



Museums for America

Sample Application MA-259311-OMS-26
Project Category: Collections Stewardship and Access

University of Colorado, University of Colorado Museum of Natural History

Amount awarded by IMLS:	\$234,345
Amount of cost share:	\$234,353

The University of Colorado Museum of Natural History will improve storage conditions and long-term care for its vertebrate collections. The museum will hire a specimen preparator and engage two graduate assistants and a graduate intern to assist the senior collections manager in the implementation of project activities. Project activities will involve processing 642 backlogged tissue specimens, including birds, mammals, reptiles, and amphibians, to meet appropriate curation standards. The museum will purchase both a walk-in and ultracold freezer to improve storage conditions for study skins, hides, fluid-preserved specimens, skeletons, and wings. The project will generate approximately 1,900 new tissue samples, more than doubling the current volume of existing genetic resources, making the specimens more readily available to research and educational communities, government agencies, conservation organizations, and public audiences.

Attached are the following components excerpted from the original application.

- Narrative
- Schedule of Completion
- Digital Products Plan

When preparing an application for the next deadline, be sure to follow the instructions in the most recent Notice of Funding Opportunity for the grant program to which you are applying.

A Frozen Focus: Addressing Specimen Backlogs and Tissue Preservation Inadequacies within the University of Colorado Museum of Natural History's Vertebrate Collection

PROJECT JUSTIFICATION

Summary. The University of Colorado Museum of Natural History (UCM) Vertebrate Collection seeks \$234,345 for a two-year project to improve the frozen environment for its tissue collection and to make accessible its unprocessed frozen specimen backlog, a data-rich resource that is currently untapped. Funds will support the hire of a museum specimen preparator to aid staff in processing valuable backlogged specimens for installation into the permanent research archives, including birds, mammals, reptiles, and amphibians. This will result in approximately 642 new specimens preserved as study skins, hides, fluids, tissues, skeletons, and spread wings that fill taxonomic gaps and broaden the utility of the collection through generating a diversity of standard and alternative specimen preparation types. Additionally, purchase of an ultralow freezer (-80C) will improve the organization and preservation of tissues associated with these specimens, enabling the transition from a relatively short-term preservation methodology (ethanol) to stable deep-freezing. Upgrading tissue management while simultaneously processing the frozen specimen backlog is essential, as the project will generate approximately 1900 new tissue samples, more than doubling the current volume of existing genetic resources. **Ultimately, these efforts will modernize the UCM tissue collection environment to meet best practice curation standards and make currently inaccessible specimens available to our audiences, including the biodiversity research and educational communities, government agencies, conservation organizations, and the general public.**

Program Objectives. This project will support the IMLS Collections Stewardship and Access goal of advancing the management and care of collections and their associated documentation through improving the frozen collections environment, preparing acquired specimens, as well as cataloging, labeling, housing, location tracking, databasing, and making accessible newly processed collections (objectives 3.1 [primary], 3.2, and 3.3).

Specimen Backlog

Overview. UCM was founded in 1902 and maintains over five million objects that document and support the investigation of flora and fauna from Colorado, the Rocky Mountains, Great Plains, and surrounding regions. From salamanders to songbirds to bison, the Vertebrate Zoology unit houses approximately 130,000 specimens dating from the mid-19th century to present and continues to build collections through broad spatial and temporal sampling to promote a deeper understanding and appreciation of our regional natural history and biodiversity via scientific study and museum programming. To actively grow this important archive, we conduct field work and partner with federal, state, and local agencies to transfer deceased wildlife to the museum for long-term preservation. Incoming collections are placed into frozen storage and await preparation as fluid-preserved specimens, study skins, hides, skeletons, spread wings, and tissue samples by staff (Collection Manager Emily Braker and a Graduate Assistant). However, despite weekly preparation sessions, an **inherited specimen backlog persists that prevents these unprocessed collections from being accessible to our target audiences, including researchers, educators, students, faculty, government agencies, and the public.**

