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THE EFFECTS OF FREEZING ON FORMALIN PRESERVATION OF SPECIMENS OF FROGS AND SNAKES

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Abstract.—Fresh specimens of the wandering garter snake and northern leopard frog were killed and divided into three groups. One group was kept frozen and one kept under refrigeration for five days before preservation in 10% formalin. The remaining group was preserved shortly after killing. After four months of storage in preservative, there were observable differences in the quality of the specimen condition.

Collectors of reptiles and amphibians commonly bring their catch into the laboratory and kill and store it by freezing. The specimens spend variable amounts of time in the freezer during which they are not only subject to separation from their data and mechanical damage, but they may also be damaged by the freezing process. Standard guides to amphibian and reptile preservation techniques do not mention the practice of freezing specimens and its ultimate effects on the quality of the preserved material (Anderson, 1948; Duellman, 1962; Pisani, 1973; Pisani and Villa, 1974; Simmons, 1987). Over the years, we have come to believe that specimens, once frozen, can never be as satisfactorily preserved as those that have never been frozen. The chance availability of a number of snakes and frogs afforded us the opportunity to test this idea.

MATERIALS AND METHODS

On 11 December 1987, 34 adult wandering garter snakes (*Thamnophis elegans*, snout-vent lengths 399–518 mm) were killed by an injection of 0.4 ml of a 7 mg/cc water solution of sodium pentobarbital (Nembutal) in or near the heart. When dead, their snout-vent lengths (SVL) and tail lengths were measured, and they were individually tagged. Snakes of the same size and sex were subjected to a series of three treatments (Table 1).

The first set (the "fresh" series) was placed in double plastic bags in a refrigerator at 2°C. Eighteen hours later, the series was removed from the refrigerator and preserved in unbuffered 10% formalin. Slits 5 mm long were made with a scalpel every 10 mm in the ventral tail skin and muscle. Formalin was injected into the tails of males and the left hemipenis was partly everted. The tail was slit, the penial retractor muscle was severed, and the hemipenis was fully everted (Dowling and Savage, 1960). Twenty-five ml of formalin were injected into the body cavity and internal organs. Snakes were coiled four to a 900 ml jar and submerged in formalin.

The second set (the "refrigerated" series) was double-bagged and placed in the refrigerator at 2°C. The third set (the "frozen" series) was double-bagged and kept frozen at -15°C. On the fifth day after sacrifice, the frozen series was removed from the freezer, held at 23°C for 1 hour, and then placed in the refrigerator. Five hours later, both the frozen and refrigerated snakes were removed from the refrigerator, thoroughly mixed, and preserved in formalin by the protocol described above. At this time, both series appeared identical, and they were indistinguishable during the preservation process.

On 16 December 1987, seven adult northern leopard frogs (*Rana pipiens*, SVL 70–80 mm) were killed in a solution of hydrous chlorobutanol (Chloretone; Simmons, 1987; Table 1). The largest specimen was immediately injected with 3 cc of 10% formalin and floated in a tray of the same solution. The other six specimens were divided into two equal groups, double-bagged, and placed in either the freezer or the refrigerator (Table 1). Five days later the frozen frogs were removed from the

Table 1. Number and sex of wandering garter snakes and leopard frogs used in formalin preservation experiments. See text for descriptions of the preservation methods.

Species and sex	Preservation method		
	Fresh	After refrigeration	After freezing
<i>Thamnophis elegans</i>			
Males	2	4	4
Females	12	6	6
<i>Rana pipiens</i>			
Males	1	3	0
Females	0	0	3

freezer, held at 23°C for 3.5 hours, put in the refrigerator for 3 hours, and then preserved along with the refrigerated specimens. After 2–3 weeks of preservation, all of the specimens were removed from the formalin, soaked in water for 5 minutes, and placed in 40% (frogs) or 50% (snakes) isopropanol.

After storage in isopropanol for 1 year and 8 months, the SVL and tail lengths were remeasured. These measurements were compared among treatments and with the measurements made on the fresh specimens using a two-tailed Mann-Whitney *U* test. Differences were considered significant when $P < 0.05$.

RESULTS AND DISCUSSION

Figure 1, taken after 4 months storage in alcohol, shows that the frozen specimens were much more limp than either the fresh-preserved specimens or the specimens stored in the refrigerator. Soft, limp specimens probably are more likely to be damaged during use and may not last as long as harder specimens, which are flexible but not limp. Harder specimens hold their shape better and are not as likely to become entangled with other specimens in storage containers.

The snakes that had been frozen were considerably darker than the specimens subjected to other treatments (Figure 2). They were darker when they were first defrosted, and, even though all of the specimens have darkened some with time, those that were frozen were still recognizably blacker after almost 10 months storage in alcohol. All of the fresh-pickled and refrigerated snakes had pale chins and throats, a prominent dorsal stripe, and a head pattern that was almost the same color and intensity as in living specimens. The frozen specimens had black heads and throats and the middorsal stripe was obscure. Several of the frozen snakes had a green spot on the venter when they were defrosted, indicating that their gall bladder had burst. The hemipenes were equally well preserved, and the *stratum corneum* was still adherent to the epidermis in all specimens.

The frozen frogs were softer and grayer than the other specimens. The fresh and refrigerated samples retained some yellow pigmentation and their dorsolateral folds were distinctively brown colored, whereas the folds of the frozen frogs were gray like the rest of the dorsum. The toes and legs of the frozen specimens were somewhat twisted after defrosting, and they were too stiff to position properly during preservation. They were shedding epidermis.

Food scientists and fishing tournament consultants have documented a wide variety of changes in iced and frozen fish as compared to fresh ones (Mills, 1975; Bello *et al.*, 1981; Otwell *et al.*, 1982). Many of the changes were difficult to quantify, but those most pertinent to our interests were seen in histological ex-



Figure 1. *Top.* Preserved specimens of *Thamnophis elegans* suspended on a wall by a pin through the tag. Left to right: refrigerated, frozen, and freshly preserved. *Bottom.* Specimens of *Rana pipiens* suspended on a wall by a pin through the left foot. Left to right: fresh, refrigerated, and frozen preserved. Photographs taken 18 May 1988, after 4 months storage in isopropanol.

