DMNH 20491* † Libognathus sheddi

DMNH 27726* Gargolyeosaurus parkinorum

DMNH 184* † Borophagus pugnator.

DMNH 39045† Cedarosaurus weiskophae

DMNH 29264** Palaictops cf. P. bridgei


DMNH 40932**† Venenosaurus dicrocei.

DMNH 43208*† Baiocodon jeffersonensis;

DMNH 44646**, 44647**, 44648, 44649**, Ctenacanthus buttersi; DMNH 45055**, 45056** Bythiacanthus sp.; DMNH 45062**, Ctenacanthus furcicarinatus; DMNH 45057** Acodylacanthus ruperus; DMNH 45058** Physonemus sp., DMNH 45059**, 45060** Petrodus patelliformis.

DMNH 304*†, Teleoceras hicksi.

DMNH 30076** Canis latrans

DMNH 49903*† Plemmyradytes shintoni.

Invertebrate Fossils and Fossil Plants

Scientific publications with Holotypes and Paratypes only
* = holotype; ** = paratypes (original designations only), † = figured specimen (non-types)
A complete list of all type, figured and referred specimens is available from the Department of Earth Sciences.

DMNH *163 Climbex vitusculus

DMNH 1978 Siphlurites explanatus * (specimen number not listed in publication)
Cockerell, T.D.A. 1924. Fossil Ichneumonidae believed to have been parasitic on sawflies. The Entomologist 57:9-11.
DMNH 1966 Megatyphon mortiferus (specimen number not listed in publication) * DMNH 170 Exenterus dormitans *

DMNH 1578 (hypotype) Carya libbeyi (lesquereux)

DMNH 6004* Uintascorpio halandrasi

DMNH 6301**, 6305-6**, 6307*, 6310** Bizona niemii; DMNH 7329* Liriodendrites bradaccii; DMNH 7713* Marmarthia pearsoni.

DMNH 16052* Nephrolenellus geniculatus; DMNH 16062* Bolbolenellus brevispinus; DMNH 16074 * Olenellus fowler; DMNH 16081* Olenellus terminatus DMNH 16085* Olenellus chieftensis

DMNH 8800* Sciadiocrinus wipsorum, Webster et al., DMNH 9048**, 10300* Dicromyocrinus baldensis, Webster et al., DMNH 10307* Neoprotencrinus rockensis

DMNH 15288*, 15289-91** Strimplecrinus dyerensis Webster and Hafley; DMNH 15293* 15294-307** Catoctocrinus? torus Webster and Hafley; DMNH 15321* Hypselocrinus bisonensis Webster and Hafley; DMNH 15325* 15326** Eireocrinus? coloradensis; DMNH 15323*, 15324** Gilnocrinus? albus Webster and Hafley; DMNH 15327*, 15328-15332** Tarassocrinus synchylus Webster and Hafley; DMNS 16044*, 16046, 16048-49 DMNH 16092-3, 16095, 16097, 16102-108**, Ophiopolytretus aethus Blake and Glass; DMNH 16099* Pleiadedeaster inceptus Webster and Hafley; **

DMNH 10307* Zelkovoxylon chadronensis; DMNH 12982* Chapronoxylon florissantensis
DMNH 15272-73** Aesculus hickeyi; DMNH 22968** Aesculus hickeyi

DMNH 22970 Synarmocrinus malosensis*

DMNH 22457 Eretomocrinus sawdoi *

DMNH 19748** Populus tidwelli

DMNH 26516* Orontium wolfei, DMNH 6711* Symlocarpus hoffmaniae


ZOLOGY

Scientific publications only
HT = holotype; PT = paratype (original designations only), LT = lectotype, ST = syntype

DMNH ZE.2784 ST Eupseudosoma floridum.

DMNH ZE.2778 ST Melitaea definita.

DMNH ZE.2782 ST Triprocris martenii.

DMNH ZE.2785 PLT Rhododipsa masoni.

DMNH ZE.2781 HT Euxoa brunneigera masoni.

Cockerell, T.D.A. 1906. Pseudorthosia variabilis var. pallidior n. var. Entomological
News 17: 204.  
DMNH ZE.2780 HT Pseudorthosia variabilis var. pallidor.

DMNH 1235 HT, 1234 PT Marmota flaviventris campioni.

DMNH 4326 HT, 4305 PT, 4309 PT, 4324 PT Colinus virginianus taylori.

DMNH 4951 HT, 4952 PT, 4953 PT, 4979 PT, 4981 PT Pedioecetes phasinellus jamesi.