Significance. A detailed freezer inventory performed in May 2025 identified **642 frozen carcasses awaiting preparation:** 479 birds, 87 reptiles and amphibians, and 76 mammals. These specimens date from 2008 to present and range in size and type from hummingbirds and rattlesnakes to owls and bears and include irreplaceable endangered and threatened species. Some of these individuals represent species not yet deposited in the Vertebrate Collection, and once prepared, **will expand the catalog and taxonomic breadth of our holdings for stakeholders to access and study.** Others **add important temporal and spatial diversity**, as each specimen serves as a unique snapshot of the specific historical and ecological context from which it was sourced. Continually building a taxonomic series sampled through space and time is a critical practice in creating an unbroken biological record for collection users to compare the conditions of the past with those of the present. Like other biological collections, those at UCM facilitate critical studies on evolutionary processes, species distributions, environmental shifts, and emerging diseases (Suarez and Tsutsui 2004). Therefore, preparing the unprocessed backlog **will provide missing specimen resources in the collection and increase the depth of exemplars available for such longitudinal and retrospective research.** The backlog also takes up freezer space, which **hampers UCM's ability to accept incoming material** (particularly larger fauna), **constraining the mission-driven work of regularly augmenting collections, archiving life on Earth, and capturing valuable data about our natural world.**

Frozen backlogs are standard in vertebrate collections due to the time-intensive nature of processing specimens (*Supporting Document 1*). For instance, even something as small as a chipmunk requires a few hours to properly skin, clean, stuff, and sample tissues; a few days to a week for dermestid beetles to process the extracted carcass; a minimum of 72 hours to freeze and decontaminate the skeleton post-beetle colony; another 2-4 days to degrease, rinse and dry the bones; followed by a few hours to label each element with a catalog number (~200 bones per skeleton). **This intensity scales considerably for larger taxa**, with a mountain lion or deer requiring a team of 4-5 people a full day to prepare; 1.5-3 months to beetle-process; 2-8 weeks for cleaning and soaking bones; and roughly a half-day for numbering the skeleton. Although Project Director (PD) Emily Braker and a half-time Graduate Assistant (GA) prioritize preparing specimens one day per week, their effort does not keep pace with the rate of incoming collections given the volume of the *inherited* backlog and the considerable range of specimen sizes, which is directly proportional to processing effort. Therefore, **hiring a skilled Specimen Preparator and dedicated Summer Interns to help staff eliminate the backlog would provide invaluable support to actively address the accumulated inventory and make these important collections rapidly accessible** for research, education, exhibits, and outreach. Once cleared, UCM staff will be able to *sustainably* keep pace with the rate of specimen acquisition (20-70 specimens/year) through weekly preparation sessions.

Proactive Specimen Processing. Further, a preparator is needed **to mitigate the current specimen degradation process**, which gradually occurs over time, even within a frozen environment. Carcasses are slowly dehydrated and oxidized in the freezer while they await processing, changing cell structure, deteriorating DNA, and causing freezer burn, making it difficult to prepare skins and tissues the longer a specimen is frozen (McLaren et al. 2008). Exposed anatomy like tails and feet become brittle and immobile when thawed, and the skin adheres to dehydrated muscles. This makes skin extremely prone to tearing when attempting to separate it from underlying structures, causing irreversible damage to preparations. When properly double-bagged and sealed, carcasses are stable for a few years in the freezer; however, deterioration is typically notable after 3-5 years, and even faster for specimens too large for bags that are directly exposed to air (e.g., elk, bighorn sheep). Thus, **processing the backlog as soon as possible is essential for generating the highest-quality specimens, and allowing for the most preparation type options** (i.e., a badly freezer-burned specimen might only be successfully prepared as a skeleton versus as a complete study skin with accompanying skeleton and tissues). Therefore, a conundrum exists for staff: the desire to prepare specimens that have been waiting in the freezer the longest to curtail this degradation process, versus the appeal of preparing newly deposited fresh specimens that will be easier to process, yield the highest-quality specimens and tissue samples, and entirely avoid the risk of deterioration. **Hiring a preparator will eliminate this paradox; by concentrating on clearing the existing specimen backlog, time will be freed up for UCM staff to proactively process incoming specimens both during and after the proposed project's completion.**

Backlogged collections are also vulnerable to freezer failure and power outages, which can result in significant loss and degradation. In the past twelve years, UCM has experienced four walk-in freezer meltdowns, necessitating rapid coordination to move thawing specimens into temporary freezer storage. The most recent equipment failure in June 2025 left three staff scrambling for an entire day to locate sufficient distributed space across campus to fully absorb the high-volume specimen backlog (nine standard freezer units), which included taxa that were challenging to accommodate due to their large size, such as mountain lions, coyotes, and cranes. By purposefully tackling the specimen backlog, **the scale of inevitable future freezer emergencies will be more limited** and can be managed with in-house back-up solutions, additionally reducing the overall risk of high-volume catastrophic loss from thawing. Hiring a preparator to fully process the specimen backlog **will move us out of our current reactive position and allow us to implement workflows that target efficiently processing incoming collections within a 1-2 year window and avoid backlogs altogether.**