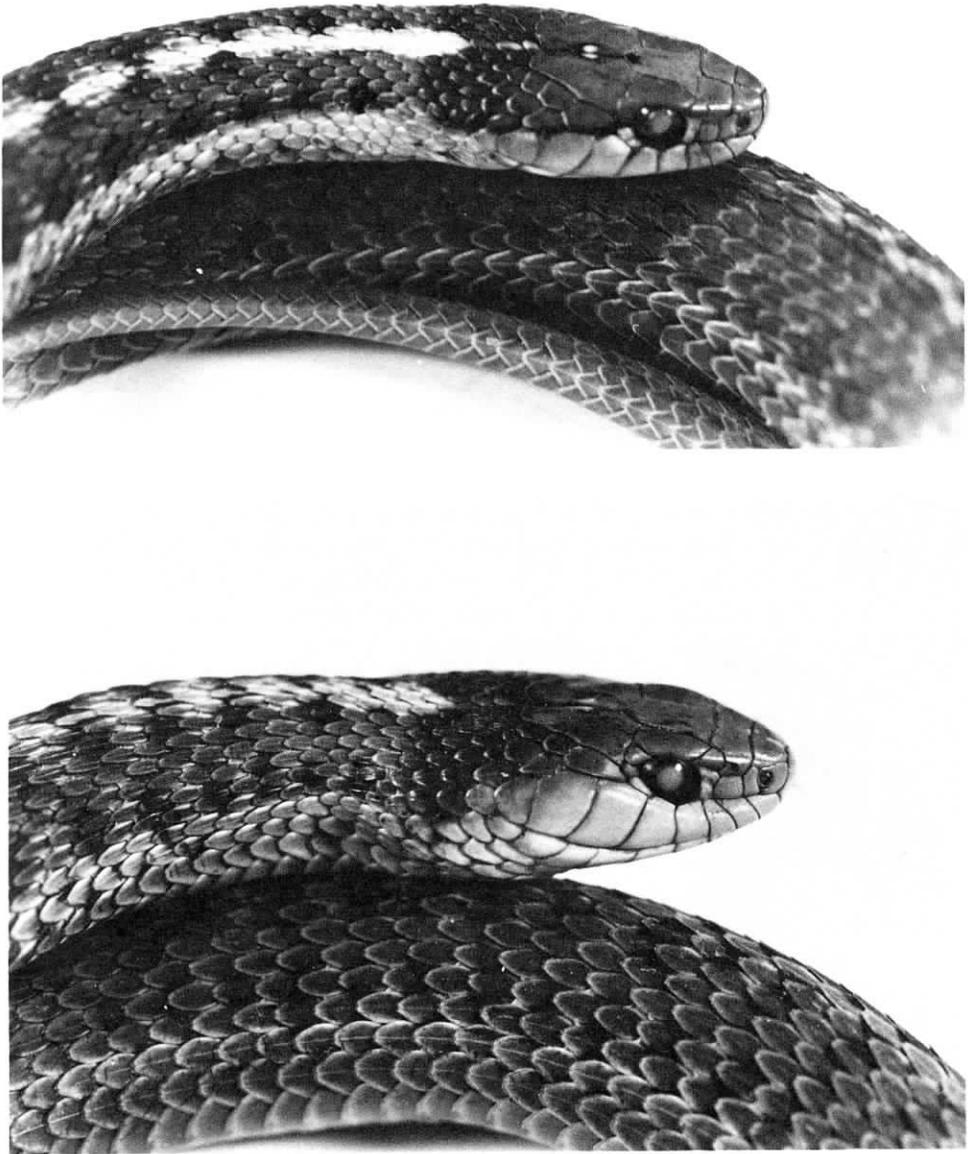


Figure 2. Preserved specimens of *Thamnophis elegans* after almost 10 months storage in isopropanol. *Top*. Fresh preserved. *Bottom*. Preserved after refrigeration. *Top-right*. Preserved after freezing. Photographs taken 3 November 1988.



(Figure 2, cont.)

aminations. Histological preparations of fresh and iced muscle tissues showed distinct, regularly arranged myofibers, intact sarcolemmas, and only minor intracellular artifacts; frozen muscle contained many irregularly shaped spaces about and within the myofibers and the sarcolemmas were disrupted and distorted. These changes were attributed to the physical damage caused by ice crystals (Ottwell *et al.*, 1982). The disruption seen at the cellular level was clearly translated into a loss of structural integrity at the level of the whole animal, resulting in limp specimens that did not completely harden in formalin. The cause of the darkening of specimens was not as clear, but was probably also a result of cell damage.

Garter snake measurements were generally 1–3% shorter in snakes preserved

Table 2. Changes in snout–vent and tail lengths of wandering garter snakes preserved after three different treatments compared to measurements of the freshly killed specimens. See text for description of treatments and preservation methods. Each cell of the table is significantly different from every other cell and from the same measurements made on freshly killed specimens, except the change in tail length is not different between refrigerated and fresh-preserved treatments. Changes in length are expressed in millimeters.

Treatment	Snout–vent length		Tail length	
	Range	Median	Range	Median
Fresh	–6 to –12	–9	+1 to –4	–2
Refrigerated	–5 to –10	–7	+1 to –2	–2
Frozen	+12 to –2	+7	0 to +4	+2.5

fresh or after refrigeration and 1–3% longer in frozen snakes when compared to measurements taken on freshly killed snakes (Table 2). Snout–vent lengths of snakes preserved fresh were also significantly shorter than those preserved after refrigeration. Frog SVL shrank 0–10%, but there did not appear to be any difference between treatments.

Our results showed clearly that pre-preservation freezing produces reptile and amphibian specimens that are softer than freshly preserved specimens. Frogs also tend to lose their epidermis. All of the preservation methods distorted the dimensions of the specimens, but the direction of the distortion was opposite in frozen specimens versus freshly preserved and refrigerated specimens. The question of the long-term stability of specimens handled in different ways is open, but there are clear observable differences over the short term.

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DOCUMENTATION GUIDELINES FOR THE PREPARATION AND CONSERVATION OF BIOLOGICAL SPECIMENS

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Abstract.—The importance of complete and accurate documentation of preparation and conservation treatments was stressed by Fitzgerald (1988) for the earth sciences, and is reiterated here for the life sciences. The guidelines presented herein represent an effort by the Conservation Committee of the Society for the Preservation of Natural History Collections to promote and standardize the documentation of specimen preservation methodologies, conditions, and treatments within natural science collections.

PREFACE

The following guidelines for biological specimens were adopted as a working document by the Conservation Committee and the SPNHC Council in July, 1989. These guidelines were drafted by Kimball L. Garrett along the lines of Fitzgerald's guidelines for earth science collections (Fitzgerald, 1988) and reviewed extensively by professionals in the United States and Canada. Because both sets of guidelines were intended to promote professional practices for the preservation of natural science collections, some wording was repeated verbatim in the introductory section.

The Conservation Committee and SPNHC Council hope that you will incorporate documentation practices into your work. The published guidelines will be revised and improved as these recommendations are tested. Please send comments and suggestions to K. L. Garrett.

Paisley S. Cato, Editor
Collection Forum

DOCUMENTATION GUIDELINES FOR THE PREPARATION AND CONSERVATION OF BIOLOGICAL SPECIMENS

Introduction

Thorough records to describe the history of preparation and conservation treatments to which a specimen is subjected are recognized by collections professionals and conservators to be an essential part of that specimen's documentation (Fitzgerald, 1988). These records provide basic information for determining the effectiveness of preparation treatments and procedures and the suitability of specimen maintenance and care activities. They also allow one to weigh the desirability of any future treatments. In addition, thorough records aid scientists in determining if previous treatments might affect the validity of analytical investigations. To be useful, documentation should be complete so that future workers will be certain of a specimen's history. The days of research based solely on gross morphology and of preparation aimed at saving only these details have passed. Modern research and conservation are becoming more complex, and thus accurate information is required to allow rational decision-making.

Within the natural sciences an awareness of the need for such information is developing. A few institutions have kept treatment records, but generally these are incomplete and therefore of limited value. Institutions are encouraged to adopt standards of documentation for preparation and conservation that will serve as an integral facet of collections care and research.

Retroactive capture of specimen treatment data is rendered impracticable by the lack of recorded information as well as the amount of time and labor involved. The guidelines proposed here should, at a minimum, be applied to new acquisitions and to future treatments of existing collections. In nearly all cases, these records are simply an extension of current record files.

Minimum Documentation Requirements

The process of documenting specimen treatments starts in the field at the time of collection and continues throughout the specimen's existence; such thorough documentation will provide a continuous, ongoing history of the specimen.

When a specimen is accessioned, treated, loaned, or put on display, a Condition/Treatment Report should be completed. This report should record the specimen's condition before and after the activity, including techniques and equipment used on it and materials and chemicals that come into contact with it. Any observed effects such as changes in color, cracking, breakage, lost parts, loss or change in tags/labels, dimensional changes, or changes in storage solutions should be noted.

Standardized procedures, techniques and treatments may be described in detail in a collection's policies and procedures document, as long as any variations are faithfully noted in the records of any individual specimens affected.

At present it is standing procedure for institutions to maintain documents for permits, field work, accessions, loans, and other activities. In most cases, the proposed minimum documentation guidelines can easily be incorporated within existing documentation procedures. Also, the increasing use of computers in biological collections can greatly facilitate documentation and cross-referencing.

Suggestions for Complete Documentation

1.0 *Field collections and initial treatments.*—Collection management procedures routinely include full documentation regarding permits, places, and individuals associated with collecting. Proper permits and documentation for salvaging, importing, exporting, and transporting specimens are fundamental to specimen acquisition. Details should be sufficient to allow the tracing of legal and physical factors impinging on the field-collected specimen.

Field collection information should completely record techniques of collection or capture, whether by shotgun, seine, trap, etc., or by salvage. It should also record preparation techniques and initial treatments such as cleaning, freezing, degreasing, fixative injection or immersion, immersion in liquid nitrogen, preservative or desiccant application, pressing, etc. Time of death and time and duration of these procedures should be recorded, as well as any materials used and quantification of fluid concentrations. Packing, transport, and pest-control of field-collected specimens constitute significant treatments which should be fully documented. For biological specimens freezing delays or en-route thawing may have significant effects on future biochemical or histological analyses. Likewise, the use of fluids for fixation, washing, and storage may affect the quality of preservation as well as the future use of the specimen.