Figgins, J.D. 1918a. Description of a new subspecific form of Taxidea taxus from Colorado. Proceedings of the Colorado Museum of Natural History 2:[1].  
DMNH 939 HT, 947 PT Taxidea taxus phippsi.

DMNH 6700, 6697 PT, 6701 PT, 6702 PT, 6970 PT, 7122 PT Passerculus sandwichensis bradburyi.

DMNH 1846 HT, 1847 PT, 1848 PT, 1849 PT, 1850 PT, 1851 PT Rangifer mcguirei.


DMNH 2340 HT, 2339 PT, 2341 PT, 2342 PT, 2343 PT Odocoileus virginianus mcilhennyi.

DMNH 6444 HT Carpodacus mexicanus smithii; DMNH 3606 LT Carpodacus mexicanus sayi.

DMNH 2412 HT, 2411 PT, 2413 PT, 2414 PT, 2415 PT Thomomys talpoides macrotis.

DMNH 19690 LT Uropelia camppestris figginsi; DMNH 12194 HT, 12195 PT, 12196 PT Picumnus arileucus; DMNH 12197 HT, 12193 PT, 12223 PT, 12224 PT, 12225 PT, 12226 PT Sicalis pelzelni danisa.
DMNH 2 HT, DMNH 1369 PT *Bison bison haningtoni*.

DMNH 721 HT, 770 PT, 2507 PT, 2508 PT *Neotoma albigula laplataensis*; DMNH 2506 HT *Conepatus mesoleucus fremonti*.

DMNH ZA.12941 PT, nn PT, nn PT, nn PT, nn PT, nn PT *Parosa delicatula*.

DMNH ZE.2890 type (not determined whether HT or PT) *Incisalia polios schryveri*; DMNH ZE.1354 PT, ZE.1355 PT, ZE.1356 PT, ZE.1357 PT, ZE.1358 PT *Papilio indra minori*; DMNH nn HT, nn PT, nn PT, nn PT, nn PT, nn PT *Cercyonis masoni*.

HT, AT, PT, PT, PT, PT, PT, PT, PT [not labeled as types, hence specimen numbers not assignable to type category: DMNH ZE.2773, ZE.2774, ZE.2775, ZE.2776, ZE.2777, ZE.2892, ZE.2893, ZE.2894, ZE.2895, ZE.2896] *Plebeius scudderii ricei*.


DMNH ZE.2772 PT *Callipsyche behrii crossi*.

DMNH ZA.13069 PT *Pardosa hetchi*.

DMNH ZA.13384 PT, nn PT *Geolycosa micanopy*.

DMNH ZE.2854 PT, ZE.2854 PT *Cicindela theatina*.

DMNH ZA.12955 PT, nn PT, nn PT *Pardosa nordicolens*.
DMNH ZA.16788 PT, ZA.16789 PT Eremobates angustus.

DMNH nn AT, nn PT, nn PT Pardosa steva.

DMNH ZA.13250 PT, nn PT, nn PT, nn PT, nn PT, nn PT, nn PT, nn PT, nn PT Pardosa tumida; DMNH 13110 PT, nn PT, nn PT, nn PT, nn PT, nn PT, nn PT, nn PT Pardosa vadosa; DMNH nn PT Pardosa valens.

DMNH ZE.2885 ST, ZE.2886 ST, ZE.2887 ST, ZE.2888 ST Amphimallon solstitialis matutinalis.

DMNH ZE.2754 PT, ZE.2755 PT, ZE.2756 PT, ZE.2757 PT Anisota finlaysoni.

DMNH ZE.2783 PT Callophrys (Incisalia) polios obscurus.

DMNH ZE.2856 PT Copaxa (Saturniodes) semioculata orientalis.

DMNH ZE.2788 PT, ZE.2789 PT, ZE.2790 PT Hemileuca maia peigleri.

DMNH ZE.2859 PT, ZE.2860 PT Hemileuca conwayae.

DMNH ZE.2889 PT Temnorhynchus endroedii.

DMNH 13108 PT Pardosa confusa.


Peigler, R.S. & Stone, S.E. 1989. Taxonomic and biological notes on the Hemileuca maia complex (Saturniidae) with description of a new species from Texas and New Mexico. Tyô to Ga 40: 149-166. DMNH ZE.2786 PT, ZE.2787 PT Hemileuca slosseri.