Organization & Efficiency. Finally, the specimen backlog occupies a large footprint, spanning a 512 cubic foot walk-in freezer and a 14.8 cubic foot chest freezer (*Supporting Document 2*). Shelving is limited within the walk-in freezer and frozen carcasses have overflowed onto the floor, making it difficult to walk, much less roll a cart inside. Although primarily employed by the Vertebrate section, the walk-in freezer is shared with other museum departments (Anthropology, Entomology, Exhibits), as it is the sole equipment capable of providing preventative freezing and integrated pest management (IPM) treatments for incoming bulk material and large-format objects. Unsurprisingly, these other units find sharing the freezer with frozen carcasses unappealing, and the crowded nature within the walk-in freezer makes access and use difficult, forcing staff to constantly rearrange material on the floor to create space. As part of the project's cost share commitment, UCM would **invest in steel shelving outfitted with tote bins to increase vertical storage space and improve organization within the freezer.** Totes would allow staff to arrange specimens by type, size,

and priority and provide secondary containment for most carcasses. While not completely physically isolated, establishing dedicated space within the freezer for ‘clean’ museum objects to simultaneously undergo IPM treatment while segregated from biohazardous material **would create more sanitary and safe conditions for cataloged collections.**

Strategic Specimen Preparation. While carrying out this project, staff will **strategically identify and prepare frozen collections that fill taxonomic and preparation gaps and expand preparation types that extend specimen utility.** Using the freezer inventory to cross-reference species cataloged in the collection’s online database, Arctos, PD Braker will evaluate multiple data points to direct the Specimen Preparator in determining the processing pipeline for each individual specimen present in the freezer (*Supporting Documents 3, 7*). This includes verifying the year that the last individual of a given species was cataloged into the collection. A *standard* preparation will be generated for any specimen that has not been incorporated into the collection within the last five years (i.e., mammals and birds will be made into study skins and skeletons, while reptiles and amphibians will be fluid-preserved). However, *alternative* preparation types will be made for common or recently collected species acquired within the last five years (i.e., birds and mammals will be fluid-preserved, while herpetofauna skeletonized). These alternative preparation types represent a growing portion of museum collections. For example, mammals and birds are historically dry-preserved as skins and/or skeletons (Hangay and Dingley 1985). However, emergent museum technologies such as CT scanning and non-traditional (non-systematist) collections users such as parasitologists are starting to change the age-old practice of discarding the internal soft-tissue anatomy during specimen processing (Blackburn et al. 2024). Recent trends instead favor retaining internal organs so that they can be made available for future examination or non-invasively visualized and “virtually dissected” using computer imaging techniques (Boyer et al. 2016). Rethinking specimen preparation to include preserving as much of an organism’s anatomy as possible has compelling applications beyond providing a wealth of novel morphological information and increasing the amount of observable traits, such as exploring ecological relationships happening within the specimen (e.g., parasites, viruses, and diet items), or investigating environmental toxins harbored within the body (e.g., mercury, microplastics) that can impact wildlife conservation and human health (Cook et al. 2016). Similarly, avian spread wings are a relatively new preparation type in ornithological collections that allow for observation of the flight feathers, which are typically obscured on a traditional study skin due to the wings being folded and dried in place (Winker 2000). Spread wings provide insights into molt limits (age), wing-aspect ratios (power), color, and patterning (Webster 2017). On the other hand, osteological preparations represent a fairly small proportion of reptile and amphibian collections (Simmons 2022), and generating skeletons can help fill this gap, especially when backlogged specimens are particularly old and freezer-burned and not suitable for fluid-preservation. By strategically processing specimens with the aid of a Specimen Preparator, we will not only **eliminate the backlog but also fill taxonomic, spatial, and temporal gaps in our holdings, and make the UCM Vertebrate Collection more useful to broader participation by non-traditional users like paleontologists, epidemiologists, and toxicologists through adding novel alternative preparation types.** Distributing preparations across standard and alternative types will also ensure relatively even growth within our fluid, skin, and osteological storage spaces rather than over-burdening any one of these collection areas during the two-year project.