Materials and techniques used in specimen preparation, whether in the field or the laboratory, should be consistently, thoroughly, and honestly recorded. This applies to skinning, fluid preservation, drying, clearing and staining, degreasing,

and other treatments. Such information should be available to researchers as a basis for determining whether prior treatments may compromise intended studies.

2.0 *Collection and laboratory treatments.*—In the laboratory or the collection, preparation and conservation treatments require detailed documentation. The specimen should be clearly identified and cross-referenced to the primary numerical catalog and other identifying catalogs (field catalog, preparator's catalog, taxonomic and geographic cross-reference files, accession catalogs, special research catalogs, etc.). A complete record will include many of the following categories of information.

2.1 *Condition reports.*—Although it is generally impracticable to report the condition of all specimens in a collection, such reports should be completed for specimens receiving special treatment, and for specimens to be loaned or exhibited. Condition reports should include details of the specimen before and after treatment, loan or exhibit. Information may include general condition, missing or broken parts, dimensional changes, chemical changes, color change, insect damage, biodeterioration, and damaged or missing tags and labels. Particular attention should be given to documenting conditions that may affect the stability of the specimen. Condition reports are often supplemented by a sketch or photograph.

Condition reports are necessary to monitor the long-term stability of collections and in time will provide a broad information base. This record will be limited to new specimens and to those which have received treatment; therefore it may not be a representative sample of the collection. To better monitor the collection as a whole, condition reports may be prepared for selected specimens representing the various preparation types, specimen proveniences, and collectors (many conservation problems are inherent in certain collectors' techniques and materials).

2.2 *Authorization.*—Treatment and analytical use of specimens are serious procedures. Specific policies relating to the loan, exhibition, treatment, and analytical use of specimens should be developed and observed. Written authorization for each specimen affected should include a description of authorized work, the reason for treatment, the signature of the person responsible (and the person performing the work), the date of authorization, and the date of treatment. Details of materials used and the extent of treatment or analysis performed should be provided.

2.3 *Treatment in storage.*—Although specimens are ideally stored in a non-reactive environment, treatments to and within storage areas may render the environment reactive to specimens. Instances of fumigation, cleaning or chemical treatment of storage containers, change in fluid preservatives, routine fluctuations and significant deviations in temperature and humidity, etc., should be documented. Any storage materials in contact with or in close proximity to the specimen should be recorded.

2.4 *Conservation treatment.*—Preventive conservation is basic to the management of biological collections; however, conservation treatment of specimens for exhibition or other purposes is sometimes required. A clear policy of responsibility for specimen treatment should be set forth as part of an institution's collection management policy. Conservation treatment authorization should be completed as outlined in Section 2.2.

2.5 *Analytical use of specimens.*—Sampling, dissection, tissue-processing, and chemical or physical testing are among the analytical uses of specimens for which

written policies should be developed and observed. Such policies should spell out the circumstances under which analytical use of specimens is allowable and the extent of use that is allowable. Written authorization should be required (see 2.2), and detailed records of procedures should be kept. Such records should go beyond mere annotations on loan invoices; they should more closely resemble condition reports.

2.6 Additional information.—Additional ongoing records to be maintained in collections may include: climatic records for collection storage facilities, recommended storage or display conditions, in-house collection use and visitorship, publications based (wholly or in part) on specimens in the collection, collection data requests, handling procedures, emergency planning, and loans. Also important is a file to record the manufacturers, suppliers, purchase dates, chemical composition, and Material Safety Data Sheets of chemicals and materials used in specimen preservation and storage.

Perhaps not often recognized as a form of documentation, appropriate collection signage influencing staff and visitor behavior is of considerable value in preventing deterioration of specimens. Such documentation might include "FRAGILE" and "OPEN SLOWLY" signs on drawers, "NO SMOKING" signs in collection areas and so on. The cost-benefit ratio of this type of documentation can be extremely low.

Implementation

Satisfactory documentation cannot be achieved unless the recording of information such as that outlined above becomes a routine and integral part of everyday collection management procedures. These procedures must be understood and supported at every staff level. The exact methods and format will depend on the resources of the institution, the type(s) of collections, and the treatments and techniques used.

To simplify the documentation process, it is recommended that checklists be developed to facilitate the recording of standardized preparation techniques and materials, conservation treatments, and specimen conditions. Complete descriptions of these standardized techniques should be maintained with the collections' conservation files; modifications or variations should be documented, including the date when the change was introduced. Well-designed checklists could simplify future computerization of the records. When identical treatments are used on a series of specimens, the procedures can be documented once, as above, and cross-referenced to the individual specimens. In many biological collections such standardization of procedures is commonplace and will greatly simplify treatment documentation.

Finally, it is important that all records (both hard copy and electronic) documenting specimen provenience, field collection, preparation, storage, use, condition, and conservation treatment themselves be safely and adequately stored.

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INTEGRATED PEST MANAGEMENT AT THE DENVER MUSEUM OF NATURAL HISTORY

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Abstract.—The Denver Museum of Natural History recently suspended regular use of toxic fumigants in the zoology research collections and substituted an integrated pest management program consisting of specimen monitoring and localized fumigation of infested cabinets. A bird conservation survey provided baseline information on the physical condition of specimens in the collection, evidence of dermestid beetles, and targeted specimens in need of conservation. The museum also expanded protection of exhibited zoological specimens by instituting systematic conservation audits, basic cleaning, and pest management, involving regular monitoring and use of low-toxicity insecticides and insect traps in dioramas.

The control of pests in collections of zoological specimens is a balancing act between providing a safe environment for museum staff and visitors, effectively treating insect and rodent infestations with toxic chemicals, and ensuring that specimens are not adversely affected by the measures taken. Recent literature (Edwards *et al.*, 1981; Peltz and Rossol, 1983; Storey, 1985; Bloomcamp, 1987; Zycherman and Schrock, 1988) has focused attention on the human health and safety factor in the use of pesticides. In an effort to provide safe and effective pest control, the Zoology Department at the Denver Museum of Natural History recently revised collections maintenance procedures for specimens in research collections and on exhibit. This integrated pest management (IPM) program resulted in improved procedures in the dermestid colony room and in dioramas, and in preventative maintenance in the research collections.

PEST MANAGEMENT IN THE COLLECTIONS

To provide a safer work environment, the Zoology office was removed from the collections storage area and a high-exchange ventilation system was installed. Routine fumigation of specimen cabinets with PDB crystals and DDVP strips was suspended. Because live larval and adult dermestid beetles had been found in the zoology collections during the last year of regular pesticide use, there was concern that suspending routine preventative fumigation might exacerbate the pest situation. Moreover, the departmental dermestid colony, located in a separate room but near the collections, was considered a potential risk to collections in the absence of routine fumigation. Therefore, the dermestid colony room was redesigned for maximum containment of beetles, and preparation procedures were redesigned to further discourage potential introduction of dermestids from the colony into the collections. All skeletal material removed from the dermestid colony receives fumigation, freezing, and an ethanol dip before leaving the dermestid colony room. A double containment system for the beetles consists of a plexi- and screen-covered inner metal box and an enclosed outer metal box. All

openings from the room are sealed or screened. Trash is placed in a covered receptacle and removed from the building daily. Clothing of those leaving the colony room is examined carefully for hidden insects.

After suspension of regular fumigation in the research collections, the Zoology Department instituted a preventative maintenance program consisting of annual physical inspection of specimens and quarterly inspections of insect sticky traps and replacement of Insectape® in specimen cabinets. Insectape® is a low-toxicity, self-adhesive, residual insecticidal strip containing propoxur (Baygon). Specimen cabinets found to contain active dermestid infestation are saturated with dimethyl-dichlorovinylphosphate (DDVP) and sealed for two weeks. The contents are then carefully examined to ensure that insect activity has ceased.

To begin the physical inspection aspect of the preventative maintenance program, a bird conservation survey was completed to document baseline information on the collection. The survey served to determine the physical condition of the specimens, locate evidence of insect infestation, provide an opportunity to clean specimens of old larval casings, and target specimens in need of conservation. The conservation survey will be repeated every five years.

