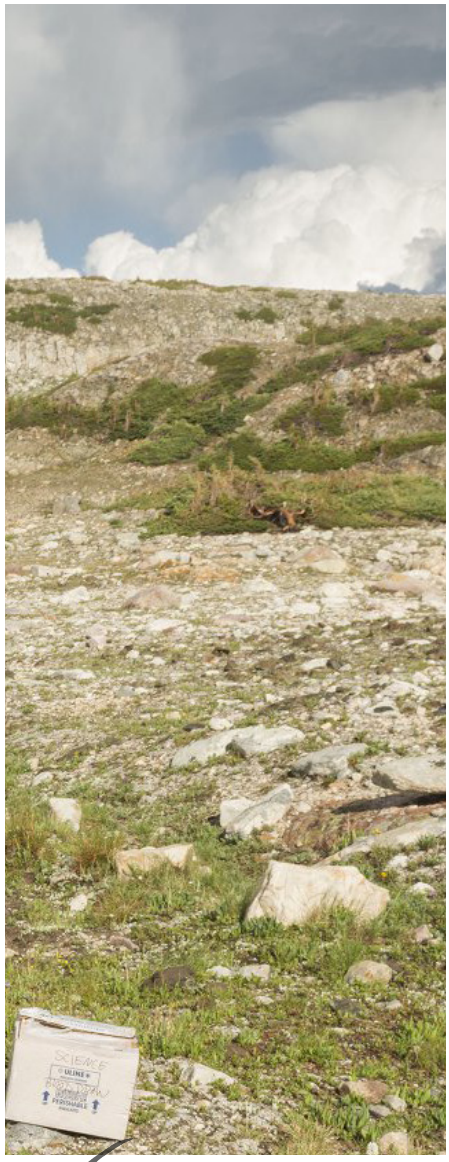

SCIENCE

DENVER MUSEUM OF NATURE&SCIENCE

2022-2026

Denver Museum of Nature & Science / Long-Term Collections & Research Plan

CONTENTS

1. EXECUTIVE SUMMARY

The mission of the Denver Museum of Nature & Science (DMNS) is "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 presents the detailed intellectual underpinning of scientific research by, and collections of, the DMNS. The audience for this document is the staff of the Science Division, the Museum's Senior Leadership Team, its President and Chief Executive Officer, the Board of Trustees, and anyone else who may be interested. The intent of this document is to guide curatorial decisions. The Board of Trustees–approved Manual of Collection Policies and its associated Ethics Policy Statement govern the collection activities at the DMNS.

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 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 also maintains collections specifically dedicated to frequent educational use. DMNS acquires and maintains archives, image archives, rare books, 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. The Museum's curators and archivists, build these collections, working in concert with collection managers and conservators to maintain and care for the collections. Much of the Museum's current collecting activity targets 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 Science Division/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.

Active research, salvage opportunities, acquisition of orphan collections, and opportunities to acquire significant regional icons and collections, drives future collecting. 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, 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 at the discretion of the to-be-hired genomics scientist. 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 will grow 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 11 curators and the five-year plan for each of the museum's 35 collections.

2. DEPARTMENT PLANS

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 field- 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, as well as international repatriation and the history of tree-ring dating in ancient Egypt. He will also continue his research on the Russian gem carvings of Vasily Konovalenko. Michele Koons will conduct research on the Front Range archaeology of Colorado, the Mogollon of New Mexico, and the Moche of Peru, as well as pursuing research opportunities as they arise. She will build on her recent book on the high-tech analysis of Egyptian mummies. Currently, the Curator of Anthropology position vacated in 2020 is held by Erin Baxter on an acting basis through March 2021; she will pursue research on the archaeology of death and on projects related to those of Nash and Koons, particularly including Department of Defense research for POW-MIAs in France, with Koons.

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. Particular emphasis will be placed on the WS Ranch Archaeological Collection and the Jones-Miller Paleoindian Collection, both of which are in dire need of basic processing and publication. 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 and seeks to understand the deep-time evolution of our planet's environments and organisms. Although much of our scholarship is global in nature, a substantial portion is anchored in the American West, has direct local impact, and involves community participation. Our team's science is diverse and currently includes the evolution of Cretaceous ecosystems; the causes and recovery of mass extinctions; regional stratigraphy and geochronology; the integration of paleoclimatology, geochronology, and tectonics in Rocky Mountain basins; and the linkages between Mesozoic biogeography and plate tectonic fragmentation of the southern supercontinent Gondwana.

Our paleontological collections primarily originate from the Rocky Mountain region; however, we also have world-class fossil vertebrate collections from Madagascar and a diverse cast collection. The vertebrate paleontology collection consists predom-

inantly of Cenozoic mammals, Jurassic and Cretaceous dinosaurs, and Cretaceous seaway fishes 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 mollusks, and Eocene insects.

Our geological collections include rocks 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 research focused on dinosaurs and crocodylomorphs from 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. As of this writing, one curatorial position, formerly held by paleobotanist Ian Miller, remains to be filled. Whether that position is filled by another paleobotanist remains to be seen.

Future Plans for Collections

The Earth Sciences collections primarily reside in the Avenir Collections Center. 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 next five years, we expect these collections to slowly grow in size in support of current and future research needs as well as needs to conserve historically or regionally unique specimens. Moderate continued growth is expected in both the vertebrate paleontology and paleobotany collections, and minor growth is expected in the invertebrate paleontology collections through active research and fieldwork and through acquisition of private collections. Minimal growth is anticipated in mineral, rock, and meteorite collections.

Audience Engagement

We engage in outreach that makes earth science 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 strive to make the Department 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 team at the Museum, and our story-telling, in all its forms (television, radio, print, books, lectures, fieldtrips, tours, hands-on-tables, social media, etc.). 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 and in training young scientists as intern, student, and postdoc mentors.

2.3 HEALTH SCIENCE

Department Focus & Collections

This plan will be updated with the hire of a new genomics scientist.

At the end of 2019, the former curator of Health Sciences left the Museum, and as of September 2021, there are plans to hire a scientist with a background in genomic to guide the direction of the lab.

Current and Future Research

This will be at the discretion of the to-be-hired genomics scientist.

Future Plans for Collections

See the collections plan for Health Sciences.

Audience Engagement

This will be at the discretion of the to-be-hired genomics scientist.

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, large-scale, multiwavelength analyses of star forming regions, and creating synthetic models of star clusters to compare with observations.

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 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 DMNS volunteers, and support of current and future exhibits, such as ***Space Odyssey*** and ***Future First***. 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 **1.29M** specimens or 30% of the Museum's total holdings (September 2021). The arachnology (spiders and their relatives) collection (~53,000 vials), one of the largest in the country, includes specimens from 10 orders. Strengths are in Araneae and Solifugae, 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 (1.1M 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 (~22,500 specimens), 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 (~56,000 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 (~7,000 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 640 specimens primarily regional and exotic (Denver Zoo), and the parasite collection (~10,820 lots) which rapidly grows in parallel with the bird and mammal collections. Approximately **275,000** specimen records are currently available on-line through Arctos or Symbiota, with data published to a different portals including SCAN, GBIF, iDigBio, GGBN, GLoBI, BISON, Map of Life, VertNet, InvertEBase, SEINet, and GenBank.

Current Research

Zoology curator research over the next five years will continue to be very active, collaborative, and specimen-based. Paula Cushing will be focused on the remaining year of her NSF project investigating North American camel spiders, training UC Denver graduate students, continuing her long-running citizen science project (Colorado Spider Survey), and continuing 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 (genetic and genomic approaches) among small mammals, primarily chipmunks, lagomorphs, 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 (City Park Nearby Nature Survey, 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 train a UC Denver graduate student, 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 focused manner, concentrating on the solid representation of regional species but also including worldwide species when appropriate (e.g., Solifugae, Scarabaeidae). Growth of collections 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 engage in a variety of internal and external outreach opportunities including, but not limited to, lectures, workshops, supporting museum programming, media opportunities, mentoring students, and behind the scenes tours. 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, particularly UC Denver and DU. 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. Acting as a resource for all programing that DMNS generates, the collections need to be wide ranging in nature but also of a size that allows for efficient and nimble management. Accordingly, the collections hold objects and specimens that are representative of the science and programing that the museum has produced.

Future Plans for Collections

In the fall of 2020, COVID-related pandemic budget cuts led to the elimination of the two Education Collections Manager positions. It was anticipated that the Science Division would transfer any appropriate specimens to the research collections, and then turn management of the education collection over to the Experiences and Partnerships Division (E&P).

As the assessment for research specimens went on, it became clear that some level of collections expertise is required to truly manage a collection that contains real specimens; knowledge is required of what the objects are and their stories, as well as knowledge of laws, ethics, mounting techniques, and numerous other collections management activities. Therefore, the day-to-day management and division of work between the Science Division and E&P continues to be assessed.

Areas identified in the assessment that will need action regardless of the ultimate management of the collection are reduction in size of the collection and simplification to the documentation process. The collection is currently too large to be well-managed by staff that must oversee this role as well as work to support the number of educational programs utilizing the collection. Continued assessment of the most actively used and needed collections will help us to remove unnecessary duplicates and items that are inappropriate for most educational programming.

An assessment of how Education Collections are documented is also planned for the near future. Moving to a system of cataloguing but not accessioning most specimens will provide for needed tracking and ease the burden on removing collections once they are no longer useful. The database will also be reassessed to create a much simpler cataloguing protocol, removing the burden of extensive and research-like cataloguing of collections to focus far more on information that is useful to educators, including images.

Much is changing in the Education Collections currently, but the end goal is to ensure we have a manageable, useful, well-documented, and nimble collection to best support the ever-changing needs of the museum's programming.

Audience Engagement

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. In object-based activities, teachers work with 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 which allow the development of such engaging programming. Working primarily with E&P, the DMNS Education Collections look for ways to best support this object-based learning.

2.7 LIBRARY & ARCHIVES

Focus & Collections

The Bailey Library and Archives has been 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.

The Bailey Library was closed in 2020 due to COVID-19 pandemic-related budget cuts, and plans to assess and disburse those collections are discussed in the Collections Plans section for the Library.

The Image Archivist position was also eliminated in October of 2020 due to COVID-19 pandemic-related budget cuts. As of that date, management of the image archives and other records was merged to fall under the purview of a single Archivist position. The two collections will be managed together for the foreseeable future.