Improper Storage of Genetic Resources

Additionally, UCM lacks appropriate conditions for the long-term preservation of specimen tissues. Advances in the realms of genetics and virology over the last three decades allow scientists to analyze DNA and viruses preserved in specimen tissues, enabling nearly limitless studies on evolutionary relationships and epidemiology, including tracking the spread of harmful pathogens that impact both animal and human populations (Suarez and Tsutsui 2004). As a result, it is now a standard practice to **preemptively remove and preserve tissue samples when processing biological specimens** (Phillips et al. 2019). This has the added benefit of extending the longevity of physical specimens through **reducing the destructive sampling of collections.** By specifically allocating and setting aside tissue for consumptive analysis during the initial preparation process, cataloged specimens are spared from future irreversible damage caused by invasive subsampling (e.g. clipping skin, toepads, tails, ears). Started twelve years ago, the UCM tissue collection is currently preserved in 95% ethanol. While pure ethanol is an acceptable preservative for tissues, it is considered a relatively short-term solution (2–10 years) (Nagay 2010). Ethanol storage is inferior when compared with deep-freezing methods such as ultralow temperatures (-80C) or liquid nitrogen that preserve samples over decades-long horizons that best align with museum preservation timelines. Deep-freezing prevents DNA from degrading by stopping biological activity and keeping cell structures intact for protein, DNA, RNA and viral analyses, and is a preferred method for museum sample storage (Nagay 2010). While liquid nitrogen is the gold-standard for preserving museological genetic resources, this method is

outside the project scope due to the financial resources, space, and permanent staffing requirements needed to safely run a cryogenic facility. However, preserving specimens in 95% ethanol within an ultralow freezer is a widely implemented strategy practiced by many major natural history institutions and biobanks around the world for long-term specimen storage (Yeates 2016), and would be a significant improvement over our existing ethanol-only preservation system.

UCM's tissue collection is now well-established and numbers over 1500 vertebrate samples. In processing the frozen backlogged material as proposed, the tissue collection would more than double in size given that heart, muscle, and liver samples are extracted from each specimen. Therefore, UCM is at a transition point to pursue better long-term tissue storage. **This recommendation was also formally counseled by the American Society of Mammalogist (ASM) Systematic Collections Committee** during a site visit in 2024 (*Supporting Document 4*). While the UCM Mammal Collection was officially reaccredited, the committee deferred to certify the genetic resource collection pending upgrades to a frozen storage system. We therefore request funds to purchase a Stirling Ultracold freezer with accompanying freezer box racks to satisfy this remit (*Supporting Document 5*). The unit has a footprint compatible with our space and can accommodate 72 standard freezer boxes (7200 samples), granting us >15 years of growth storage capacity, and is stackable should we eventually add another unit. A built-in event log, alarm, and lack of a compressor (less maintenance) are also desirable features. Securing this caliber of equipment has been a long-term curation goal, and our existing tissue samples were transferred to cryovials rated for ultra-low temperatures in 2017 in preparation for the eventual purchase of such a unit. This ultralow freezer **will drastically improve the tissue preservation environment, helping us meet best practice curation standards and directly enhance the longevity of these resources for future collections users.**

Relevance to UCM's strategic plan. This project advances UCM's strategic plan of serving as "a museum for the 21st century" in several ways (see *Strategic Plan Summary*). The plan calls for investments in key technologies, specifically tissues and DNA repositories to, "prepare for the collections of tomorrow." While we have initiated tissue sampling practices within the last 12 years, procuring an ultralow freezer would represent a major benchmark in achieving this goal and **align our genetic resource collection with best practice standards and ultimately facilitate cutting-edge molecular research.** Another strategic goal is to make collections more accessible to professional and lay audiences. Processing the frozen specimen backlog will unlock our currently inaccessible frozen specimens and their associated 'dark data' (Heidorn 2008), making them **physically and digitally accessible to more and diverse collections users**, including online audiences via multiple publicly accessible outlets: Arctos (our main data portal), and museum biodiversity data aggregator platforms: VertNet, iDigBio, and GBIF. When specimens are processed, valuable occurrence and trait data are recorded in Arctos and published online for immediate use by bioinformaticians and potential collection users interested in requesting the specimens for loan. Better preserved and more accessible collections will provide the raw data to enable another strategic objective of "tackling bold questions," such as addressing species responses to climate change, predicting biological invasions, studying the effects of pesticides on biodiversity, and other high-impact societal issues investigated by our own research faculty, students, and external user base. Eliminating the backlog will also align with unit-specific strategic goals to meet the recommendations put forth by the ASM accreditation committee which urged the processing of frozen specimens, noting that, "[they] are critical to establishing baselines for environmental change research...and there are many examples of catastrophic specimen loss due to freezer failures" (*Supporting Document 4*). Finally, a strategic goal within the museum's graduate Museum and Field Studies (MFS) program will also be met while conducting the proposed project: "fostering scholarship through hands-on experience." A Graduate Assistant (GA) will work closely with PD Braker and the hired Specimen Preparator to process specimens through established preparation, cataloging, and digitization workflows (see *Project Work Plan* section), gaining critical practical experience for their future as a museum collection manager. Graduate assistantships are funded positions for MFS students, who receive tuition remission and a stipend in exchange for a 0.5 FTE appointment in a collection as part of their applied museum studies schooling. Additionally, this project will also initiate our first paid Graduate Internship offering to students enrolled in museum studies programs around the country, offering two unique opportunities (summers Y1 and Y2) for emerging professionals in the field to learn transferable specimen preparation skills (see *Project Work Plan* section).