DMNH ZE.164 PT, ZE.170 PT, ZE.171 PT, ZE.172 PT, ZE.173 PT, ZE.174 PT, ZE.2875 PT Antheraea pankstidorm.


DMNH ZE.2770 PT, ZE.2865 PT, ZE.2866 PT, ZE.2867 PT, ZE.2868 PT, ZE.2869 PT, ZE.2870 PT, ZE.2871 PT, ZE.2872 PT, ZE.2873 PT, ZE.2874 PT Euphydryas anicia carolae.


DMNH ZE.2861 PT, ZE.2862 PT Piruna purepecha.


DMNH 40722 HT, 40723 PT Centrocercus minimus.


DMNS ZA.10002 HT, ZA.10003 PT Eremobates chihuavaensis; DMNS ZA.10000 HT, ZA.10001 AT, nn PT, nn PT, nn PT Eremobates gerbae; DMNS ZA.10008 HT Eremobates oregonensis; DMNS ZA.10005 HT, nn AT, ZA.17366 PT, ZA.17367 PT, ZA.17368 PT, ZA.17369 PT, ZA.17370 PT, nn PT, nn PT Hemerotrecha conuta; DMNS ZA.10006 HT, ZA.10007 AT, ZA.17371 PT, ZA.17372 PT, nn PT, ZA.17373 PT, ZA.17374 PT, ZA.17375 PT, nn PT Hemerotrecha sevilleta.


DMNS ZA.17380 HT, ZA.17379 AT Eremobates corpink; DMNS ZA.17376 HT, ZA.17377 AT, nn PT, nn PT, ZA.17378 PT, ZA.17379 AT, ZA.17380 PT Eremobates icenoglei; DMNS ZA.17378 PT Eremobates soca.


DMNS ZE.2876 PT Proagoderus yvescambeorti.


DMNS ZA.17382 PT Eremochelis albaventralis; DMNS ZA.17310 PT, ZA.17381 PT Eremobates inkopaensis.

6.2 APPENDIX 2: List of Museum Curators

Note: The term "curator" has been used inconsistently in the past. Included in this list are individuals who have been in charge of collections, whatever their titles.