The survey form was a simple checklist (Fig. 1) that could be filled out by volunteers. Major inspection categories included on the survey form are: presence of dermestids or dermestid larval casings, presence of oily residue on specimen tags and birds, physical damage to specimens (broken body parts), dermestid damage (loosened feathers, bald spots, and chewings), rodent damage (presence of feces, urine, and chewings), other insect damage (clothes moths or silverfish), detached or missing specimen tags, corrosion of tags, dirty specimens, crowded storage conditions potentially damaging to specimens, and presence of extraneous materials (paint, string, wire, or rubber bands affixed to specimens).

Each birdskin was examined thoroughly, probed with a soft brush and tweezers to free insect frass, and cleaned. As all old dermestid larval casings were removed, future pest evidence could be dated as post-1987.

Results of examination of 30,076 study skins showed that dermestid larval casings were present on 7.6% of the specimens, but only 1.3% showed insect damage, mostly at the base of the tail. Only one live dermestid was found during the survey, and no specimens were heavily damaged by dermestids. In addition to completion of the survey forms, a summary sheet that outlined necessary conservation treatment was prepared for each specimen cabinet (Fig. 2).

A central file of Pest Incident Reports (Fig. 3), which documents the presence of insect or rodent pests in the zoological collections in storage and on exhibit, is part of the collection permanent records. The results of bimonthly monitoring of insect sticky traps placed on floors throughout the Zoology Department are used to track patterns of pest incursion.

PEST MANAGEMENT IN DIORAMAS

Coincident with the monitoring program in the research collections, the museum expanded protection of exhibited zoological specimens by instituting a more comprehensive maintenance program in its 88 dioramas. The IPM program for dioramas, which began in January 1988, was precipitated by severe dermestid infestations in two dioramas triggered when overhead fire-prevention sprinkler

CONSERVATION SURVEY
ZOOLOGY DEPARTMENT BIRD SKIN COLLECTION

ASSESSMENT FOR CABINET TYPE SPECIMENS

DRAWER 4 (cont.), 5, 6, 7

CATALOG NUMBER	Larval Casings	Oily Tag	Oily Bird	Broken Parts	Bald Skin Damage	Insect Damage	Metal Tags	Missing Tags	OTHER:
4 (cont) 27343	x	x							
14716	x					x			lots of casings
Skeleton from #11077		x							
5 19690				tail & belly x					
4952	x								
26859	x								possible rodent damage possible urine damage
21547				Head x					
6444				Left wing x					
Corvus Cystolegus									urine damage rodent chewing
6 Curasson									many loose feathers wire from beak and feet
Passenger Pigeon in a box									molting overall poor condition tape on beak!
33742									rodent damage & urine on tail
skull									rodent dropping
27080						feathers x			
7 2506				Left front paw x					
ADDITIONAL COMMENTS:									
#5 over crowding									

Figure 1. Bird Conservation Survey Worksheet.

heads malfunctioned and watered the exhibits for several minutes. The increased humidity in the foreground vegetation created an ideal habitat for dermestids.

Based on experience from this crisis, a comprehensive pest management program was initiated. Each diorama receives an annual conservation inspection, basic cleaning, and administration of the IPM program. All procedures are documented on Exhibit Maintenance Report forms (Fig. 4). The conservation inspection is a detailed assessment of the physical condition of the diorama and a search for evidence of insect infestation. The basic cleaning includes washing exhibit glass, removing dust and insect frass from mounted specimens and foreground vegetation, and vacuuming catwalks, perimeter walkways and other surfaces such as tree trunks. Light fixture UV filter tubes, which also act as insect traps, are checked for insects monthly. A Diorama Alert form (Fig. 5) was created to quickly communicate problem situations to appropriate staff for immediate action.

CONSERVATION SURVEY
ZOOLOGY DEPARTMENT BIRD SKIN COLLECTION

CABINET #: TYPE SPECIMENS

ORDER:

FAMILY:

DATE: APRIL 6, 1987

SURVEYED BY: Paul Benson & Ann Cunningham, Rocky Mountain Regional Conservation Center

PEST EVIDENCE	YES <u> X </u>	NO _____
DERMESTID:	ACTIVE _____	INACTIVE <u> X </u>
MOTH:	ACTIVE _____	INACTIVE _____
RODENT:	FECES <u> X </u>	CHEWINGS <u> X </u>
EVIDENCE:		

WHERE FOUND (LIST DRAWERS):

1 - 6,8

STORAGE PROBLEMS? NO _____ YES X DRAWERS #5 over crowding SPECIMEN DAMAGE? NO _____ YES x DRAWERS (see attached) TREATMENT RECOMMENDED NO _____ YES X

URGENT _____ SINGLE DRAWER #5 crowding #6 tape on GENERAL _____
beak

NEEDS PROFESSIONAL EXAM X #2, #5, #6 for rodent damage FUMIGATION _____ DATE FUMIGATED April 3, 1987

STRUCTURAL PROBLEMS WITH STORAGE _____

DAMAGE TO SPECIMEN(S) _____

MAINTENANCE

DRAWERS CLEANED X SPECIMENS CLEANED OF INSECTS X

ACTION TAKEN

CURATOR NOTIFIED _____

CABINET FUMIGATED _____ DATE _____ CHEMICAL _____

PEST SAMPLE IDENTIFIED _____

CHANGES IN STORAGE _____

Figure 2. Bird Conservation Survey Summary Sheet.

In the diorama IPM program, low-toxicity, residual insecticides and insect sticky traps are used, and monthly monitoring occurs. A fine mist solution of 0.5% chlorpyrifos (Dursban®) in a water base, which leaves no visible residue, is applied to the foreground. This is supplemented with treatment of cracks and

DENVER MUSEUM OF NATURAL HISTORY

PEST INCIDENT REPORT

For Documentation of Presence of Insect and Rodent Pests

DATE: _____ SPECIMEN# _____

LOCATION: _____

REPORTED BY: _____

PEST EVIDENCE:

	Active	Inactive
Dermeestid	_____	_____
Moth	_____	_____
Silverfish	_____	_____
Rodent	_____	_____
Unidentified	_____	_____
Other	_____	_____
Describe _____		

DESCRIPTION OF SITUATION: _____

TREATMENT RECOMMENDED: no____ yes____(describe)

professional consultation needed____

ACTION TO BE TAKEN WHEN, BY WHOM:

Distribution: Zoology Department
 Exhibit Maintenance Technician

11/5/87

Figure 3. Pest Incident Report.

DENVER MUSEUM OF NATURAL HISTORY

EXHIBIT MAINTENANCE REPORT

For Documentation of Diorama Treatments
Cleaning, Refurbishment, and Conservation

TREATMENT	DATE	BY WHOM	METHODS/MATERIALS
Conservation Audit			
Clean Specimens			
Clean Foreground			
Clean Case Interior			
Clean Glass			
Exhibit Restoration			

REMARKS:

Distribution: Chief Curator
Exhibits Division Manager
Zoology Department
Exhibit Maintenance Technician

11/5/87 cfile:TREAT III

Figure 4. Exhibit Maintenance Report.

DENVER MUSEUM OF NATRAL HISTORY

DIORAMA ALERT

For Documentation of New or Potential Damage to Dioramas

DATE OF REPORT:

DIORAMA TITLE:

HALL AND FLOOR:

WHEN OBSERVED:

OBJECT AND CONDITION:

RECOMMENDATIONS/ACTION TO BE TAKEN:

REPORTED BY:

REPORTED TO:

ACTION TO BE TAKEN WHEN, BY WHOM:

Distribution: Chief Curator
Exhibits Division Manager
Zoology Department
Exhibit Maintenance Technician

11/5/87

crevices inside the diorama with bendiocarb (Ficam D®) dust. Dry boric acid powder also is blown across the floor beneath the exhibit substrate. Chemicals are not applied directly to specimens.

CONCLUSIONS

Although none of the methods mentioned in this paper are revolutionary or novel, they represent an attempt to consolidate proven, conservative methods into an integrated pest management program for both stored and exhibited specimens. The program is experimental and new methods undoubtedly will be incorporated in the future. As methods are refined they will be appended to the Museum Collections Policies and Procedures Manual and the Museum Disaster Plan.