Beneficiaries. This project would make nearly 650 specimens with 1900 accompanying tissues physically and digitally accessible to our user communities. Researchers, such as taxonomists, biologists, conservationists, and morphologists form a major stakeholder base and actively use our specimen resources during in-person visits and via specimen loans. As mentioned above, the creation of alternative specimen preparation types during this project would additionally expand participation by non-traditional collections users, such as paleontologists, parasitologists, and toxicologists. By generating

tissue samples, we will also increase the availability of genetic resources to investigators specializing in molecular research disciplines. Specimens and occurrence data will be used by agency collaborators that have transferred or repositied currently frozen collections at UCM, including Colorado Parks and Wildlife, Boulder County Open Space and Mountain Parks, and the National Park Service, as well as taxonomically-focused organizations like Colorado Partners in Reptile and Amphibian Conservation. Data associated with specimens processed during this project (taxonomic, geographical, temporal, and traits such as sex, life stage, reproductive status, and measurements) will be captured and made available to online audiences through publication in our Arctos data portal and shared with global data aggregators. We will also create publicly accessible webpages within Arctos for each wildlife agency donor to easily view and track collated information about the specific specimens that they have transferred to the museum (see *Digital Products Plan*). These metrics will grant agencies the ability to easily monitor how these specimens are used over time, including loan, publication, media, and download statistics, providing a valuable tool for tracking impacts. In addition to serving the research community, specimen data from this project can be used by educators and students in biodiversity and informatics fields, and vouchers generated by this project will be heavily utilized by the CU campus community through direct incorporation into faculty and student research projects across the arts and sciences (dissertations, theses, capstones), exhibits at the museum, specimen-based courses (archaeozoology, mammalogy, ornithology, herpetology), as well as integrated into programming activities with the public through outreach and behind-the-scenes tours.

PROJECT WORK PLAN

Project Team and Responsibilities. Collection manager Emily Braker will serve as the project director (PD) to plan and guide project activities and manage personnel (*Specimen Preparator, Graduate Assistant, Graduate Interns*). A full-time Specimen Preparator will be hired to process backlogged specimens according to best practice standards (Hangay and Dingley 1985, Phillips et al. 2019, Simmons 2022, Winker 2000). The preparator will also be responsible for supervising a Graduate Intern specializing in specimen preparation (cost share) for each of the two summers that the project runs. One day per week, PD Braker and a Graduate Assistant (GA) will prepare specimens alongside the Specimen Preparator in order to meet project goals as well as aid the Specimen Preparator in processing large specimens that necessitate multiple people. The GA will additionally contribute time towards post-preparation curation tasks and integration of newly prepared specimens into the permanent collections such as cataloging, housing and databasing. Throughout the course of this project, both the GA and Graduate Interns will gain essential skills for working within a zoological collection.

Pre-grant (PD Braker, Graduate Assistant)

- Continue to accession incoming collections and prepare backlogged specimens at current pace (1 day/week).

Phase I (PD Braker)

- Write Specimen Preparator job description and recruit candidates through museum listservs and job boards.
- Order project equipment and supplies.
- Identify and map specimen preparation priorities (e.g., endangered or rare species) and preparation types using the freezer inventory spreadsheet and Specimen Preparation Type Decision Tree (*Supporting Documents 3, 7*). This includes targeted database queries for each species represented to see when specimens were last deposited in the collection in order to determine an individual's prep type trajectory (standard or alternative).
- Draft protocols and high-volume workflows for the Specimen Preparator and post-preparation curation steps for the Graduate Assistant. Such protocols will incorporate efficiency measures like batching fluid-preserved specimens by size in order to step through formalin and ethanol ladder phases at the same pace (transition from 0->20->40->60->70%), using shared chemical baths for skeletal material, and ensuring constant beetle colony throughput (see *Supporting Document 6* for general processing steps).