Future Plans for Collections

The archives (records and images) 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 digitally, requiring specialized software and the involvement of technology staff in the process. As of 2021, funding was received from the National Endowment for the Humanities to hire consultants to help assess the Science Division's digital assets—including those in the archives—and to select, purchase, and implement a Digital Asset Management System. This will allow the Archives to take a more proactive approach to managing the digital assets and records we anticipate will make up the majority of the new acquisitions moving forward.

The Archives and rare book collections will see some growth of physical analog collections through donation and ongoing documentation of the Museum's history. Work to digitize and make analog collections digitally available will be a priority along with proper management of born-digital collections.

Audience Engagement

The Archives will collaborate with each of the Museum's departments to make more of their collections available through archives channels and aggregators. 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 STEVE NASH, DIRECTOR OF ANTHROPOLOGY & 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 seven books on the history of anthropology, archaeology, museums, and collections. The first two, Time, Trees, and Prehistory: Tree-Ring Dating and the Development of North American Archaeology 1914 - 1950 (U of Utah Press, 1999) and It's About Time: A History of Archaeological Dating in North America (U of Utah Press, 2000), stem from my National Science Foundation-funded dissertation research on the history of archaeological tree-ring dating in particular and on archaeological dating method and theory in general. My third book, Curators, Collections, and Contexts: Anthropology at the Field Museum 1893 - 2002 (Fieldiana, 2003) focuses on the history and scholarly impact of Anthropology at The Field Museum. Readings in Chronometric Analysis: Selections from American Antiquity and Latin American Antiquity 1935 – 2006 (Society for American Archaeology Press, 2009) is an edited compilation of previously published papers on archaeological dating. Crossroads of Culture: Anthropology Collections at the Denver Museum of Nature & Science (University Press of Colorado, 2010) highlights a remarkable collection of material culture that was previously not well known. With Chip Colwell, I edited and published An Anthropologist's Arrival: A Memoir by Ruth M. Underhill (2014, University of Arizona Press). That volume compiled oral histories, written memoir fragments, and an incredible photographic record into a small but powerful volume about a pioneering anthropologist. Most recently, I published Stories in Stone: The Enchanted Gem Carvings of Vasily Konovalenko (2016, University Press of Colorado). That volume is the first comprehensive, English language account of a remarkable collection of Russian gem-carving sculptures of which the Museum has the world's best examples on public display. Each of these seven volumes required independent research in archives, libraries, and museums as well as collaborative work with scholars from a number of different institutions.

I have published more than 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 several years, I have made contributions to a number of print and on-line 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, as well as Dr. Erin Baxter, who has held several titles at DMNS and is currently Acting Curator of Anthropology. 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.org, an on-line magazine that makes anthropology accessible to the public. Since then, I have published more than 50 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. 450,000 reads. All told, the Curiosities column has been read more than 800,000 times since its inception.

Goals for the next 5 years

My primary research goals for the next five years focus on the WS Ranch Archaeological Project, the Jones-Miller Paleoindian Collection, and the Reserve Area Archaeological Project, all broadly defined. With Dr. Michele Koons, 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 publish 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 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 does the environment constrain and facilitate 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 though 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.

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 2018 and 2019, we conducted excavations 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. We are working closely with members of the Zuni tribe and co-publishing the results of the survey and excavation.

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 ran for three seasons (2016-2018).

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. 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 were publish through the University Press of Colorado in March 2021.

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 the results. I continue to pursue research on Tiwanaku, which builds on my MA work and a collection of Tiwanaku pottery at DMNS.

In 2019, I began working in Peru on a project at the site of Pañamarca in the Nepeña Valley. Pañamarca is a large ceremonial center that was occupied for roughly 2000 years, but I am researching the Moche presence at this site. We planned to continue the project in 2020 and 2021, but COVID prevented this work. Work will resume when conditions allow.

In 2021, I co-directed a community archaeology project at the historic Astor House in Golden, CO. The building was constructed in 1867 and was a hotel for over 100 years. We excavated in the backyard where an addition with a basement is scheduled to be built in 2022. Also in 2021, I led a project in northern France to look for the remains of a B-17 bomber pilot that crashed during WWII. The project is a partnership between the Department of Defense POW/MIA Accounting Agency and the Center for the Environmental Management of Military Lands based at Colorado State University.

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. I plan to continue fieldwork in Peru at the site of Pañamarca and also in the far north of the country. Both projects aim to address Moche sociopolitics from the extreme northern and southern boundaries of the Moche sphere of influence. I also plan to continue work in the Reserve region of NM. The Reserve work will alternate with the work in Peru. I have a strong desire to continue community outreach projects and will work to make this happen when opportunities arise. 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.

We are finishing the move and reorganization of our archaeology collection. This will facilitate visiting researchers and descendent communities to visit and study our collections. We acquired the WS Ranch collection from Texas and a large grant will allow us to process and research this collection. I will play a role in these efforts. 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 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, geochemistry, and to a lesser extent, geochronology. Through a combination of fieldwork, laboratory analyses, and collections-based work, I seek to understand how environments and ecosystems changed in key intervals of earth history. My deep-time scientific scholarship grounds my concern for human impacts on our planet's surface envelope; thus, 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 a lifelong student of science communication, my research is aligned with the museum's mission – to discover, archive, and interpret the record of earth and human history while conveying the relevance of science, and scientific thinking, to community.

Personal Research History

My past research can be divided into four realms of inquiry, focused on triggers for the appearance of animals and the onset of biomineralization, the colonization of land by animals, the shift from pre-vegetated to vegetated landscapes, and how microbes influenced preservation, ecologies, and sedimentology in earth history.

Goals for the next 5 years

My research goals for the next five years center on working with community scientists, DMNS colleagues, and regional partners to improve understanding of how the Rocky Mountain region changed through the end-Devonian and end-Permian extinction events, what this region was like during the time of Permian ergs, how certain late Cretaceous sandstones and volcanic deposits reflect evolution of the Western Interior Seaway, how fossil preservation and unusual mountain-proximal conditions fostered the unusual fossil preservation typified by the Cretaceous-Paleogene succession at Corral Bluffs, and how we can better integrate the stratigraphic record of Cambrian sedimentary and volcanic rocks in southwestern North America to better frame understanding of changing environments, tectonics, and life during the Cambrian period.

3.2.2 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 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 28+ 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, screening [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 accessed 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 unparalled 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 an 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.

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"; a pop-up exhibit on the "crazy beast"). Since coming to the DMNS, I have also welcomed the opportunity to become involved in the Colorado Springs project led by Curator Tyler Lyson, which has allowed me to continue to pursue research interests in the evolution of mammals that survived the K/Pg mass extinction.

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 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 28+ years, which includes approximately 25,000 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 Madagascan 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. To that end, I have led an effort to apply for funding from the National Science Foundation for collections assistance.

I also plan to revitalize my earlier work by analyzing the recovery after the K-Pg mass extinction by assisting my colleague Tyler Lyson in uncovering the mysteries of early Paleocene mammalian evolution as part of his Colorado Springs 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). One major paper has been submitted for publication and another is in the works.

I also will strive to assist in ensuring the long-term success of the DMNS Digital Research Lab, which I founded in 2017 through funding from the National Science Foundation. 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 various avenues of research in the Science 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 exhibition and other 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.

3.2.3 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 regarding 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: Fort Union Formation of southwestern North Dakota and eastern Montana (Williston Basin) and the Denver Basin (West Bijou and Corral Bluffs) 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 curators 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.

Research: As part of a three year NSF grant (2020-2023) 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. As part of my current NSF grant, I will 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 and as part of my current NSF grant, 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, and as part of the Colorado Springs Research project funded by the No Walls Initiative and a generous anonymous donor, I plan to continue to build vertebrate, paleobotanical, and geochemical datasets that document the K/Pg extinction and subsequent recovery. In particular, I will focus my work on an exceptional fossil: a fossilized hollowed out tree stump filled with vertebrate fossils found at Corral Bluffs. Many of the fossils inside the tree represent new species and are the oldest and most complete fossil placental mammal skeletons ever discovered. Each skeleton will be documented to get a broader understanding of the early evolution of placental mammals in the aftermath of the End-Cretaceous mass extinction. This work will be coupled with a similar analysis of North American fossil turtles and plants to get a broader understanding of how life recovered after the K/Pg mass extinction.

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.

3.2.4 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 deep-time factors including tectonics, climate, and sea-level fluctuation influence vertebrate evolution and ecology. 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, 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. 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 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, 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, the San Juan Basin of northwestern New Mexico, and fossiliferous Cretaceous localities from elsewhere in Colorado and Texas.

- Continue collaborative work in Cretaceous deposits of Gondwana to address biogeographic and phylogenetic questions. This includes description of Cretaceous vertebrates from Africa (Kenya, Tanzania, Egypt) and 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 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 SPACE SCIENCE

3.3.1 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 earlier work involving near-infrared spectroscopy of massive young stars at the heart of the W40 cloud, I have continued to characterize the extended W40 star cluster in the Aquila Rift. This includes using the wide-field, near-infrared UKIDSS Galactic Plane Survey for finding young stars, creating extinction maps, finding clumps of young stars, and comparing observations of them with synthetic model star clusters. I am also working with collaborators on a new imaging optical campaign of other regions in the Aquila Rift to look for Herbig-Haro emission from outflows from undiscovered young stars.

Personal research history

Although trained as an observational astrophysicist studying 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, then 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 Science Division, I explored educational research by examining how computer-generated immersive virtual environments in planetariums could be used for astronomy education. The long-term study involved nearly 1000 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 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 infrared and new observations to survey for narrow-line optical emission, 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. A new model for star cluster evolution with updated distribution functions for

binary and K-band excess properties will allow us to test stellar cluster evolution assumptions against observations. Aggregating imaging, spectral, and theoretical modeling 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.

3.4 ZOOLOGY

3.4.1 JOHN DEMBOSKI, DIRECTOR OF ZOOLOGY & HEALTH SCIENCES & SENIOR CURATOR OF MAMMALS

Nature of Research

I am an evolutionary biologist that employs fieldwork and genetic-genomic techniques to study small mammals. My research program is primarily centered on western North America and relies heavily upon research collections, including DMNS and other museums. Fieldwork is combined with molecular approaches, morphological data, and informatics to address questions concerning evolutionary relationships, natural history, phylogeography, and mechanisms of speciation and divergence. I have also occasionally branched out 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 25 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 lagomorphs. 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 25 years, which has been primarily focused on chipmunks, shrews, 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, University of Denver, 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 chipmunks, shrews, and lagomorph 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.