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COLLECTION AUTOMATION: TAILORING DATABASE AND COLLECTION MANAGEMENT TO SUIT A NATURAL HISTORY COLLECTION

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Abstract.—Automating natural history collection data can have far-reaching effects on collection management. It is vital that the planning of a system include appraisal of present and possible future uses of the data (on-line and as output). The software's limitations also need to be considered.

A number of important issues to consider include database management requirements such as: (1) standardization of terminology, (2) updating data, (3) use of catch-all fields and unique fields, (4) conventions and use of term characteristics to produce desirable hardcopy products, and (5) data quality requirements (including precision, accuracy, use, and coding of data). Collection management issues involve organization of the collection and how it can be improved by implementing user-based hierarchies. Finally, documentation, along with gathering of data, and training of personnel are briefly discussed.

Numerous authors have discussed hardware, software, and some organizational aspects of automating a natural history collection (McAllister, 1983; Cato and Folse, 1985; Folse and Cato, 1985; Holm, 1986; Woodward and Eger, 1987). Other publications have dealt with format requirements in certain disciplines for specific data (Black *et al.*, 1973; Williams *et al.*, 1977; Seymour, 1986; Woodward, 1989). Yet, to date a reference has not specifically addressed the many changes required in data that are collected and how data should be organized for a collection that is converted from a manual system to an automated system.

Utilizing the decision-making capabilities of computers presents new constraints upon organization and information content of specimen records. Developing a workable system requires all planning personnel to know collection requirements and the uses of a database. This includes knowing the fields or parts of fields required for input, retrieval, sorting, data manipulation, and output. The database structure should be kept flexible to permit future revisions and conversions to other formats, software, or hardware, and/or to permit new uses to be achieved smoothly wherever possible.

DATABASE MANAGEMENT

Definitions and Examples

In this paper a number of terms are used that may have a variety of connotations. To assure clarity I will define the most frequently used terms.

Field.—a subset of a record's (or specimen's) data that is distinct in content (e.g., Genus or Habitat).

Term.—a single word or group of words (in a field), distinct in meaning, and separated from the next term by a break character.

Break Character.—a unique character used to denote the end of a term in a field. Frequently, a field has a number of terms within it, each separated from the next by a break character.

Syntax.—the word order in a term.

Punctuation.—the break characters and other non-alphanumeric characters used in a term or field.

String.—a series of alphanumeric and/or punctuation characters in a term or a field. A word is a string, just as part of a word or a series of words is a string.

Acronym.—a unique string of alphanumeric characters that is a contraction of a field name (e.g., SPENA may be the acronym for the field Specimen Nature).

Flagname.—a unique string of characters that identifies specific data within a field. An example of using flagnames in the Remarks, a catch-all field, that contains an amalgamation of unrelated data is "CLR=ALBINO: TYP=TOPOTYPE: EAR TAG, WOODWARD, #586". CLR= is the flagname that identifies the beginning of a string of data pertaining to a specimen's colour, while a colon denotes the end of the desired string.

Unique Field.—a field whose resident data are narrowly defined, such as Breeding Data or Country.

Format.—a field's design, including the terminology, syntax, punctuation, and term order.

Convention.—a standard practice.

The examples given in this paper are from the database at the Department of Mammalogy, Royal Ontario Museum (ROM), Toronto, Ontario, Canada. Upper case words are examples of actual or possible data. Field names are capitalized, e.g., Breeding Data. Canadian Heritage Information Network (CHIN) field mnemonics (Delroy *et al.*, 1988) are used as flagnames in catch-all fields throughout this paper.

The examples given represent solutions to problems I have encountered when automating collection data. This is not to say that there are no alternate solutions to these problems. The intent of all people automating collection data is to find solutions to problems that serve automation, management, and documentation needs while also conserving collection data in an accurate and usable fashion. Collections vary and some of the solutions that I have presented may require revision to encompass circumstances not encountered in the ROM Mammalogy collection.

Some may expect automated data to directly mirror data as it appears in field catalogues. The ROM keeps all field catalogues and field notes associated with specimens. These serve to supplement database information as some details are not or cannot be entered on the computer. The database does however contain all the data most frequently required by users, managers, and curators of the collection. The captured data may appear in a rearranged, updated, or simplified form to permit searching and sorting by the computer and operator, while retaining accuracy and most details.

Standardization

Terminology.—The format of fields, particularly terminology, should be precise and standardized. If you want to easily retrieve and sort data, it must be input

in a simple and organized fashion compatible with the uses expected of the database and the way the software accesses data within a field.

The following should be standardized: (1) spelling (e.g., British or American), (2) language (e.g., English or French), and (3) tense. To help prevent cluttering data, avoid or minimize the use of articles, prepositions, and pronouns. Descriptions should be simplified to specific terms that best state the data, without altering its original meaning. With known terms the database can be easily searched for a particular phrase, noun, or adjective. Adhering to the use of either singular or plural forms throughout the database minimizes the number of unique terms and thus simplifies search strategies. Consistency in standardized terminology throughout the database keeps the database uncluttered and predictable, and minimizes synonymous input.

Example 1. When describing the condition of a specimen there are only four nouns (CRANIUM, MANDIBLE, SKELETON, and SKIN) and five adjectives (DAMAGED, SEPARATED, PARTIAL, ABSENT, and MISSING) from which to choose (Woodward, 1989). Descriptions are translated to the term(s) that best state the specimen's condition. For example, "tail and ears chewed by ants, and hindlimbs missing" would be input as "SKIN DAMAGED; SKELETON PARTIAL".

One can easily search for the appropriate string to isolate, for example, all missing skins (search string = SKIN MISSING), damaged specimens (search string = DAMAGED), or problems encountered with skulls (search string = SKULL). Seymour (1986) describes a complex system for describing individual bones and teeth for a vertebrate palaeontology collection.

Updating data.—Data that are out of date, such as nomenclature and country names, should be updated in the database to an accepted standard. As stated by McLaren *et al.* (1987) synonyms amongst terms used in a field should be avoided. Synonyms prevent efficient and accurate searching of the database and can have a negative impact on collection organization. Fields commonly used to organize a collection and/or search the database (Genus, Species, Country, Province/State, Collector, etc.) are particularly important fields for which standards should be maintained. Scrutinizing and editing important fields should be a routine practice.

Some clutter is unavoidable with biological and geographical data. Often these situations can be dealt with by using a thesaurus that is either documented in a user's manual or an option in the software package used. A thesaurus lets the user or system know that one term is synonymous with another.

Example 2. Today, it cannot be determined if a specimen came from Kenya, Uganda, or Tanzania if the only locality data documented in 1920 was the country name, British East Africa. With the appropriate thesaurus, a search for specimens from Kenya will include in the subset retrieved, the British East African specimen. Thus British East Africa is recognized by the user or system as a possible synonym of Kenya.

Word order within a term.—Syntax affects how a field is searched, and sorted. Syntax in the English language places adjectives before nouns. If the noun of a term is followed by the adjective the sorting of terms by computer will be based upon the noun. It is more logical to group data by the subject (noun) rather than the description (adjective). Multiple terms have to appear in proper sequence for successful searching. (See Example 1.)

Catch-all fields and unique fields.—Two types of fields are commonly used. A catch-all field contains a mixture of data that could be placed in a number of separate fields. Because these possibly separate fields are not applicable to every record, they may be grouped into a single, catch-all field. These catch-all fields may be necessary where there are significant space constraints for data-storage. Most microcomputer database packages have fixed field lengths and function more slowly as record size (i.e., size and number of fields in a record) and number of records in the file increase. This is particularly true for hardware using floppy disks rather than a hard drive. Some fields may be so infrequently used that they not only waste disk space but only serve to slow microcomputer response time. From the standpoint of users and database management, it is preferable to keep the software performance optimal.

Unique fields, on the other hand, are commonly used in mainframe systems for different data types, whether they are regularly encountered in each record or not. Mainframe software, which frequently does not have fixed field lengths, and hardware is not as adversely affected by record size and response time as that of microcomputers.