Phase II (PD Braker, Specimen Preparator, Graduate Assistant)

- Hire, onboard, and train Specimen Preparator (includes completing mandatory CU Environmental Health and Safety courses: General Biosafety, Chemical Safety and Hazardous Waste, and Bloodborne Pathogen trainings).
- Install purchased equipment (walk-in freezer shelving and totes, ultralow freezer), transfer and organize specimens into the new units based on size, type, priority, and preparation trajectory.
- Create a tissue tracking schema in Arctos using the object tracking module: set up a series of hierarchically nested containers (freezer, rack, box, position) and link to associated specimen records as tissues are processed.

- Prepare and process priority specimens: (i) endangered/threatened species, (ii) uncommon species and taxonomic gaps, (iii) species from outside of the Boulder-Denver metropolitan area and state of Colorado, and (iv) species not deposited in the collection within the past 5 years (see *Supporting Document 3*).
- Specimen curation: catalog, number, label, house, database, location track, and install processed specimens.

Phase III (PD Braker, Specimen Preparator, Graduate Assistant, Graduate Intern)

- Continue preparing and processing specimen backlog (common species, alternative prep types).
- Specimen curation: catalog, number, label, house, database, location track, and install processed specimens.

Administrative/Evaluation (PD Braker)

- Schedule and facilitate meetings with project team members.
- Manage payroll and track grant and cost-share expenditures.
- Quality-check all steps in the workflow and evaluate progress at regular intervals.
- Complete interim and final reports.

Access/Dissemination (PD Braker)

- Ensure that all specimen data (collecting info, occurrence data, trait measurements, etc.) are databased in Arctos for immediate access. All data will be additionally published to biodiversity data aggregators on a monthly basis (GBIF, iDigBio, VertNet).
- Submit an abstract for an oral/poster presentation to be delivered at the annual Society for the Preservation of Natural History Collections (SPNHC) meeting, June 2028.
- Publish an article highlighting the project in the CU Museum's member newsletter.
- Engage with UCM's community using museum social media channels.
- Create agency project webpages in Arctos that summarize holdings, occurrence, trait data, and preparation types for processed specimens collected and transferred from agency properties/employees and/or repositied collections, and communicate these resources with agency contacts. These pages will automatically track loan, media, download, and publication metrics for the individual specimens linked to each page.

Risk Mitigation. Complexity is a major component of this project given the large volume and the various preparation trajectories and timelines associated with each specimen awaiting processing (*Supporting Documents 1, 3, 6*). Therefore, it is essential to understand and track specimens moving through multiple task stages at different cadences (see below). Well-defined roles and responsibilities are critical for addressing this complexity as well as hiring an experienced preparator well-versed in processing large quantities of specimens into various preparation types. A collaborative team that tightly coordinates activities reinforces that no player will act independently, and that any issues that arise will be quickly identified and addressed. Should we find that we are falling short of described objectives, both PD Braker and the GA are able to dedicate more time to the project (cost share) to aid the Specimen Preparator in preserving and processing specimens. However, we believe that the creation of Graduate Intern positions (summers Y1 and Y2) will ensure that sufficient time and staff resources are available to complete the outlined project within the two-year timeframe.

Project Tracking and Evaluation. All team members will be responsible for logging activities, with ultimate progress monitored by PD Braker. Project tracking will be centralized within the master freezer inventory spreadsheet that lists every specimen using its freezer inventory number, with each major project activity documented and timestamped (e.g., when prepared, by whom, prep types generated, catalog number assigned, and confirmation that each specimen has been databased, see *Supporting Document 7*). Ultimately, performance will be evaluated against how many specimens were fully prepared, cataloged, and databased from this manifest, with the major objective being a complete processing of the existing frozen backlog. All activities will take place within the Vertebrate Collection preparation lab, where it will be straightforward to visually assess the workflow stage and status of specimens (soaking, drying, unnumbered, unlabeled, etc.). The team will meet biweekly to communicate progress, troubleshoot issues, and anticipate supply needs. The PD will quantitatively evaluate overall project progress quarterly to ensure that project objectives are being met.

Resources. UCM requests \$234,345 to: (i) hire a Specimen Preparator, including salary and fringe benefits, (ii) purchase a Sterling Undercounter Ultralow Temperature Freezer (model SU105UE) outfitted with standard box racks to cryopreserve and organize existing and project-generated tissues, (iii) specimen preparation and curation supplies (e.g., processing

chemicals, scalpel blades, cryovials, skeleton boxes), and (iv) support conference travel to disseminate project activities. UCM will contribute \$234,353 in cost share, including: (i) UCM staff salaries for the Project Director (0.30 FTE) and Graduate Assistant (0.40 FTE) dedicated to the project, (ii) two 220-hour Graduate Intern summer stipends, and (iii) purchase of steel wire shelving and plastic totes to outfit the walk-in freezer to better organize frozen collections.