3.4.2 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 18 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 40,000 databased and identified records (lots) published in an online database with another 20,000 vials (lots) remaining in the backlog. The collection represents 107 families of arachnids in 539 genera including over 1,800 described species.

Goals for the next 5 years

From 2022 - 2027, I will be focusing on a completing grant funded research from an 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 supported one postdoctoral scholar, a doctoral student, a master’s student, and several undergraduate students. The graduate students are supported in my lab. The MS student has defended his Master’s project, which resulted in two peer-reviewed papers, and is continuing in my lab as a doctoral student.

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, has already revealed 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 have also collaborated with colleagues to re-initiate a project focused on spider myrmecophiles (symbionts inside ant colonies). My colleague in Texas, Dr. Norm Horner, and a colleague at the California Institute of Technology, Adrian Brückner are focusing on the biology of spiders in the genus *Myrmecicultor* (family Myrmecicultoridae), species of which are found associated with ants in the genera *Pogonomyrmex* and *Aphaenogaster*. I also hope to work with colleagues Taro Eldridge and Mike Draney on projects involving a myrmecophilic spider in the genus *Masoncus* (family Linyphiidae) that is also found in association with ants. We will also explore the biogeography of the spiders and the ants to uncover details about their natural history and will likely describe new species.

The research projects carried out in my lab will be presented at public lectures, highlighted in Science in the News exhibits, 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 on the Council of the International Society of Arachnology and serve as the Secretary and Press Officer for the American Arachnological Society and will continue my work with those scientific societies. 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.

3.4.3 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 Palaearctic 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 233 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 similar projects here in Colorado is long-term goal. 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 in future. 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 at least by genus, 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, in 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.

City Park/Nearby Nature Project: Supported by Teen Science Scholars, we have established a monitoring program for the arthropod fauna accompanying the transformation of the play area adjacent Boettcher Plaza in City Park. In 2021 we are establishing a baseline for further comparison with the arthropod fauna after the new nature play areas have been built.

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.

3.4.4 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 20 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 in 2015, 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 140 Rosy Finch genomes and collected blood samples from populations at eleven different Colorado Mountain ranges. The genomes and samples have provided valuable data regarding the speciation and population history of Rosy Finches. New landscape genomics analysis of these data indicate that Rosy Finches are locally adapted to mountain ranges, but that they harbor enough genetic variation to adapt to changing

climate. This work has produced one peer reviewed publication (one more is in preparation) and several conference talks. I plan to continue working on Rosy Finches over the next five years.

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. These data should be published in the next year or two.

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. 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 my "Personal Research History." I conduct fieldwork annually in hybrid zones and various mountain ranges to support these research efforts. This work involves collaboration with researchers from CU Boulder, Texas Tech, the University of Washington, the University of Lethbridge, and Auburn University. In the last five years, we have identified interesting hybrid zones involving several different avian species or subspecies. The hybrid zones are found in Colorado, Wyoming, Oregon, Washington, and Arizona. We use whole genome sequencing of samples collected inside and outside these zones of contact to address questions about the origin of species and the evolution of genomic incompatibilities. Work on these projects will likely continue for the remainder of my research career.

Within the last two years, I began a project exploring the structure, function and evolution of the avian middle ear with Dr. John Peacock at CU Anschutz. For this work, we are able to utilize the thousands of bird specimens in the DMNS collection to explore variation in the morphology of the middle ear and use cadavers in the freezer to measure sound transference across the middle ear. We can then explore how structure and function are related. We have already published two papers on the middle ear. Over the next five years, we plan to seek NSF funding to advance our research in to the avian ear.

4. COLLECTION PLANS

4.1 ANTHROPOLOGY

4.1.1 WORLD ETHNOLOGY

Curator: To Be Hired

Plan author: Stephen Nash

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 pertains 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 5,500 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 zoological-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, Mbukushu, 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.

In 2020, DMNS received a CARES grant from the National Endowment for the Humanities that allowed us to process, at a minimal level, the World Ethnology Collection, such that it is now in the Avenir Collections Center. This provides a baseline on which to build, but large swaths of the collection need focused attention. Jason Baird Jackson may work on publishing the Chinese bamboo basket collection if the COVID-19 pandemic allows.

4.1.2 AMERICAN ETHNOLOGY

Curator: To Be Hired

Plan author: Stephen Nash

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 Herold 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'être* 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. We will publish the Peace Medals, the Southern Plains Beadwork, and other collections as part of our effort to make these collections accessible. We will practice inclusive collections management and conservation activities, and will continue our NAGPRA-related work.

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 580,000 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 uncataloged 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 armband/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 re

search 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. 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 authors: 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 scholarly and historic 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 3,000, and derives from many friends Paul Seel had in South Africa.

Elements of the micromount collection have a Colorado/Rocky Mountain focus, but most of the collection 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, but potentially could go on display with viewing apparatuses.

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 could be acquired. Three volunteers have been working with the Assistant Collections Manager to transcribe and clean up locality data for the micromount database and integration into EMu. Substantial work remains to scan and integrate historic specimen drawings and images of the collection into the database. This is an area where we would like to see the next Archivist or Image Archivist (two positions that are currently vacant or have been cut) support us by having them or their team do this work.

The potential of the micromount collection as a public or research resource has never been realized, despite a recent paper (Kosman et al. 2016), an atlas (Havens et al., 2018) 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 to popularize the collection, which will hopefully improve awareness. Improved access to 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 authors: 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 a fundamental 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 the majority of specimens are housed in archival mounts. The mineral collection has no historic backlog of unprepared, unidentified, and uncatalogued specimens, with only a small number of recent donations in queue for curation. 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 housed in padded trays or mounts, and most of the smaller specimens are stored in 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 85 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 and has been working in consultation with Curator of Anthropology Steve Nash to ensure their care and access. 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, or are directly linked to significant state historic events.

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 of 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, relatively 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 easily accessible online to the global scientific and avocational communities, but also because much of the collection is more of interest to the collector community than to the scholarly community. Customization and advertisement of the online mineral catalog data 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. In terms of archiving of the collection, a portion of the mid- to large-sized specimens that are hosted in cardboard boxes or on the oversize racks need to have their foam padding upgraded to archival foam because the original material is starting to degrade.

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 sister stone to the Centennial Diamond, 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 that is/was on display in the offices of the 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 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 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.

Little scholarly research has been conducted on the museum's rock collection—principally because its catalogue is not easily accessible 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 mineralogically 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. A recent atlas documents the collection and makes its catalogue publically available (Hagadorn et al., 2019). 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 692 specimens in the meteorite collection, that are either on display in Space Odyssey (8) or housed in two cabinets in the B1 Earth Sciences collections storage room in the Avenir Collections Facility (667), as well as a suite of 17 larger meteorite specimens stored on the bottom shelf of an oversize shelving rack in that room.

Meteorites have formal names that are recognized and published by 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 187 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 to 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 easily accessible online. 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 Venusian meteorites (should one be discovered and confirmed). However, once the fate of the Education Collections (now in transition to the Experiences and Partnerships team) is known, we may need term staff assistance to transfer some or all of the meteorites in that collection (originally in Earth Sciences, or purchases with Reynolds Morse Funds) back to the Earth Sciences collection.

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 303,842 cataloged specimens and lots, of which more than 290,000 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 the DMNS Avenir Collections Center. 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 79 holotype specimens, which serve as the name-bearers and morphological standards for various species. 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 holotype 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 303,842 cataloged specimens and lots currently in the electronic database. As of the end of August 2021, our records show that the collection contained the following numbers of specimens of different classes of vertebrates:

Fishes	Amphibia	Reptilia	Aves	Mammalia
18,663	8,645	25,079	283	161,799

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 79 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 wthat 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.

The global nature of the collection is anchored by a large collection of fossil vertebrates from the Late Cretaceous of Madagascar consisting of approximately 25,000 specimens, many of them complete or nearly complete skeletons. These skeletons are among the most complete and best preserved for entire groups of vertebrates from the southern supercontinent Gondwana.

Because much of the collection has been acquired over the past 35 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 early history of the growth of the vertebrate collections is taken from the Annual Reports (1910–present) and the 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 Colorado and 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 Paleoecology and Evolution. Stucky retired in early 2013 but has maintained his relationship with DMNS as Emeritus Curator of Vertebrate Paleontology. All of these scientists had active field collecting programs 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/Chew & Bown/Nichols-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 Neu-Yagle (2018-present). The ability to conduct digital research on 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), partnerships (e.g., Weld County ceratopsian), and major salvage (e.g., Snowmass Pleistocene, Thornton *Torosaurus*). 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 and Wyoming; 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 Maevarano Formation and other rock units 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 Plains 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: TBD

Plan author: S. Augusta Maccracken (Research Associate), building on Ian Miller's work.

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 contain 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, paleoecology, and paleoclimate of extinct ecosystems and forms a framework for understanding associated extinct terrestrial animals (e.g. dinosaurs, early placental mammals, early primates, insect herbivores, 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 Denvers* 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 institution's 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 and collecting procedures are 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 95,700 specimens as of 1/1/2021 from 1,809 discrete quarries in 148 geological formations from more than 31 US states, 4 Canadian Provinces, and 13 countries. A total of 37,336 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, 2,026 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 100 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 438 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 8,500 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 (>10,000) from approximately 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 censused 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 Ampoliy 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, collecting protocols, 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, such as insect herbivory on said leaves.

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 Center was completed in 2017. Although Ian Miller left his position as Curator of Paleobotany in the summer of 2021, S Augusta Maccracken, an NSF postdoctoral fellow specializing in Cretaceous–Paleocene floras, will continue the work of collecting and curating fossil plants at DMNS until the position is filled or her fellowship ends in 2024. Floral assemblages from Corral Bluffs and other Denver Basin sites will be prioritized to supplement ongoing research, as well as from the Kaiparowits Formation of southern Utah. 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. 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. Since it was moved into the Avenir Collections Center in 2014-2016, the collec-

tion has been reorganized, and about 80% of the collection needs to be inventoried to drawer-specific level, a process through which any of the minority of specimens which may not yet have archival boxes will be upgraded. 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 Bertie 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

Prior to 2010, DMNS did not have a curator with expertise in 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. Dena Meade-Hunter volunteered throughout the 1990s to keep the fossil insect collection organized.