If data entered on microcomputers are uploaded to a mainframe which stores all data in unique fields, any catch-all fields used on the microcomputer may need to be split up appropriately. To avoid further expenditure of human time on this task a conversion program can be written. The various data types in the catch-all fields must have associated flagnames to permit data to be targeted, excised, and routed to the appropriate mainframe fields. If there is no break character terminating the data following a flagname, the program logic should assume that all the remaining data in the field belong to the last encountered flagname. The string "FLAGNAME=" and a colon (:) used as a break character terminating the data to be relocated (so that it is not confused with a semi-colon break character used to separate terms within a field), can be easily deleted from the catch-all field. There will frequently be some data that do not fit into any particular unique field. Any data not excised from the catch-all field can remain in that catch-all field (usually called Remarks) in the mainframe database.

Example 3. Data like "CLR=RED PHASE: TYP=HOLOTYPE: SALIVARY GLANDS REMOVED AND DISSECTED, I.M. SHORT, GUELPH UNIVERSITY, 19560330" permits "RED PHASE" to be moved to the Colour field. The data from the beginning flagname "CLR=" and the ending break character are now unnecessary and can easily be deleted from the catch-all field. Similarly, the Type data, "HOLOTYPE", can be relocated.

Using microcomputer software with the carry-over template option allows the contents of the last record to be written in the record being appended. This option permits repetitive data in consecutive records to be generated by the computer rather than being typed by the operator for each record. Only the fields in which data change from one record to the next need be altered. The use of unique fields facilitates data entry with carry-over templates because data is more likely to be similar or identical between records than that in a catch-all field.

Setting up unique fields for different types of data helps to clearly define the data set. It assures consistent data entry by prompting users where to enter or change information. Unique fields should be defined so that data contents are mutually exclusive to avoid any confusion concerning the location of a specific

records), (2) useful (e.g., there is amusing but useless anecdotal data), or (3) meaningful (e.g., there are unusual measurements taken for no apparent reason). On the other hand, one must seriously weigh the risk of possibly discarding data that may be useful in some unforeseeable way in the future.

Example 7. Keeping latitude and longitude coordinates to the level of seconds is an example of false precision and accuracy in data. Most terrestrial locality information refers to towns, cities, mountains, etc., whose coordinates often cannot be accurate to the level of minutes without using a midpoint or accepted reference point location. Furthermore, most gazetteers for terrestrial localities are precise to the level of minutes only.

If variable accuracy unavoidably exists for certain data an accuracy coding system can be instituted. This coding immediately identifies the reliability of the data. Where computer-generated plots of the data are done (e.g., distribution maps) different characters can be used, based upon the accuracy code, to indicate the relative accuracy of individual data points.

Example 8. A letter code designates the accuracy and thus reliability of the coordinates associated with a specimen's locality data. Coordinates determined directly from topographical maps using very precise locality descriptions on field catalogues are coded "M" for map; coordinates obtained from gazetteers for precisely described localities are coded "G" for gazetteer; coordinates obtained from gazetteers for vaguely described localities (e.g., a locality "x" km N of a town, or locality data in which two different towns are given) are coded "V" for vague; and, coordinates of unknown origin and unknown localities have a blank accuracy field.

Many data fields can have their data simplified to suit the needs of those most frequently using the data. Although this simplification may appear to compromise precision, it may in fact increase the utility of the field's data. By grouping data to limit the number of acceptable terms, users of the database will not have to remember to search for unlikely or anomalous terms. Also, some data serve indirectly to denote information, such as location of specimens within the collection.

Example 9. Some groups of mammals are difficult to age while for others, ages are defined differently by different people. Furthermore, in the past, some specimens were not aged when processed. Unaged specimens may be input as adults so that a single age term may be used when searching for subsets of adults or probable adults within a taxon. Seymour (1986) also assumes that a fossil specimen is an adult unless specific Age data are present. Anyone studying a taxon will likely want to look at unaged specimens as some, if not many, will likely be adults. People unfamiliar with the database will not have to remember to search for two or three different terms (ADULT, unaged specimens (blank field), and/or specimens of an unknown age (UNKNOWN)).

Embryos, neonates, and juveniles are identified as such in the Age field. Embryos in alcohol are kept in a separate section of the collection, thus Age can also denote location within the collection. Generally neonates and juveniles are of no systematic use but may be of interest for the purposes of developmental research and identification.

There is also utility in grouping similar types of data within one field to eliminate potential overlap in definitions of fields and redundancy in input. This also permits

searching only one field for data. Seymour (1986) illustrates the utility of grouping different types of data in a single field to satisfy common usage needs for Specimen Nature in a vertebrate paleontology collection.

Example 10. All Specimen Nature data in the ROM Mammalogy database is placed in a single field. CHIN (Delroy *et al.*, 1988) defines Partial Specimen as anatomical parts or partial specimens (including such things as skull or the name of a particular bone). Specimen Nature is defined as the "nature of the specimen or kind of specimen, and may include terms for preservation technique or anatomical parts." The overlap in definition and redundancy of data between these two fields and many other related fields in the Natural Sciences Data Dictionary for CHIN are troublesome. Although some of the fields may be useful for a particular discipline, for the Mammalogy database it is far more logical and practical for all data pertaining to the physical character and method of preparation of the specimen to be placed in one field. This is particularly practical where some terms imply data (e.g., the term "ALC" implies that a specimen is wet, stored in 70% alcohol, has been fixed in 10% formalin, and includes the entire animal).

Codes.—Standardization of data entered by using codes should be user-friendly and codes should be able to be retrieved and sorted efficiently. One must ascertain whether the time spent determining the appropriate code for original data, the error rate in determining and entering the code, and the probability of detecting errors in coding justify using the code rather than entering the raw data. The codes should be sensible, unique, and hierarchical when information is additive (Woodward, 1989). Data that are frequently encountered within a discipline often have traditionally used codes that are perfectly acceptable for computer use also. Sometimes, however, optimal coding must be compromised to accommodate tradition and user preferences. With unique, hierarchical codes programs can easily locate and translate coded strings into proper English for print-outs when necessary. Conversion of data to other formats is also easily achieved.

Example 11. Following are examples of Specimen Nature codes developed by Woodward (1989). "SN-TAN" is a tanned skin, while "SS-TAN" is a tanned skin plus a skull, and "SSS-TAN" is a tanned skin plus a skull and post-cranial skeleton. To search for all the specimens that have a tanned skin one simply seeks the unique string "-TAN".

An example of where codes have not been used is the two-letter codes for province or state used by the postal systems of Canada and the United States. The disadvantages of inconvenience and time taken to determine the correct code and the fairly high chance of input error outweigh the advantage of short time spent actually entering data. In most field collections, specimens all come from one province or state so the carry-over template capability of software precludes the need for repetitive entry of Province/State data.

COLLECTION MANAGEMENT

Practical Versus Traditional Organization

Many collection practices have been adhered to because they are traditional. Sometimes upon appraising the philosophical and logical implications of traditional practices it becomes apparent that they no longer make sense, serve a function, or worse, they are counter-productive.

Numerous collection management problems can be alleviated by removing unnecessary hierarchical tiers of organization within collections. Hierarchical data may be inaccurate or lacking, because of difficulty assigning the category or temporally varying management practices. By removing hierarchical designations for which data are poor, the negative impact upon the standards and/or organization of the collection may be alleviated. Cabinet space and collection materials are often saved as a direct result.

Example 12. The utility of organizing a mammal collection to the subspecies level is questionable. Although philosophically valid, this concept causes numerous problems for collection managers. Not all collection specimens have been or can be identified to subspecies. Those specimens for which a subspecies is indicated may have been identified using different references that do not concur on the identification. The literature for subspecies found outside of North America is scattered and often difficult to locate, if it exists at all. Even where a major reference does exist, like Hall's (1981) publication pertaining to North American mammals, often the subspecies name of specimens has been assigned using distribution maps only. Thus subspecies have become clerical rather than biological taxa as specimens are rarely examined for subspecific characters. Assignment of subspecies for specimens collected near boundaries is another real problem for Hall's maps are small-scaled. Although it is accepted traditionally to apply subspecific nomenclature, it is of little practical value to collections or many researchers.

The present policy for the ROM Mammalogy collection states that if subspecies data are associated with a specimen they are entered into the database, but they are not printed on cards or labels. This way the information is kept for specimens where it may be of biological importance and can be retrieved from the database.