<table>
<thead>
<tr>
<th>NAME</th>
<th>CURATOR COUNT</th>
<th>PHD</th>
<th>BEG YR</th>
<th>END YR</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mason, John T.</td>
<td>1</td>
<td>1901</td>
<td>ca. 1909</td>
<td></td>
<td>managing curator (volunteer)</td>
</tr>
<tr>
<td>Ward, William S.</td>
<td>1</td>
<td>1905</td>
<td>1914</td>
<td></td>
<td>Curator, Mineralogy &amp; Art</td>
</tr>
<tr>
<td>Oslar, Ernest J.</td>
<td>1</td>
<td>1908</td>
<td>1911</td>
<td></td>
<td>Curator of Entomology</td>
</tr>
<tr>
<td>Figgins, Jesse D.</td>
<td>1</td>
<td>1910</td>
<td>1935</td>
<td></td>
<td>Museum Director</td>
</tr>
<tr>
<td>Hersey, L.</td>
<td>1</td>
<td>1911</td>
<td>1912</td>
<td></td>
<td>Curator, Ornithology &amp; Mammalogy</td>
</tr>
<tr>
<td>Hills, Richard C.</td>
<td>1</td>
<td>1911</td>
<td>1913</td>
<td></td>
<td>Honorary Curator, Geology</td>
</tr>
<tr>
<td>Hammer, Raymond H.</td>
<td>1</td>
<td>1914</td>
<td>1914</td>
<td></td>
<td>Acting Curator, Geology &amp; Mineralogy</td>
</tr>
<tr>
<td>Hills, Richard C.</td>
<td>1</td>
<td>1914</td>
<td>1922</td>
<td></td>
<td>Honorary Curator, Geology &amp; Mineralogy</td>
</tr>
<tr>
<td>Lincoln, Frederick C.</td>
<td>1</td>
<td>1914</td>
<td>1914</td>
<td></td>
<td>Acting Curator, Ornithology</td>
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<tr>
<td>Lincoln, Frederick C.</td>
<td>1</td>
<td>1915</td>
<td>1920</td>
<td></td>
<td>Curator, Ornithology</td>
</tr>
<tr>
<td>Bradbury, William C.</td>
<td>1</td>
<td>1918</td>
<td>1925</td>
<td></td>
<td>Honorary Curator, Oology</td>
</tr>
<tr>
<td>Howland, Frank</td>
<td>1</td>
<td>1919</td>
<td>1922</td>
<td></td>
<td>Asst. Cur., Geology &amp; Mineralogy</td>
</tr>
<tr>
<td>Bailey, Alfred M.</td>
<td>1</td>
<td>1921</td>
<td>1926</td>
<td></td>
<td>Curator, Birds &amp; Mammals/Birds</td>
</tr>
<tr>
<td>Howland, Frank</td>
<td>1</td>
<td>1923</td>
<td>1935</td>
<td></td>
<td>Curator, Geology &amp; Mineralogy</td>
</tr>
<tr>
<td>Cook, Harold J.</td>
<td>1</td>
<td>1925</td>
<td>1927</td>
<td></td>
<td>Honorary Curator, Paleontology</td>
</tr>
<tr>
<td>Miller, F. Walter</td>
<td>1</td>
<td>1925</td>
<td>1935</td>
<td></td>
<td>Curator, Biology &amp; Mammals</td>
</tr>
<tr>
<td>Cook, Harold J.</td>
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<td>1928</td>
<td>1929</td>
<td></td>
<td>Curator, Paleontology</td>
</tr>
<tr>
<td>Nininger, Harvey H.</td>
<td>1</td>
<td>1930</td>
<td>1942</td>
<td></td>
<td>Curator, Dept. of Meteorites</td>
</tr>
<tr>
<td>Niedrach, Robert J.</td>
<td>1</td>
<td>1935</td>
<td>1946</td>
<td></td>
<td>Curator, Dept. of Birds</td>
</tr>
<tr>
<td>Bailey, Alfred M.</td>
<td>1</td>
<td>1936</td>
<td>1969</td>
<td></td>
<td>Museum Director</td>
</tr>
<tr>
<td>Brandenburg, Frederick G.</td>
<td>1</td>
<td>1936</td>
<td>1939</td>
<td></td>
<td>Asst. Cur. Dept. of Birds</td>
</tr>
<tr>
<td>Cross, Frank Clay</td>
<td>1</td>
<td>1936</td>
<td>1938</td>
<td></td>
<td>Honorary Curator, Dept. of Entomology</td>
</tr>
<tr>
<td>Howland, Frank</td>
<td>1</td>
<td>1936</td>
<td>1937</td>
<td></td>
<td>Curator Emeritus, Geology</td>
</tr>
<tr>
<td>Markman, Harvey C.</td>
<td>1</td>
<td>1936</td>
<td>1948</td>
<td></td>
<td>Curator, Dept. of Geology</td>
</tr>
<tr>
<td>Womington, H. Maine</td>
<td>1</td>
<td>1936</td>
<td>1940</td>
<td></td>
<td>Curator, Dept. of Archaeology</td>
</tr>
<tr>
<td>Manz, Charles A.</td>
<td>1</td>
<td>1938</td>
<td>1943</td>
<td></td>
<td>Curator, Arachnid Anthropology</td>
</tr>
<tr>
<td>Holmes, Elizabeth B.</td>
<td>1</td>
<td>1939</td>
<td>1942</td>
<td></td>
<td>Assoc. Cur. Dept. of Archaeology</td>
</tr>
<tr>
<td>Brandenburg, Frederick G.</td>
<td>1</td>
<td>1940</td>
<td>1946</td>
<td></td>
<td>Assoc. Cur. Dept. of Birds</td>
</tr>
<tr>
<td>Womington, H. Marie</td>
<td>1</td>
<td>1940</td>
<td>1945</td>
<td></td>
<td>Honorary Curator, Dept. of Archaeology</td>
</tr>
<tr>
<td>Nininger, Harvey H.</td>
<td>1</td>
<td>1943</td>
<td>1945</td>
<td></td>
<td>Honorary Curator, Dept. of Meteorites</td>
</tr>
<tr>
<td>Van Riper, Walker</td>
<td>1</td>
<td>1943</td>
<td>1949</td>
<td></td>
<td>Curator, Dept. of Spiders</td>
</tr>
<tr>
<td>Womington, H. Marie</td>
<td>1</td>
<td>1945</td>
<td>1948</td>
<td></td>
<td>Curator, Dept. of Archaeology</td>
</tr>
<tr>
<td>Niedrach, Robert J.</td>
<td>1</td>
<td>1947</td>
<td>1948</td>
<td></td>
<td>Curator, Dept. of Zoology, Div. of Birds</td>
</tr>
<tr>
<td>Rogers, Albert C.</td>
<td>1</td>
<td>1948</td>
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