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 collections, 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 which are being integrated into the collections so that they are accessible, and the Shropshire Collection is dominated by invertebrates from the Midwest and West which has aligned well with our existing strengths. 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.

Compared to the other paleontology collections at the DMNS, little scholarly research has been conducted on the Museum's invertebrate paleontology collection in the last twenty years—potentially due to the lack of participation in collaborative data sharing collections networks. Publication of the invertebrate paleontology database records to thematic collections networks and collections data aggregators could substantially change awareness and use of this collection, should the Museum make this a priority.

4.3 HEALTH SCIENCES

Curator: To Be Hired

Plan author: John Demboski (Acting), building on Nicole Garneau's previous work

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.

Human Genetics: The focus of the department's research until 2019, population genetics, led to the creation of a large human DNA collection. This subcollection includes DNA samples that were collected at an average rate of 1500 samples per year until 2019. Individual samples consist of 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 research direction the genetics lab takes. The use of the collection by external researchers is guided by the Institutional Review Board-approved informed consent and the acting curator.

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. The department has worked to transfer some 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.

Future Plans for Collections

Human DNA Subcollection: With the end of the NIH SEPA Genetics of Taste grant in 2020, current growth of this subcollection has been halted and the future growth (or not) will be tied to the new genomics hire.

Tissue (Histopathology) Subcollection: We anticipate that from 2022-2026 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.

4.4 SCIENTIFIC INSTRUMENTS

Curator: Ka Chun Yu

Plan authors: Ka Chun Yu, building on Kristen Busch and Veronika Hall's previous work

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 the 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 2nd floor SE collections hall. The Miller-Urey apparatus (ESI.1) has been put on public display in Prehistoric Journey. Other instruments (e.g., Zentmayer Histological Microscrope 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 2013-2017 Long-Term Collections & Research Plan, 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. These will need to be labeled and catalogued.

4.5 ZOOLOGY

4.5.1 ARACHNOLOGY

Curator: Paula E. Cushing

Plan author: Paula E. 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, Scorpiones, Solifugae, and Uropygi. Of these, the order Araneae ranks seventh in global species diversity amongst all organisms on earth with over 49,000 described species. Despite this diversity, arachnid taxonomy is poorly known. For example, the 49,000+ 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 in 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 provided over 1,000 members of the public with information about the biology of 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. 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/science/zoology/projects/colorado-spider-survey/). The arachnology collections data is published on a live online website through the Symbiota Collections of Arthropods Network, or SCAN (https://scan-bugs.org/portal/sitemap.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 40,000 records in the SCAN-DMNS arachnology database, 99% of which are georeferenced, 587 are imaged, 97% are identified to species. The collection includes 40 – 60,000 vials of arachnids.

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 ecoregion 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 nearly 60,000 representing 107 families of arachnids in 539 genera including over 1,800 described 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. Prior to the establishment of the DMNS collection, our knowledge of the arachnid diversity in the Rocky Mountain / Great Plains ecoregion was poorly known and poorly represented in the other major arachnid collections. The DMNS collection has reversed this paucity of knowledge. 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 for various studies. 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 the Colorado Spider Survey (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, Robert Fisher, Wendell Icenogle, Karen Cangialosi, Christy McCain, and NEON (National Ecological Observatory Network).

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 ecoregion 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 ecoregion. 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 ecoregion.

Collection growth will continue to occur largely through active fieldwork by DMNS staff, students, and volunteers. Such fieldwork will be in conjunction with funded projects, such as the NSF funded Solifugae project. Collections support of student research projects (undergraduate and graduate) is critical in training the next generation of scientists. Collections growth will also occur through donations. Donations offered of material from within the ecoregion will be accepted in order to further strengthen the taxonomic focus of the collection. Material offered for donation collected outside the ecoregion 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. The active loan program increases the relevance and importance of the collection by facilitating research and scholarship outside the focus of the DMNS staff. Loaning specimens to other researchers is critical to maintain the vibrancy, importance, and relevance of the collection.

4.5.2 ENTOMOLOGY

Curator: Frank Krell

Plan author: Frank Krell

Intellectual Framework

Insects are 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 pest, 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 1,080,000 specimens (January 2021). At its current growth rate (~1.9% per year), we are adding an average of 20,000 specimens per non-pandemic 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. Tyeryar 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. Moretto, 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. The LepNet grant Lepidoptera of North America Network; Seltmann et al. 2017), concluded in 2020, established the DMNS collection as part of LepNet and supported cataloguing, databasing, and photographing a part of the butterfly and moth collection. A temporary curatorial assistant, Eric Knutsen, was employed by this grant.

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 the next decades. This collection is generally well-curated and contains over 3,000,000 specimens in 2,100 drawers (1,200 sq ft) including 50 primary and 2,500 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 and 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 is 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* magazine 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. The data from this collection is published via the publicly accessible online data portal, Arctos (https://arctos.database.museum/) and is pushed out to the Global Biodiversity Inventory Facility (https://www.gbif.org/) biodiversity data portal and iDigBio (https://www.idigbio.org), making the DMNS Marine Invertebrate collection accessible to a worldwide audience.

Scope of the Collection

The marine invertebrate collection currently contains almost 50,000 lots of which over 31,500 (63%) are fully catalogued. These 31,500 lots are 68% geolocated, and they contain 86,000 individual specimens from micromollusks less than 0.25 inches (6 mm) to giant clams more than 2 feet (0.6 m) long. Our collection is worldwide with particular strength in material from the Caribbean, western North America, and the Pacific (including Hawaii, the Philippines, and Australia). The largest of the 490 families in the collection are Conidae, Cypraeidae, Muricidae, Strombidae, Mitridae, Volutidae, Veneridae, and Pectinidae. The collection contains fourteen paratypes. Endangered or CITES-protected species include queen conchs (*Aliger gigas*), *Tridacna* species, *Achatinella* from Hawaii, and *Liguus* from Florida. Legacy collections include shells from Trustee Henry Porter (collected by Mary Pratt) and John Evans, and soft 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, Richard Schaake and others. 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 en-

tirely 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 under the direct supervision and oversight of curator Paula E. Cushing.

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 to Arctos, an online database, which immediately provided public access to all specimen records. Arctos enables us to geolocate lots and add images of significant specimens to the specimen record. Over 1,100 SEM (Scanning Electron Microscope) and light microscopy images of specimens have been created with a focus on micromollusks which tend to be underrepresented on the internet. Arctos uploads the DMNS data and images 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. Locality data may reflect expansion or contraction of species distribution with warmer oceans. 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 ~21,000 (September 2021) cataloged and databased specimens (~22,500 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 121-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 publish DMNS mammal specimen records via our database Arctos, and secondarily, through other data portals such as GBIF, GGBN, GLoBI, iDigBio, VertNet, BISON, Map of Life, 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 on the curation of the "extended 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., that are linked to resulting publications and datasets.

Collection-use metrics from 2006 to Summer 2021 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 ~22,500 specimens, or at a rate of about 800 new specimens annually. In addition, frozen tissues associated with ~10,000-plus mammal specimens and ecto/endoparasites (~10,820 specimen lots) have also been archived. Over this 15-year period, 225 loans have been processed, over 500 researchers have visited the collection, and 170 publications (Google Scholar) have been produced using DMNS specimens and/or associated data. Citations of publications using DMNS mammal specimens over this period number 9,330 according to Google Scholar. Virtual visits and use of specimen records is reflected in query stats from Arctos and since 2010 there have been ~184,000 queries capturing 2.7M 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 4.3M 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 public through informal science education. There are a lot of opportunities to both learn about and view specimens and in many instances visit the collections behind the scenes. 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 and virtually.

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, 15,000+ 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; zoology volunteers have donated over 150K hours since 2006 including preparing specimens, working in the dermesterium, databasing, specimen inventory, data verification, and many other general collection tasks.

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 22,500 specimens which includes ~21,000 cataloged specimens (9/2021), and a backlog that is rapidly diminishing with the hire 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 268 genera, and 390 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 (*Conepatus mesoleucus figginsi* and *C. m. fremonti*), badger (*Taxidea taxus phippsi*), 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 mogollonensis*; 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=1,764), Sorex sp. (shrews; n=1,400), *Peromyscus maniculatus* (deer mouse; n=2,300), *Cynomys ludovicianus* (Black-tailed prairie dog; n=166), *Zapus hudsonius preblei* (Preble's jumping mouse; n=~160), and *Ochotona princeps* (pikas; n=210).

Large series of Front Range mammals (n=~2500) received from wildlife rehabilitation centers over the last decade. An important record of regional, urban biodiversity from Colorado.

Exotic mammals such as elephants, giraffe, hyenas, 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 Figgin'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-ft^2 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 15 years was the formation of an in-house frozen tissue collection; tissues have been archived from approximately 10,000 plus mammal specimens as of September 2021. 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 (~8,000 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 25 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 "extended 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 (~800 specimens/year since 2006), this collection is expected to reach ~29-30,000 specimens by the end of 2030. 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 because of the rapidly expanding frozen tissue collection given that tissue loans constitute a large percentage 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 and other mammals. 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= ~1,980 mammals; 2006-2021). Other growth will come from local wildlife rehabilitation centers which have donated approximately 5,000 Front Range mammals over the last 15 years, and this is expected to continue.

Concurrent with the acquisition of mammal specimens is the roughly 25,000 tissue cryotubes from about 10,000 specimens currently housed in a -87°C ultracold freezer, with records easily searchable in Arctos. This sub-collection is very active with an annual growth in loans for samples. 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 year 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.

Zoology staff will also be focused on corralling 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 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. 64,000 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: genomic analysis of speciation in Rosy Finches (Funk et al. 2021), population genetics and speciation in the Warbling Vireo (Carpenter et al. 2021), the role of genomic architecture in allopatric speciation (Manthey et al. 2021), 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)yet little is known about how the basin ecosystem, where breeding red-legged kittiwakes primarily forage, is affected by climate variability. We examined when and under what conditions red-legged kittiwakes experienced food shortages. Head feathers (winter; 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 ~2% 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 become the catalyst for the founding of the Museum.