Taxa are virtually always requested by species, not subspecies. When required, taxa at the subspecies level can be retrieved geographically using ranges of Latitude and Longitude, or alternatively, by using Continent, Country, Province/State, and/or County designations.

User-based Hierarchies in Collections

There is no reason why some hierarchies that are based solely upon collection needs cannot be used to develop a database system. Some creative thinking that dares to break common practice can facilitate collection and database management considerably. An assessment of how the collection is actually used rather than how it is thought to be or may occasionally be used can lead to some surprising revelations. Innovative groupings of data used to organize a collection can save materials and space in the collection, and time spent locating specimens. Organization that is logical biologically can also facilitate searching the database since logical groups offer another means by which data may be retrieved.

Example 13. Occasionally biologically and geographically meaningful designations of "continents" or "countries" are used. In a biological database, it is not logical to put "FRANCE" in the Country field for a specimen collected on the island Guadeloupe (a French colony). Instead, the Antillean Islands (Continent field) are composed of islands (such as Guadeloupe). The island name appears in the Country field. This organization permits simple retrieval by island or by geographic region, as mammals rarely have any respect for colonial status or

political boundaries. Researchers are most frequently interested in a fauna from a particular geographic region.

Elevating some island groups to an appropriate organizational level simplifies searches and collection organization. The Antillean Islands of the Atlantic and the Oceanic islands of the Pacific are considered "continents" for organizational purposes. The United Kingdom is considered a "country" which includes the "provinces" England, Scotland, Wales, and Northern Ireland. Ireland is considered a separate country. New Guinea is considered to be two countries, Papua and West Irian in the ROM collection. It must be decided by managers and curatorial staff when best to follow political designations and where it is most helpful to institute a user-based hierarchy.

Collection Organization Mirroring that of the Database

The organization of the database should be echoed in the actual collection to maximize the utility of automation as a collection management tool. Use of volatile organizational systems, such as taxa below the order level being organized by phylogenetic order, are not intuitive and are virtually impossible to keep current in a large collection. Organizing specimens within the collection alphabetically by taxa (at least, Family, Genus, and Species), by locality information (Country, Province/State, and County), and numerically by Accession or Catalogue Number parallels the organization of the database as fields sort alphanumerically. This logical arrangement of the collection permits the easy location of taxa in the collection even by novice users. Furthermore, lists of specific taxa can be generated that are sorted as required for loan requests or to assist inventory or reorganization activities.

DOCUMENTATION

Database Manual

All decisions should be documented in a users' manual. The type of data considered pertinent to the database and the format of data entered should be documented for every field in the database. By documenting decisions, future consistency is assured, although there is no escaping some human failure to comply even when adequate documentation is available.

As any programmer knows, consistency of format is essential to permit reliable decision-making and manipulation of data within a field to produce a desired output format. On the harmless end of the spectrum, inconsistent data simply may not be located by a program. On the harmful end, unexpected data can cause a program to output undesirable data, or to fail or "crash." To help prevent programs from malfunctioning, it is desirable to enter data in the format in which it can be printed on hardcopy products with minimal or no manipulation. The fewer decisions and format conversions in a program, the faster the program will run and the less likely it is that aberrant data will cause the program to crash.

Example 14 (Excessive output). If a program is looking for a particular break character to end a term and the wrong break character is used, the program will not find the term anticipated. Consider the Specimen Nature data "SSS-TAN: MANDIBLE MISSING: SKIN DAMAGED". If the program is looking for a semi-colon as the break character to extract the first term from the field, no

extraction will occur because there are no semi-colons in the field. The whole field is interpreted as one term since there are no recognized break characters. The result is the whole field (and, in this case, an unusually long term) will be printed on hardcopy products, likely overwriting other data or hardcopy product margins.

Example 15 (Term not recognized). In another example, two scenarios may develop depending upon what is asked concerning the Breeding Data data "P: 3 EMB: CR=16". If the first term is required (as in Example 4), the whole field would appear because a valid break character between terms is not present. If the first term was tested for a specified length of two or fewer characters (as in Example 5), the output would be "+" since the first term is greater than two characters in length.

Example 16 (Program crashing). An example of how incorrectly entered data can crash a program is the case where the set of acceptable terms for a field is fixed. If translation tables are used, the program will crash when it encounters a value for which there is no translation given. For some translations such as month number to month name, limits for the value the program can expect to find in a field can be defined. When an unacceptable value is encountered an error message can be programmed to pinpoint the problem data for the user. Where alphanumeric data is involved, possible typographical errors cannot be anticipated. In these cases, it is essential that data are carefully input and edited before hardcopy products are produced.

Field Catalogue Design and Personnel Training

To help ensure that the appropriate data are gathered for each specimen and that they are formatted properly, data sheets or field catalogues should be developed that encourage proper data gathering. See Seymour (1988) for an example of preparation/conservation worksheets for fossil vertebrates. It is also helpful to have personnel who will actually be gathering field data or be making decisions pertaining to the collection to become familiar with the database, through inputting, editing, and searching. A quick reading of documentation is not sufficient to gain a true understanding and appreciation for the format, needs, constraints, and logic of a database system.

SUMMARY

The Mammalogy collection at the ROM has undergone many changes resulting from the constraints and necessary organization of data within the collection database. These include: (1) dropping the subspecies nomenclature from the physical organization of the collection and supporting hardcopy products, (2) updating country names to presently accepted political status (by using a thesaurus), (3) amalgamating geographically associated, yet politically separate islands into single "continents" or "countries" where convenient and logical, (4) developing codes for specimen nature data that are both user-friendly and computer-efficient, (5) developing and instituting a location accuracy code to indicate the relative level of accuracy of locality coordinates for a specimen, (6) changing data format to suit software indexing requirements and hardcopy product space constraints, (7) not inputting biologically unnecessary types of data and/or simplifying data cap-

tured, (8) developing a new field catalogue, and (9) educating department members and users about the database system.

The general needs to consider when developing a database are data entry forms and methods, searching and sorting requirements, and output demands and constraints. More specific considerations relating to data include its gathering, standardization, syntax, codes, conventions, accuracy, organization, and input. The needs of managing the collection, using the collection, and producing hardcopy products should also be examined when developing a database. Once developed, the system should be fully documented to help ensure consistent treatment of data by acting as a resource used to train users as well as to record decisions.

To develop a system that satisfies the needs of a museum collection and an automated database is a common mandate for natural history collections today, including the ROM's Mammalogy collection. Automation of collection data requires numerous changes in data gathering and documentation practices. By making use of the inherent structure of the database imposed by the software used, the collection can be organized to mirror the organization of the database. The unification of collection and database management into an integrated system encourages good documentation, logical organization, and good curation of a collection.

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A CODING SYSTEM FOR NATURE OF SPECIMEN FOR RECENT MAMMAL COLLECTIONS: MIXING DOCUMENTATION NEEDS, TRADITION, AND COMPUTERS

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Abstract.—A coding system to describe the nature of Recent mammalian specimens is presented. It addresses human and computer restrictions while remaining flexible and expandable. A single term is comprised of two parts, a primary descriptor and a secondary descriptor, that are separated by a hyphen. The primary descriptor of this code indicates the parts of a specimen that have been prepared. The secondary descriptor of the code indicates the preparation methods used. Several terms may be required to adequately describe a specimen. Standardized terminology used to describe the condition of a specimen for collection management purposes is also presented. Useful, unique, and consistent strings are the optimal goal from a perspective of computer compatibility.

The nature of a specimen determines, among other factors, whether specimen parts are appropriate for research, exhibit, or teaching. Some codes used to describe the nature of a specimen are traditional within an institution. With collection automation, software capabilities of the computer need to be considered. Consistent terminology and user-friendly codes that permit a database to be searched efficiently, reliably, and completely must be developed.

Coding systems developed for vertebrate palaeontological collections describe individual bones and teeth, and parts thereof (Seymour, 1986; Black *et al.*, 1973). These systems are too detailed for a Recent mammal collection.