PROJECT RESULTS

Improved care, management and access. The major results of this project include newly processed and accessible vertebrate specimen collections and a significantly improved frozen storage environment for tissues, as well as refreshed organizational systems (e.g., walk-in freezer shelving, database location tracking). Processing backlogged specimens will halt the process of deterioration currently underway in the freezer and produce both standard and alternative preparation types that fill taxonomic, spatial, and temporal gaps in the collection. Diverse stakeholders will gain access to the physical specimens generated by this project and the constellation of associated data to ultimately advance knowledge, education, and foster public appreciation about the patterns and processes underlying vertebrate biodiversity. In addition, transforming the tissue preservation environment from ethanol to deep-freezing will extend the longevity of UCM genetic resources and align this collection with best practices. In conducting this project, a GA enrolled in the University of Colorado Museum and Field Studies program as well as two Graduate Interns will receive practical training in vertebrate specimen preparation and curation methods, directly preparing them for future careers in collections management and gaining irreplicable hands-on experience and knowledge transfer of time-honored specimen processing techniques.

Tangible products generated include:

- Processing approximately 642 vertebrate specimens into standard and high-utility alternative prep types that fill taxonomic, temporal, and geographic gaps in the UCM Vertebrate Collection.
- Cataloging, numbering, labeling, housing, databasing, and installation of newly processed collections.
- Immediate accessibility of processed specimen data to online audiences via Arctos, iDigBio, GBIF, and VertNet.
- Installation of a steel wire shelving and tote system within the walk-in freezer unit (organization, hygienic).
- Transfer of tissues into an ultralow freezer for improved long-term preservation.
- Creation of a hierarchical tissue sample location tracking schema in Arctos.
- Employment and training for four staff (Specimen Preparator, Graduate Assistant, Graduate Interns x 2)
- Dissemination activities: conference presentation, newsletter article, museum social media posts, and creation of agency donor project webpages that track usage, data products, and impacts (Arctos).

Sustainability. Limited staffing, the time-intensive nature of preparing specimens, and the sheer volume of an inherited specimen backlog dating back to 2008 have converged to impede meaningful progress in processing acquired UCM specimens. A common strategy for clearing backlogs is a project-based approach, and **the proposed activities will critically establish a new baseline for incoming collections and rectify the current specimen processing imbalance.** Rather than juggling the decision of whether to prepare long-frozen collections in order to halt deterioration processes at the expense of newer collections following the same path, hiring a Specimen Preparator will eliminate the accumulated backlog so that we can focus on the timely processing of newly acquired collections as they are accessioned. This has the added strategic benefit of reducing the risk of specimen loss in the face of future freezer failure by drastically decreasing the number of specimens awaiting processing, and thereby the volume of specimens in need of rapid relocation in the event of an emergency. **In fully clearing the specimen backlog, this project will serve as a collection-wide triage and reset and enable staff to maintain sustainable workflows that proactively process incoming collections and advance the benefits of this program into the future.** With the legacy backlog eliminated, PD Braker and future collection assistants will be able to sustain a steady processing pace with the current manageable rate of acquisitions (20-70 individuals/year) during their routine weekly preparation sessions. In working closely with a preparator, UCM staff and students will increase proficiency and knowledge through exposure to new skills, approaches, and tips from an expert that can be incorporated into existing and future practices. Further, the purchase of an ultracold freezer will not only accommodate existing tissue holdings as well as those generated by the project, but allow for an additional >15 years of growth and long-term preservation of this important collection. Ultimately, this project holistically addresses a major processing bottleneck and environmental shortcomings in the UCM Vertebrate Collection and will promote results that can be sustainably carried forward all while making valuable frozen collections accessible to our core user audiences.

FY26 MFA Collections Stewardship and Access | Schedule of Completion
University of Colorado Museum of Natural History (UCM)

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Digital Products

In the course of the proposed project, approximately 642 vertebrate specimens will be prepared and cataloged into the UCM Vertebrate Collection. As part of this process, their associated data will be captured as unique specimen records in our collection management system and public data portal, Arctos. This includes taxonomic identification and classification information, geographic occurrence data, measurements and biological attributes (age, sex, reproductive status, etc.) gleaned during the preparation process, preservation method, and ancillary information such as cause of death, injuries, and other curatorial notes. The Arctos data model is DarwinCore (DwC) compliant and uses DarwinCore exchange standards to package data. DwC archives and associated Ecological Metadata Language (EML) files will be automatically published monthly via the VertNet Integrated Publishing Toolkit (IPT), where they will be harvested by biodiversity aggregators such as the Global Biodiversity Information Facility (GBIF), VertNet, and the Integrated Digitized Biocollections (iDigBio) portal to share on a global scale. End users directly navigating the Arctos portal will be able to view specimen record updates in real-time.