Order (Clements 2004)	# of Specimens
Accipitriformes	1809
Aepyornithiformes	1
Anseriformes	3336
Apodiformes	88
Bucerotiformes	27
Caprimulgiformes	968
Casuariiformes	13
Cathartiformes	64
Charadriiformes	6021
Ciconiiformes	961
Coliiformes	2
Columbiformes	1346
Coraciiformes	247
Cuculiformes	271

Order (Clements 2004)	# of Specimens
Falconiformes	672
Galliformes	1890
Gaviiformes	248
Gruiformes	455
Passeriformes	30968
Pelecaniformes	611
Phoenicopteriformes	25
Piciformes	1993
Podicipediformes	209
Procellariiformes	405
Psittaciformes	407
Pterocliformes	14
Rheiformes	32
Sphenisciformes	51
Strigiformes	1414
Struthioniformes	16
Tinamiformes	28
Trogoniformes	64

Table 1. Summary of taxonimic coverage

Region	# of Specimens
Africa	308
Antarctica	5
Asia	467
Atlantic Ocean	6
Australia	662
Central America	1096
Eurasia	1
Europe	172
North America	50279
North Atlantic Ocean	1
North Pacific Ocean	1
Pacific Ocean	478
South America	1205
South Atlantic Ocean	1
West Indies	189
no higher geography	376

Table 2. Summary of geographic coverage

Year(s)	# of Specimens (Growth)
2012	48,940
2013-2015	51,531 (5%)
2016-2021	64,593 (5%)

Table 3. Ornithology specimen growth

Year(s)	# of Frozen Tissues (Growth)
2012	1,381
2013-2015	2,591 (188%)
2016-2021	14,007 (256%)

Table 4. Ornithology frozen tissue growth

The Ornithology Collection includes approximately 64,000 objects, including approximately 56,500 birds (study skins, mounts, and skeletal material), nearly 7,500 egg sets, and 1,200 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 Grat 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 levyi*), saffron finch (*Sicalis pelzelni danisa*), savannah sparrow (*Passerculus sandwichensis bradburyi*), house finch (*Carpodacus mexicanus smithi*), and two lectotypes, the long-tailed ground dove (*Uropelia campestris 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 Benedicto Island Rock Wren (*Salpinctes obsoletus exsul*), Guadalupe Island Ruby-Crowned Kinglet (*Regulus calendula obscurus*), Heath Hen (*Tympanuchus 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 6,500 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 1,000 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 2013-2017 Long-Term Collections & Research Plan was written. 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 2,700 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 250% 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 the 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 >220,000 web-queries of our bird collection, representing >25,000,000 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

Amphibians and reptiles represent large vertebrate groups with about 17,000 species worldwide, with approximately 74 species found in Colorado. The amphibian and reptile collection at DMNS is small, but growing, and 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 in 70%-95% ethanol and stored at room temperature in the Zoology Wet Collections space. 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 frozen tissue collection associated with the collection (<124 specimens). To date, 226 specimens have been cataloged and are currently available in Arctos (Summer 2021). 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, work will be directed at sorting, rehousing, and cataloging 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 15 years. The collection has grown rapidly along with its visibility and to date, multiple loans and 15 publications (Google Scholar) have been produced based on DMNS parasites. Virtual visits and use of specimen records is reflected in query stats from Arctos since 10/2016 with 5,400 queries capturing 322,700 individual record instances. The collection also publishes data to SCAN, GBIF, iDigBio, BISON, GLoBI, GGBN, and GenBank.

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, and embody the philosophy of the "extended specimen".

Scope of the Collection

The collection consists of about 8,500 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 1,200 specimens or specimen lots have been cataloged and are currently available in Arctos (September 2021). 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. 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 being accessioned and cataloged 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. 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 4,650 plant specimens (pressed plants mounted on sheets or in books, leaf litter samples, pinecones, 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. 4,150 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). 2,498 databased specimens are from the

United States (1,128 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. In 2021, we received 156 specimens from the former DMNS Education Collection.

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 Intermountain Region Herbarium Network at https://intermountainbiota.org/portal/collections/index.php?catid=1#. 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: Melissa Bechhoefer (Acting)

Educational Merit and Impact of the Education Collections

Object Based Inquiry (OBI) is a tool used by DMNS that combines Object Based Learning (learning from an object that is in front of you), and Inquiry Learning (individuals construct much of their understanding of the natural and human-designed worlds). Education Collections at DMNS provide the objects needed for programs to implement an OBI approach with a wide array of audiences.

Philosophy of the DMNS Education Collections

The DMNS Education Collections serves as a resource for science programming at DMNS. As such, it is necessary to maintain high quality collections that represent the major study areas of our research departments and programming. Ensuring proper documentation, appropriate preservation, and reliable access are paramount to the success of the collection in supporting science programming.

Community Impact of the Collections

Programming and object-based support was much reduced in 2020-2021 due to COVID-related closures and reductions in programming. Support was also affected by the pandemic-driven budget cuts that caused our two Education Collection Manager positions to be eliminated. Science Division staff continued to provide Education collections in support of programs such as Field Trip Adventures, Summer Camps, Teacher Professional Development, Temporary Exhibit enhancements and Discovery Zone. The museum is anticipating still reduced attendance in 2022, but slowly returning to pre-pandemic levels over the course of the year. It is anticipated that a similar return to collections use will also return.

Museum Collections versus Teaching Aids and Props

Moving forward, the DMNS Education Collections will continue to not be responsible for things like posters, building materials like Legos or Kiva sticks, or exhibit components or props. The department has transferred costumes and props that the Enactor Program utilizes to E&P for management.

Care of Education Collections Objects

The Education Collection, while often containing real specimens and objects, is designed and maintained for the purpose of educational use. Therefore, care of these collections is different from those in research collections. While some levels of preventive conservation, such as IPM, will be similar to other museum collections, it is anticipated that these collections will be handled, used, and eventually worn enough to be removed from the collection. Appropriate care will be maintained so as to allow for needed programming support, while allowing collections items to last as long as is reasonable.

Documentation of collections will be thorough enough to allow for good documentation of an object's educational value, tracking, and use. There is no need to catalogue these materials as thoroughly as research collections, but maintaining accurate records will allow for efficient access and accurate use of collections in programming.

Current Scope of the Collection

There are approximately 20,000 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, as well as uncatalogued material. The Education Collections are stored separately from the Research Collections so as to not introduce any agent of deterioration into the research 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. It is acknowledged that the collection is designed to facilitate tangible learning moments, and yet we need to have special considerations for CITES listed species, species that are under federal regulation and fossils that are protected by US and international entities.

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 (now Science Division), with staff who reported to the Chief Curator. In 2006 the Education Collections was reorganized again to 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 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 received 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 increased the Education Collections connection with other collections and collections staff. It was the first time in the history of the Education Collections that the department was aligned with other collections and had the support of colleagues from other collections staff.

Future of the Collection

In the fall of 2020, COVID-related pandemic budget cuts led to the elimination of the two Education Collections Manager positions. It was anticipated that the Science Division would transfer any appropriate specimens to the research collections, and then turn management of the education collection over to the Experiences and Partnerships Division (E&P).

As the assessment for research specimens went on, it became clear that some level of collections expertise is required to truly manage a collection that contains real specimens; knowledge is required of what the objects are and their stories, as well as knowledge of laws, ethics, mounting techniques, and numerous other collections management activities. Therefore, the day-to-day management and division of work between the Science Division and E&P continues to be assessed.

Areas identified in the assessment that will need action regardless of the ultimate management of the collection are reduction in size of the collection and simplification to the documentation process. The collection is currently too large to be well-man-

aged by staff that must oversee this role as well as work to support the number of educational programs utilizing the collection. Continued assessment of the most actively used and needed collections will help us to remove unnecessary duplicates and items that are inappropriate for most educational programming.

An assessment of how Education Collections are documented is also planned for the near future. Moving to a system of cataloguing but not accessioning most specimens will provide for needed tracking and ease the burden on removing collections once they are no longer useful. The database will also be reassessed to create a much simpler cataloguing protocol, removing the burden of extensive and research-like cataloguing of collections to focus far more on information that is useful to educators, including images.

Much is changing in the Education Collections currently, but the end goal is to ensure we have a manageable, useful, well-documented, and nimble collection to best support the ever-changing needs of the museum's programming.

Future of Education Collections Object Acquisition:

The assessment of existing objects continues with a goal to make the collection smaller, better documented, and more flexible. Object acquisition in the DMNS Education Collections will focus on objects and specimens that are requested for programming or to replace heavily-used collections. We will acquire, or help acquire, things primarily to support DMNS Programing and Exhibits. 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:

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 the object or specimen a higher quality than one we currently have in the collections that it could potentially replace?

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.

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 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 and is working to remove these from the collection. Any item known or suspected to be treated with hazardous chemicals or in any other way poses a hazard will not be accepted into Education Collections.

4.7 BAILEY LIBRARY & ARCHIVES

4.7.1 ARCHIVES

Curator: Melissa Bechhoefer (Acting)

Plan author: Melissa Bechhoefer (Acting)

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 accept 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 scientific 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. Specific areas of born-digital records to focus on are data sets and emails.

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.

As of 2021, funding was received from the National Endowment for the Humanities to hire consultants to help assess the Science Division's digital assets—including those in the archives—and to select, purchase, and implement a Digital Asset Management System. This will allow the Archives to take a more proactive approach to managing the digital assets and records we anticipate will make up the majority of the new acquisitions moving forward.

4.7.2 RARE BOOKS

Director: Melissa Bechhoefer (Acting)

Plan author: Melissa Bechhoefer (Acting)

Future of the Collection

The rare book collection, as of 2019, was transferred to and will continue to be managed as a part of the Archives. With the 2020 closure of the library, existing library books will be assessed for inclusion into the rare book collection and those selected retained and managed by Archives. It is anticipated that collection will grow slowly and opportunistically in the future. Donations of rare books will only be accepted when they fit our collection development guidelines. In the future, the rare book collection will be included with reporting by the Archives department.

Short Term Priorities for the next 1-5 years:

- Establish parameters for inclusion of books in rare book collection

- Use parameters to asses existing library collection for books to designate as rare books
- Transfer rare books to Archives collection for ongoing management
- Work to catalog rare books into EMu for ongoing archival management
- Assess best way to share these resources with outside researchers

History of the Collection

In the early years of the museum, library collections were stored in various curatorial offices and 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.

In 2019, the rare book collection was transferred to the archives as the rest of the Bailey library was closed for remodel. As part of the cost-savings required by pandemic-related budget cuts, the decision was made in 2020 to permanently close the Bailey Library. The rare book collection will remain in the DMNS archives and be accessible to staff and researchers through this department.

Intellectual Framework for the Rare Book Collection

The rare book collection followed the collection development plan for the rest of the library, which specified which subject areas, and to what depth, to collect. The plan focused on the Museum's core competencies and regional emphasis. Its audiences included 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 1,826 titles, comprising 2,791 volumes. The earliest publication date is 1773. Volumes are housed in the Archives collection under climate-controlled conditions.

4.7.3 LIBRARY

Director: Melissa Bechhoefer

Plan Author: Melissa Bechhoefer (acting)

Future of the Collection

As part of the COVID-19 pandemic budget cuts faced in 2020, the Bailey Library was permanently closed. Rare books will remain at DMNS in the archives, and books needed by curatorial or collections staff for ongoing work or research will be retained within departments. All other books and serials will be offered to other libraries and institutions over the next couple of years. Any books not wanted by other institutions will be sold with proceeds being used for collections acquisition or ongoing care of other collections.

The Museum's curatorial staff continues to require online journal access, and is transitioning to using access through other institutions obtained via associated researcher status. The Chief Curator continues to work with local universities on obtaining associated researcher status for any curatorial staff that otherwise don't have this association.

Short Term Priorities for the next 1-5 years:

- Identify any additional library materials that should remain at DMNS not already identified as rare books or in possession of departments
- Hire library assistant to help coordinate offering of library materials to other institutions, prioritizing those with widest circulation and inter-library loan
- Deaccession and disposition of books, serials, and other library materials
- Physical transfer of books to other institutions
- Books not wanted by other institutions to be sold via existing vendor

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 OCLC[1] 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 Branch. 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 was anticipated for late 2020 or early 2021. The audience focus upon reopening was intended to be prioritized in the following way: museum scientists, other staff, and volunteers.

As noted above, in 2020, the decision was made to permanently close the library.

Intellectual Framework for the Library Collection (prior to closure)

The Museum's Bailey Library supported 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:

- 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.

Scope of the Collection (prior to closure)

The Library purchased materials to add to the library, including books, periodicals, and media and maintained subscriptions

[1] Online Computer Library Center based in Dublin, Ohio.

to online periodical databases BioOne and JSTOR[2] prior to 2020. Since 2020, curatorial staff have relied on academic access through other institutions through which they have associated researcher status.

Donated books, journals, and other resources met the same criteria as purchased resources in terms of relevance to our core competencies.

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.
3. Geology of the Rocky Mountains.
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.

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.
6. Zoology 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. As the library collection is assessed over the next few years, titles can be added to our rare book collection. Others will be offered to appropriate institutions to ensure they are available to the research community.

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.

[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.

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 was vacated due to construction activities. The collections were packed and stored on-site at the museum. These collections, as well as those behind dioramas, were slated to be consolidated into the 2nd floor SE Collections storage area, along with the Education Collection. With the closing of the library in 2020, the move to the SE Collections area did not happen, and materials will be unpacked for assessment and offered to other institutions.

4.7.4 IMAGE ARCHIVES & DOCUMENTARY ARTS

Curator: Melissa Bechhoefer (Acting)

Plan author: Melissa Bechhoefer (Acting)

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, records in our collections database, EMu, can be searched along with our other Archives collections at https://imu.dmns.org/dmns/archive.html.

Scope of the Collection

Size of the collections: There are approximately 770,000 analog items and 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 Denvers 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 down-sized 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.

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. This position has added high-quality photo documentation, with appropriate metadata, to the collections.

As of October, 2020, the Museum's Image Archivist position was eliminated due to COVID-19 pandemic-related budget cuts. The management of the image archives was transferred to the Archivist position.

Future of the Collection

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 Archivist must 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 is to encourage the fullest appropriate use of the image collections.

As such, Archives will continue to increase the number of images collections it makes digitally accessible. With over one hundred years of archives and an ever-growing digital collection, thoughtful curation and digital content creation will continue to bring the museum's treasures to researchers and the public. The future of this program necessitates continued support from volunteers.

With the implementation of the Digital Asset Management NEH grant in 2021-2022, we will begin a thorough assessment of management and preservation needs of digital assets, including those in the Archives. Archives, other Science Division, and IT staff will work together to implement a management solution that is scalable to accommodate the fast-growing collection

of digital assets. It will also assess whether these management software packages provide sufficient digital preservation or if additional programmatic systems must be implemented.

5. REFERENCES

ENTOMOLOGY

Aaron, E.M. & Aaron, S.F. 1884. List of a collection of diurnal Lepidoptera from southern Texas: *Papilio*, 4: 172–182.

Cockerell, T.D.A. 1905: Miscellaneous notes: *Canadian Entomologist* 137: 361–362.

Cockerell, T.D.A. 1906: *Pseudorthosia variabilis* var. *pallidior* n. var.: *Entomological News* 17: 204.

Cross, F.C. 1937a. Butterflies of Colorado: *Proceedings of the Colorado Museum of Natural History* 16: 1–28.

Cross, F.C. 1937b. A new race of *Plebeius scudderii*: *Pan-Pacific Entomologist* 13: 88.

French, G.H. 1884. A new zygaenid: *Triprocris martenii*, n. sp.: *Papilio* 3: 191–192.

Grote, A.R. 1882. New moths: *Canadian Entomologist* 14: 181–188.

Krell, F.-T. (ed.) 2009. Program and Abstracts, High Country Lepidopterists, 20th Annual Meeting, October 23 and 24, 2009, Denver Museum of Nature & Science. *Denver Museum of Nature & Science Technical Report*, no. 2009-8, 11 pp.

Krell, F.-T., Bettman, D. & Gilligan, T. (eds) 2012. Program and Proceedings of the International Lepidopterists' Conference, Denver, July 23–29, 2012. *Denver Museum of Nature & Science Technical Report*, no. 2012-6, 65 pp.

Krell, F.-T. & Stephenson, J.T. 2014. The entomology collection at the Denver Museum of Nature & Science has a new home. *Denver Museum of Nature & Science Reports* 1: 8-10.

Nonveiller, G. 1960. Speziation bei den Rhizotroginae als Folge tageszeitlicher Sonderung. Verhandlungen, XI. I*nternationaler Kongress für Entomologie Wien* 1: 88–91.

Peigler, R.S. 1992. A new species of *Syntherata* from the Trobriand Islands (Lepidoptera: Saturniidae): *Tropical Lepidoptera* 3: 105–108.

Peigler, R.S., and Kendall, R.O., 1993, A review of the genus *Agapema* (Lepidoptera: Saturniidae): *Proceedings of the Denver Museum of Natural History* (3) 3: 1–22.

Seltmann, K.C., Cobb, N.S., Gall, L.F., Bartlett, C.R., Basham, M.A., Betancourt, I., Bills, C., Brandt, B., Brown, R.L., Bundy, C., Caterino, M.S., Chapman, C., Cognato, A., Colby, J., Cook, S.P., Daly, K.M., Dyer, L.A., Franz, N.M., Gelhaus, J.K., Grinter, C.C., Harp, C.E., Hawkins, R.L., Heydon, S.L., Hill, G.M., Huber, S., Johnson, N., Kawahara, A.Y., Kimsey, L.S., Kondratieff, B.C., Krell, F.-T., Leblanc, L., Lee, S., Marshall, C.J., McCabe, L., McHugh, J.V., Menard, K.L., Opler, P.A., Palffy-Muhoray, N., Pardikes, N., Peterson, M.A., Pierce, N.E., Poremski, A., Sikes, D.S., Weintraub, J.D., Wikle, D., Zaspel, J.M. & Zolnerowich, G. 2017. LepNet: The Lepidoptera of North America Network. *Zootaxa* 4247: 73–77.

Webb, E.A., and Peigler, R.S., 1990, The John T. Mason collection at the Denver Museum of Natural History: *Journal of the Lepidopterists' Society* 44: 194–198.

GEOLOGY

Havens, L. G., Bucknam, S. H. & Hagadorn, J. W. 2018. The micromount mineral collection of the Denver Museum of Nature & Science. *Denver Museum of Nature & Science Reports* 11: 726 pp.

Kosman, C. W., Kopylova, M. G., Stern, R. A., Hagadorn, J. W., & Hurlbut, J. F. 2016. Cretaceous mantle of the Congo craton: evidence from mineral and fluid inclusions in Kasai alluvial diamonds. *Lithos* 265: 42–56.

ORNITHOLOGY

Bailey, A. M. & Niedrach, R. J. 1965. Birds of Colorado. Denver Museum of Natural History, Denver.

Manthey, J. D., Klicka, J., & Spellman, G. M. 2021. The Genomic Signature of Allopatric Speciation in a Songbird Is Shaped by Genome Architecture (Aves: *Certhia americana*). *Genome Biology and Evolution* 13(8): evab120. https://doi-org.aurarialibrary.idm.oclc.org/10.1093/gbe/evab120

Carpenter, A. M., Graham, B. A., Spellman, G. M. Klicka, J., & Burg, T. M. (*In press*). Genetic, bioacoustics and morphological analyses reveal cryptic speciation in the warbling vireo complex (*Vireo gilvus*: Vireonidae:Passeriformes). *Zoological Journal of the Linnean Society*.

Funk, E. R., Spellman, G. M., Winker, K., Withrow, J. J., Ruegg, K. C., Zavaleta, E., & Taylor, S. A. 2020. Phylogenomic Data Reveal Widespread Introgression Across the Range of an Alpine and Arctic Specialist. *Systematic Biology*: Syaa071.

Murray, G. G. R., Soares, A. E. R., Novak, B. J., Schaefer, N. K., Cahill, J. A., Baker, A. J., … Shapiro, B. 2017. Natural selection shaped the rise and fall of passenger pigeon genomic diversity. *Science 358*(6365): 951. doi:10.1126/science.aao0960

Phillips, A. R. & Webb, E. A. 1991. Type material of birds in the Denver Museum of Natural History (Series 3) 1: 1-7.

Preston, C. R. & Haglund, K. A. 2000. Ornithology at the Denver Museum of Natural History. Memoirs of the Nuttall Ornithological Club. No. 13: 123-152.

Webb, E. A., Patterson, C., Meaney, C. A., & Snellgrove, B. 1989. Integrated pest management at the Denver Museum of Natural History. *Collections Forum* 5: 52-59.

Will A. P., Kitaiskaia E. V., & Kitaysky, A. S. 2018. Red-legged kittiwake feathers link food availability to environmental changes in the Bering Sea. *Marine Ecology Progress Series 593*: 261–274.