At the end of the proposed project, we will also create publicly accessible Arctos Project pages for several government and wildlife conservation agencies who have transferred vertebrate material to the museum (e.g. Colorado Parks and Wildlife, Boulder County Open Space and Mountain Parks, Colorado Partners in Amphibian and Reptile Conservation, Rocky Mountain National Park, and Mesa Verde National Park). These webpages are integrated within the Arctos platform and are straightforward to set up. Each page will be titled with the relevant organization name and provide overview information. We will then attach corresponding specimen records to each page so that all specimens transferred from the organization to the museum will be viewable and easily explored as they are prepared and cataloged. Although an agency could theoretically use Arctos' main search interface to query all specimen records associated with their organization, Project pages save this step, create a shareable URL, provide space for summary text and images, and conveniently collate all specimen records collected by different people within the same organization for streamlining discovery. Eventually, products resulting from specimen usage such as loans, publications, or digital images and connected projects will be automatically tracked and populated on the associated webpage when any one of the child/dependency specimen records are updated. This allows agencies and other stakeholders to view the downstream impacts of their activities and is an incredibly valuable communication tool for our agency partners. It will also enable us to easily track and summarize specimen donations and transfers to the UCM Vertebrate Zoology collection from these organizations.

Availability

All specimen data and Project pages will be made available via the Arctos web portal (arctos.database.museum), a cloud-based platform. Records and projects can be freely queried and navigated, and data downloaded in table format with a user login. Specimen data will be further distributed to biodiversity data aggregator services, including GBIF (<https://www.gbif.org/>), VertNet (<https://www.vertnet.org/>) and iDigBio (<https://www.idigbio.org/>), for use and download by diverse end user communities.

Accessibility

Once ingested, UCM data will be made available on Arctos using a machine-readable CC-BY-NC Creative Commons license, which conveys that data can be freely used for any purpose provided that appropriate attribution is given, except for commercial uses (which would require a separate licensing agreement). Data will be packaged as DwC exports to biodiversity aggregators using this same license. All Arctos specimen records contain DwC triplets (UCM:[collection code]:[catalog number]) embedded

in the catalog record URL, which can be conveniently hyperlinked when citing records in publications or datasets. The UCM institutional identifier is registered with GRSciColl, ensuring that the triplet serves as a unique identifier for each specimen. End users can access Arctos' data policy for recommended data citation practices through the Arctos Consortium website. All UCM data will align with FAIR principles. In rare cases, some locality data may be redacted, such as precise coordinate locations of endangered or threatened species. In these limited cases, only county-level data will be made available online, with the ability for users to contact the collection to request more specific information. Such requests will be reviewed on a case-by-case basis to ensure that revealing precise collecting localities will support research rather than actively harm vulnerable populations.

The Arctos code is available on a public GitHub repository and released under an Apache 2.0 license, which allows for free and open access software use, distribution, and modification. The platform runs on an open-source PostgreSQL database with a Lucee-enabled interface.

Sustainability

All data generated by this project (specimen records, Project pages) will be maintained long-term in the Arctos Collection Management System. Arctos data are stored at the Texas Advanced Computing Center (TACC), a petascale cyberinfrastructure and decades-long Arctos partner. TACC provides security controls and web hosting for both Arctos data and media. TACC is a geographically replicated service that protects against hardware failure and catastrophic data loss events, with data, code, and database copies additionally saved on a secondary backup instance hosted at the University of California Berkeley. The UCM Vertebrate Collections have used Arctos as a collection management system for more than ten years, and in 2024, four additional UCM collections (Entomology, Invertebrate Zoology, Vertebrate and Invertebrate Paleontology) have started the process of migrating to the platform. This is an initiative supported by museum director Nancy Stevens to consolidate UCM data into a single system, gain efficiencies, and link connected data. Given the increasingly large role of data management and dissemination in the daily functioning of biodiversity collections, we view this migration as a long-term strategic solution and prioritize data accessibility as a core museum mission.

Drafts of social media posts and museum newsletters resulting from this project will be disseminated to UCM audiences via Facebook and Instagram and the museum member listserv. This content will be stored in the museum's News and Communications Archive on a dedicated museum server maintained by the University of Colorado Office of Information Technology for medium-term storage. This server is backed up on the cloud using Microsoft One Drive services.