6. APPENDICES

6.1. APPENDIX 1: COLLECTION SUMMARY

DEPARTMENT	COLL #	COLLECTION	CURATOR & PLAN AUTHOR	COLLECTION MANAGER	TOTAL CUBIC FEET USED (1/1/2022)[1]	AVAILABLE CUBIC FEET (1/1/2022)	% COLLECTION SPACE USED (including growth 1/1/2022)	OBJECTS IN COLLECTION = DOCUMENTED + BACKLOG (1/1/2022)	CATALOGUED SPECIMENS OR LOTS (1/1/2022)
Anthropology	1	World Ethnology	Colwell	Alhambra	7,339	8,038	91.30%	5,536	5,536
Anthropology	2	American Ethnology	Colwell	Alhambra	31,533	28,286	111.48%	21,204	21,204
Anthropology	3	Archaeology	Nash/Koons	Alhambra	8,971	12,896	69.56%	576,445	34,345
ANTHROPOLOGY TOTAL					**47,843**	**49,220**	**97.20%**	**603,185**	**61,085**
Earth Sciences	4	Micromount minerals	Hagadorn	MacKenzie	237	285	83.16%	29,673	22,583
Earth Sciences	5	Mineral Collection	Hagadorn	MacKenzie	3,953	4,879	81.02%	18,874	18,874
Earth Sciences	6	Rock Collection	Hagadorn	MacKenzie	332	499	66.53%	1,703	1,504
Earth Sciences	7	Meteorites	Hagadorn	MacKenzie	194	593	32.72%	684	684
Earth Sciences	8	Vertebrate Pelontology	Sertich/Lyson/ Krause	MacKenzie	38,533	60,971	63.20%	1,570,379	297,809
Earth Sciences	9	Paleobotany	Miller	MacKenzie	4,916	7,980	61.60%	155,236	96,855
Earth Sciences	10	Invert Paleontology	Hagadorn	MacKenzie	1,250	1,710	73.10%	34,391	24,830
EARTH SCIENCES TOTAL					**49,415**	**76,917**	**64.24%**	**1,810,940**	**463,139**
Health Sciences	11	Health sciences	Demboski	TBH	225	453	49.67%	27,738	11,052
HEALTH SCIENCES TOTAL					**225**	**453**	**49.67%**	**27,738**	**11,052**
Space Sciences	12	Scientific Instruments	Yu		86	86	100.00%	71	71
SCIENTIFIC INSTRUMENTS TOTAL					**86**	**86**	**100.00%**	**71**	**71**
Zoology	13	Arachnology	Cushing	Doll	583	616	94.64%	54,122	40,791
Zoology	14	Marine Invertebrates	Cushing	Doll	2,351	2,351	100.00%	44,911	31,767
Zoology	15	Entomology	Krell	Doll	3,342	4,531	73.76%	1,089,273	875,301
Zoology	16	Botany	Krell	Doll	76	76	100.00%	4,721	4,531
Zoology	17	Ornithology	Spellman	Doll	19,800	26,597	74.44%	57,536	57,182
Zoology	18	Eggs & Nests	Spellman	Doll	840	855	98.25%	6,946	6,946
Zoology	19	Mammals	Demboski	Doll	20,500	25,398	80.72%	21,885	21,832
Zoology	20	Parasites	Demboski	Doll	31	40	77.50%	10,883	1,454
Zoology	21	Amphibians and Reptiles	Demboski	Doll	195	331	58.91%	649	151
ZOOLOGY TOTAL					**47,718**	**60,795**	**78.49%**	**1,290,926**	**1,039,955**
Education Collections	22	Anthropology	Nash	Stephenson	1,481	1,481	100.00%	4,631	4,571
Education Collections	23	Biology	Demboski	Stephenson	4,640	4,640	100.00%	6,574	6,224
Education Collections	24	Geology	Hagadorn	Stephenson	192	192	100.00%	2,757	2,557

DEPARTMENT	COLL #	COLLECTION	CURATOR & PLAN AUTHOR	COLLECTION MANAGER	TOTAL CUBIC FEET USED (1/1/2022)[1]	AVAILABLE CUBIC FEET (1/1/2022)	% COLLECTION SPACE USED (including growth 1/1/2022)	OBJECTS IN COLLECTION = DOCUMENTED + BACKLOG (1/1/2022)	CATALOGUED SPECIMENS OR LOTS (1/1/2022)
Education Collections	25	Health Sciences	Garneau	Stephenson	243	243	100.00%	1,490	1,490
Education Collections	26	Museology		Stephenson	162	162	100.00%	58	58
Education Collections	27	Paleontology	Miller	Stephenson	382	382	100.00%	3,250	3,150
Education Collections	28	Space Sciences	Yu	Stephenson	80	80	100.00%	194	194
Education Collections	29	Scientific Instruments	Yu	Stephenson	-	-	100.00%	3	3
EDUCATION COLLECTIONS TOTAL					**7,180**	**7,180**	**100.00%**	**18,957**	**18,247**
Library & Archives	30	Rare Books	Bechhoefer	TBH	see total	see total	see total	2,525	2,525
Library & Archives	31	Archives	Bechhoefer	TBH	see total	see total	see total	39,721	39,721
Library & Archives	32	Image Archives	Bechhoefer	TBH	see total	see total	see total	188,406	188,406
Library & Archives	33	Archives Over-sized	Bechhoefer	TBH	see total	see total	see total	3,168	3,168
ARCHIVES TOTAL					**7,992**	**18,321**	**43.62%**	**233,820**	**233,820**
Library & Archives	34	Library Books	Bechhoefer	TBH	-	-	0.00%	29,962	29,962
Library & Archives	35	Library Periodicals	Bechhoefer	TBH	-	-	0.00%	5,960	5,960
LIBRARY TOTAL[2]					-	-	0.00%	35,922	35,922
				TOTAL	**168,451**	**231,293**	**72.83%**	**4,021,559**	**1,863,291**

[1]As Archival material and periodicals typically measured in linear feet, number of catalogue records used for these collections.
[2]The Library collections were packed for temporary closure in 2020, then the Library was permanently closed in 2021.

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.

Name	Curator Count	PhD	Beg Yr	End Yr	Title
Mason, John T.	1		1901	ca. 1909	managing curator (volunteer)
Ward, William S.	1		1905	1914	Curator, Mineralogy & Art
Oslar, Ernest J.	1		1908	1911	Curator of Entomology
Figgins, Jesse D.	1		1910	1935	Museum Director
Hersey, L.J.	1		1911	1912	Curator, Ornithology & Mammalogy
Hills, Richard C.			1911	1913	Honorary Curator, Geology
Hammer, Raymond H.	1		1914	1914	Acting Curator, Geology & Mineralogy
Hills, Richard C.	1		1914	1922	Honorary Curator, Geology & Mineralogy
Lincoln, Frederick C.	1		1914	1914	Acting Curator, Ornithology
Lincoln, Frederick C.			1915	1920	Curator, Ornithology
Bradbury, William C.	1		1918	1925	Honorary Curator, Oology
Howland, Frank	1		1919	1922	Asst. Cur., Geology & Mineralogy
Bailey, Alfred M.	1		1921	1926	Curator, Birds & Mammals/Birds
Howland, Frank			1923	1935	Curator, Geology & Mineralogy
Cook, Harold J.	1		1925	1927	Honorary Curator, Paleontology
Miller, F. Walter	1		1925	1935	Curator, Biology & Mammals
Cook, Harold J.			1928	1929	Curator, Paleontology
Nininger, Harvey H.	1	1	1930	1942	Curator, Dept. of Meteorites
Niedrach, Robert J.	1		1935	1946	Curator, Dept. of Birds
Bailey, Alfred M.			1936	1969	Museum Director
Brandenburg, Frederick G.	1		1936	1939	Asst. Cur. Dept. of Birds
Cross, Frank Clay	1		1936	1938	Honorary Curator, Dept. of Entomology
Howland, Frank			1936	1937	Curator Emeritus, Geology
Markman, Harvey C.	1		1936	1948	Curator, Dept. of Geology
Wormington, H. Marie	1	1	1936	1940	Curator, Dept. of Archaeology
Mantz, Charles A.	1	1	1938	1943	Curator, Asiatic Anthropology
Holmes, Elizabeth B.	1		1939	1942	Assoc. Cur. Dept. of Archaeology
Brandenburg, Frederick G.			1940	1946	Assoc. Cur. Dept. of Birds
Wormington, H. Marie			1940	1945	Honorary Curator, Dept. of Archaeology
Nininger, Harvey H.			1943	1945	Honorary Curator, Dept. of Meteorites
Van Riper, Walker	1		1943	1949	Curator, Dept. of Spiders
Wormington, H. Marie			1945	1968	Curator, Dept. of Archaeology
Niedrach, Robert J.			1947	1948	Curator, Dept. of Zoology, Div. of Birds
Rogers, Albert C.	1		1948	1958	Curator, Div. of Mammals
Markman, Harvey C.			1949	1954	Curator, Dept. of Geology & Paleontology

Name	Curator Count	PhD	Beg Yr	End Yr	Title
Niedrach, Robert J.			1949	1967	Asst. to the Director & Curator Dept. of Zoology, Div. of Birds
Van Riper, Walker			1950	1959	Curator, Div. of Insects & Spiders
Brandenburg, Frederick G.			1955	1969	Curator, Library & Publications
Markman, Harvey C.			1955	1955	Curator Emeritus, Geology & Paleontology
Roberts, John	1		1955	1955	Curator, Dept. of Geology & Paleontology
Markman, Harvey C.			1956	1968	Curator Emeritus, Dept. of Geology
Murphy, John A., Jr.	1		1956	1956	Acting Curator, Geology
Van Nattan, William R.	1		1956	1958	Curator, Planetarium
Murphy, John A., Jr.			1957	1966	Curator, Dept. of Geology
Tyeryar, W.H.	1		1958	1958	Assoc. Cur. Div. of Insects & Spiders
Brunquist, Ernest H.	1		1959	1959	Honorary Curator, Dept. of Botany
Neal, Arminta P.	1		1959	1971	Curator, Dept. of Graphic Design
Samples, Robert E.	1		1959	1961	Curator, Planetarium
Wichers, Henry C.			1959	1969	Curator, Div. of Mammals
Brunquist, Ernest H.			1960	1968	Curator, Dept. of Botany
Lunetta, Donald M.	1		1962	1969	Assoc. Curator, Planetarium
Wright, Robert R.	1		1963	1971	Curator, Photography
Mitchel, D.H.	1		1965	1966	Curator, Div. of Mycology
Cajori, Florian A.	1		1967	1978	Honorary Curator, Dept. of Geology
Crane, Francis V.	1		1968	1968	Honorary Curator, Dept. of Ethnology
Crane, Mary W.A.	1		1968	1971	Honorary Curator, Dept. of Ethnology
Murphy, Jack A.	1		1968	1968	Asst. Curator, Dept. of Geology
Nelson, Martha C. (a.k.a. Martha N. Hartmann)	1		1968	1968	Asst. Curator, Planetarium
Niedrach, Robert J.			1968	1969	Curator, Dept. of Zoology
Akerley, Robert L.	1		1969	1974	Asst. Curator, Dept. of Graphic Design
Brunquist, Ernest H.			1969	1978	Honorary Curator, Dept. of Botany
Crockett, Charles T.	1		1969	1970	Curator, Dept. of Paleontology
Murphy, Jack A.			1969	2004	Curator, Dept. of Geology
Nelson, Martha C. (a.k.a. Martha N. Hartmann)			1969	1978	Curator, Dept. of Education
Noel, Karen A. (a.k.a. Karen Wadell)	1		1969	1979	Asst. Curator, Planetarium
Peterson, Mark B.	1		1969	1982	Curator, Planetarium
Raymond, Susan Grant	1		1969	1971	Curator, Dept. of Anthropology, Div. of American Ethnology
Smith, Dorothy K. (a.k.a. Dorothy K. Hodgkins)	1		1969	1978	Asst. Curator, Education
Bailey, Alfred M.			1970	1978	Director Emeritus

Name	Curator Count	PhD	Beg Yr	End Yr	Title
Brandenburg, Frederick G.			1970	1970	Curator, Dept. of Public Services
Crockett, Charles T.			1970	1970	Curator, Dept. of Conchology
Eastman, William R., Jr.	1		1970	1971	Curator, Dept. of Natural History Exhibits
Morrison, Pauline A.	1		1970	1983	Honorary Curator, Dept. of Conchology
Niedrach, Robert J.			1970	1970	Asst. Director & Ecologist and Curator of Biology
Woods, Charles A.	1		1970	1970	Honorary Curator of Mammals and Birds
Brandenburg, Frederick G.			1971	1980	Curator Emeritus
Lindsey, K. Don	1		1971	1974	Asst. Curator, Paleontology Division
Putnam, Jack D.	1		1971	1973	Curator, Natural History Exhibits
Thatcher, Donald A.	1		1971	1980	Honorary Curator, Ornithology
Wichers, Henry C.	1		1971	1972	Curator, Mammals & Zoological Preparation
Neal, Arminta P.			1972	1974	Curator, Dept. of Anthropology/Graphic Design
Wright, Robert R.			1972	1974	Curator, Photography & Manager of Auditoriums
Herold, Joyce	1		1973	1974	Asst. Curator, Anthropology/Graphic Design
McCann, Leonard	1		1973	1975	Asst. Curator, Dept. of Interdepartmental Projects and Sculptural Restorations
Webb, Elizabeth A.	1		1973	1973	Acting Curator, Dept. of Special Collections
Wichers, Henry C.			1973	1974	Curator, Mammals & Dept. of Interdepartmental Projects and Sculptural Restorations
Putnam, Jack D.			1974	1975	Curator, Dept. of Natural History
Webb, Elizabeth A.			1974	1975	Curator, Zoological and Special Collections
Akerley, Robert L.			1975	1980	Asst. Curator, Anthropology Exhibits
Herold, Joyce			1975	1989	Curator, Anthropology
Lindsey, K. Don			1975	1984	Curator, Paleontology
Stowe, Stephanie H. (a.k.a. Stephanie Chase and Stephanie C. Haas)	1		1975	1984	Librarian
Wichers, Henry C. (a.k.a. Henry C.W. Inchumuk)			1975	1978	Curator, Interdepartmental Sculptural Restorations
Wright, Robert R.			1975	1982	Curator, Photography & Manager Lecture Series
Webb, Elizabeth A.			1976	1979	Curator, Dept. of Zoological Collections
Dines, Dorothy	1		1977	1977	Honorary Curator, Pre-Columbian Collections
Haglund, Kristine A.	1		1977	Present	Archivist
Smith, Dorothy K. (a.k.a. Dorothy K. Hodgkins)			1979	1984	Curator, Education
Smith, Ronda B. (a.k.a. Ronda Barlow)			1979	1979	Asst. Curator, Photography
Wichers, Henry C.			1979	1980	Curator Sculptural Projects and Taxidermy
Kloverstrom, Karen R.	1		1980	1981	Asst. Curator, Education
Seyfarth, Paisley A.	1		1980	1981	Curator, Zoological Collections

Name	Curator Count	PhD	Beg Yr	End Yr	Title
Withers, C.E.	1		1980	1981	Honorary Curator, Mineralogy
Akerley, Robert L.			1981	1984	Asst. Curator, Anthropology
Chase, Charles A., III	1		1981	1982	Curator, Zoological Collections
Ledgerwood, Kristy K.	1		1981	1984	Asst. Curator, Education
Chase, Charles A., III			1982	1984	Curator, Ornithology
Sessions, Larry	1		1982	1983	Acting Curator, Planetarium
Webb, Elizabeth A.			1982	1991	Curator, Zoology
Clancy, Elizabeth H.	1		1983	2006	Photo Archivist/Image Archivist
Cobban, Robert R.	1		1983	1983	Acting Curator, Mineralogy
Herold, Joyce			1982	1988	Chief Curator
Wright, Robert R.			1983	1984	Curator, Photography
Cobban, Robert R.			1984	1984	Curator, Mineralogy
Wallace, Robert	1		1984	1987	Director, Planetarium
Day, Jane S.	1	1	1986	1993	Curator, Archaeology
Meaney, Carron A.	1	1	1985	1991	Curator, Mammalogy
Stone, Barbara	1		1985	1989	Curator, Anthropology Collections
Cobban, Robert R.			1986		Acting Curator, Mineralogy
Stacey, Peter B.	1	1	1986		Curator, Ornithology
Bourcier, David W.	1		1987	1989	Asst. Curator, Anthropology
Day, Jane S.			1988	1995	Chief Curator
Wallace, Robert			1988	1993	Manager, Planetarium
Stucky, Richard K.	1	1	1989	1995	Curator, Paleontology
Wood, Cindy	1		1989	1991	Asst. Curator, Archaeology
Wormington, H. Marie			1989	1994	Curator Emeritus, Archaeology
Herold, Joyce			1989	2005	Curator, Ethnology
Preston, Charles R.	1	1	1990	1998	Curator, Ornithology
Johnson, Kirk R.	1	1	1991	1992	Assoc. Curator, Paleontology
Pickering, Robert B.	1	1	1991	1999	Curator, Anthropology
Gully, Katherine B.	1		1992	2012	Librarian
Jones, Cheri A.	1	1	1992	2003	Curator, Mammalogy
Dixon, E. James	1	1	1994	2000	Curator, Archaeology
Johnson, Kirk R.			1993	2004	Curator, Paleontology
Peigler, Ric	1	1	1993	1996	Curator, Entomology
Asquin, Don	1		1994	1998	Manager, Planetarium
Day, Jane S.			1996	2003	Curator, Latin American Archaeology
Graham, Russell W.	1	1	1996	2003	Curator, Paleontology
Stucky, Richard K.			1996	2001	Chief Curator
McBrinn-Howard, Maxine	1		1997	1997	Asst. Curator, Archaeology

Name	Curator Count	PhD	Beg Yr	End Yr	Title
Cushing, Paula	1	1	1998	Present	Curator, Entomology & Arachnology; Invertebrate Zoology
Danly, Laura	1	1	1999	2003	Curator, Space Sciences
Celaya, Michael	1	1	2000	2001	Curator, Earth & Planetary Science
Ramey, Rob Roy	1	1	2000	2005	Curator, Zoology
Ray, Ella Maria	1	1	2000	2006	Curator, Anthropology
Carpenter, Kenneth	1	1	2002	2010	Curator, Paleontology
Graham, Russell W.			2002	2004	Chief Curator
Holen, Steven	1	1	2002	2013	Curator, Archaeology
Lee, Steven	1	1	2002	2016	Curator, Planetary Science
Day, Jane S.			2004	2016	Curator Emerita
Ivy, Logan	1	1	2004	2006	Acting Curator, Geology
Johnson, Kirk R.			2004	2012	Chief Curator
Murphy, Jack A.			2004	Present	Geology Curator Emeritus
Yu, Ka Chun	1	1	2004	Present	Curator, Space Sciences
Stucky, Richard			2005	Present	Curator Emerita
Coughlin, Bridget	1	1	2005	2016	Curator, Health Science
Herold, Joyce			2005	Present	Ethnology Curator Emerita
Wilson, Greg	1	1	2005	2007	Curator, Vertebrate Paleontology
Coughlin, Bridget			2006	2009	Deputy Chief Curator & Curator, Health Science
Demboski, John	1	1	2006	Present	Curator, Vertebrate Zoology
Grinspoon, David	1	1	2006	2013	Curator, Astrobiology
Morgan, Paul	1	1	2006	2008	Curator, Geology
Nash, Steve	1	1	2006	Present	Curator, Anthropology
Koelling, Jill	1		2007	2007	Image Archivist
Krell, Frank	1	1	2007	Present	Curator, Entomology
Colwell-Chanthaphonh/Colwell, Chip	1	1	2007	2020	Curator, Anthropology
Payne/O'Connell, René	1		2008	2020	Image Archivist
Miller, Ian	1	1	2008	2021	Curator, Paleontology
Levine, Marc	1	1	2009	2012	Assistant Curator, Mesoamerican Archaeology
Garneau, Nicole	1	1	2009	2019	Curator, Health Sciences
Hagadorn, James "Whitey"	1	1	2010	Present	Tim and Kathryn Ryan Curator of Geology
Sertich, Joseph	1	1	2011	Present	Curator, Vertebrate Paleontology
Koons, Michele	1	1	2013	Present	Curator, Archaeology
Lyson, Tyler	1	1	2014	Present	Curator, Vertebrate Paleontology
Spellman, Garth	1	1	2015	Present	Curator, Ornithology
Krause, David	1	1	2016	Present	Curator, Vertebrate Paleontology
Baxter, Erin	1	1	2020	Present	Curator, Anthropology (Acting)
TOTAL	**112**	**41**			