Williams *et al.* (1977), Choate *et al.* (1977), and Williams *et al.* (1979) reported coding systems that are very similar to one another. The most extensive system for describing the nature of a mammal specimen appears in Williams *et al.* (1979). There are two difficulties with this coding system. (1) The codes are not additive. Multiple terms must be used for the same type of specimen when treatments or associated material may differ. For example, if one wished to search for all the skull material for a taxon, one would have to search on a maximum of ten unique codes in nature of specimen. (2) The coding system is not flexible. When an unusual specimen preparation is encountered one must simply flag an existing code as a "partially accurate code"; the actual nature of the specimen information is then entered in a remarks field (Williams *et al.*, 1979). Searches are less efficient because two fields are involved. It is likely that data are recorded in a variety of ways if terminology is not documented. The existence of variable data in a field can result in incomplete searches.

"Nature of specimen" refers to both an accessioned specimen's physical parts and the method of preparation of the individual parts. The method of preparation gives information about how a specimen is preserved (e.g., fluid in which it is stored), treated (e.g., method of preparing the skin), and/or presented (e.g., whether a specimen is mounted).

The records for mammals housed at the Royal Ontario Museum (ROM) are stored on CHIN, the Canadian Heritage Information Network. A coding system

for mammal specimens was developed with the intent of being compatible with the CHIN system (Delroy *et al.*, 1988) while meeting the collection management needs of the Department of Mammalogy. Terms that are indexed as searchable units in CHIN must be separated from one another by a semi-colon (;) (Delroy *et al.*, 1988). There is unlimited space for data in this field on CHIN; however, constraints exist with the mammalogy database used in-house through which data are initially entered.

The mammalogy database uses dBase III plus software with PC-compatible hardware. The field housing nature of specimen data is allocated sixty spaces. On the rare occasion that more space is required, overflow data are entered in a remarks field. A unique acronym associated with the data allows it to be found by the computer. The overflow data can be reunited with the appropriate field on the CHIN database, when data from the in-house database are uploaded, or transferred to CHIN.

Only ten characters or less of the nature of specimen field data are printed on cards and labels produced in-house using programs written by the author. Codes are entered in the field in a priority fashion to insure that the most frequently required data (i.e., that regarding the skin, skull, and skeleton) will appear on hardcopy products. If all of the data in the field cannot be printed, a plus sign (+) is appended to the printed data to indicate that further data reside on the database (See Woodward, 1989).

The coding system described here should be applicable to mammal collections, big and small. Collections vary so that this coding system may not fully meet the needs of another collection. There is no reason why additional primary and/or secondary descriptors cannot be added where necessary. A separate field could be defined to house data pertaining to the condition of the specimen, if additional space was required.

It is likely that this code will be most useful to individuals facing automation for the first time. If compatibility with others using it is desired, however, existing databases could have their data converted to fit this code; simple conversion tables could be developed to translate the existing terminology to that presented here. Programming of this nature is relatively simple using dBase, and certainly should be on any mainframe system.

The main intent of this paper is to present an example of a concise, flexible, and expandable coding system that is easy to apply and is useful in today's computer environment.

DESCRIPTION OF SYSTEM

Each term in the nature of specimen data is composed of two parts that are separated by a hyphen (-). The primary descriptor acts as the noun of the code. It may be followed by a hyphen and a secondary descriptor which acts as an adjective.

The primary descriptor indicates the physical parts of the specimen that have been prepared (Table 1). It also denotes whether the specimen is dry or in fluid, except in the case of organs or specific anatomical parts of a mammal.

The secondary descriptor is used in conjunction with the primary descriptor to indicate a less common preparation method (Table 2). Because the majority of skins in the collection are prepared as study skins, it is assumed that the skin is

Table 1. Primary descriptor codes.

Code	Definition
SN	skin
SK	skull
SL	skeleton (skull + post-cranial skeleton)
SS	skin + skull
SSS	skin + skull + skeleton (post-cranial skeleton)
ALC	whole specimen in alcohol
ALC SK	whole specimen in alcohol, skull removed
GLY	whole specimen in glycerin (cleared and stained specimen)
ANTLER	antler(s) (from Cervid)
HORN	horn(s) (from Antilocaprid or Bovid)
BONE	bone(s)
BACULUM, BALEEN, HEART, STOMACH	infrequently collected part of skeleton or specific anatomical part or organ that warrants being noted
CARCASS	remains of a mammal which has had the skin removed
EMBRYO	embryo (used when mother and embryo(s) bear the same accession number)
HEAD	head
MANDIBLE	mandible

a study skin if it has no secondary descriptor. Other types of skin preparation include flat skins, tanned skins, skins mounted by a taxidermist, and skins prepared as dry specimens after having been stored in alcohol. For whole specimens, the secondary descriptor indicates specimens that have been freeze-dried, mounted, or mummified. Skull and/or skeletal material can include horns, antlers, or skulls mounted on plaques, skeletons mounted on a stand, skulls or skeletons *in situ* or enclosed within a specimen, or material prepared from a specimen previously stored in alcohol. Carcasses and anatomical parts of specimens can be stored in a preservative fluid.

Also included in the nature of specimen field is information concerning the condition of the specimen. This information is particularly useful when filling out loan requests where damaged or partial specimens are not required. It is also helpful when choosing specimens for display or teaching purposes. Its intent is not to document sufficient information for a detailed condition report upon a particular specimen. Ideally this data should be captured for the whole collection; however, this is not a practical goal for most collections. The priority is that large incoming collections of a single species can easily be documented by technicians that are preparing them, before specimens are placed in boxes. When good specimens are required, the physical search is dramatically reduced.

The condition terms in Table 3 are used where applicable. The physical part of the specimen is always stated first with the appropriate adjective following. This way, listings of terms are sorted alphabetically by noun rather than adjective.

Table 4 illustrates some examples of completed nature of specimen data. Most specimens in the mammal collection at the ROM can be described by a single term involving a primary descriptor code (Table 4, examples 1 and 2). A single specimen, however, may have several phrases describing it. A semi-colon is used to separate one term or phrase from another (See examples 3, 5, and 6). Data are

Table 2. Secondary descriptor codes.

Code	Definition
	Carcass or anatomical part stored in a particular fluid:
-ALC	alcohol
-GLY	glycerin (cleared and stained)
	Other less common preparation methods:
-ALC	dry specimen preparation from a specimen stored in alcohol
-ENCL	enclosed within a specimen
-FLAT	flat skin
-FDRY	freeze dried
-MTD	mounted (horn(s), antler(s), skull, head, skeleton, or entire specimen)
-MUM	mummified
-TAN	tanned

entered in order of priority, so that the first term refers to the treatment of the skin, skull, and/or skeleton. Where necessary, terms appear in the order of skin, skull, then skeleton (See example 6).

Codes may be added that follow the basic logic and structure of the system presented here. The mammalogy tissue collection at the ROM is entered into a separate database from the main collection because of its temporal nature. Yet many collections maintain a single collection database. A primary code for tissue (perhaps, "TISS") could be used with secondary codes of a single letter to indicate the specific tissue(s). For example, the separate terms "TISS-H" and "TISS-K", or alternatively a single term like "TISS-H,K" could be used to represent heart and kidney tissue.

Data concerning non-anatomical or non-mammalian material associated with a specimen, like blood smears, karyotypes, or parasites, appear in separate fields from nature of specimen on the ROM's mammalogy database. However, appropriate codes could easily be developed if a database or collection manager wished to document all of these data in the nature of specimen field.

Finally, there will always be anomalous and sporadic data associated with

Table 3. Terminology used for describing the condition of a specimen.

Noun	
CRANIUM	part of specimen being described (cranium + mandible make up the skull)
MANDIBLE	
SKIN	
SKELETON	
Adjective	
ABSENT	if the whole cranium or mandible was never associated with the specimen
DAMAGED	broken, cracked, in pieces, nicked, predated, etc.
MISSING	if a part of a specimen has become misplaced
PARTIAL	if a specimen received is incomplete or obvious parts have been irretrievably lost somehow
SEPARATED	refers to mandibles, which frequently become disassociated during preparation

Table 4. Some examples of complete data entered in the nature of specimen field.

1. SSS
study skin, skull, and post-cranial skeleton
2. ALC SK
alcoholic specimen whose skull has been removed and prepared as a dry specimen
3. SSS-FDRY; SL-ENCL
skin with skull and post-cranial skeleton within, freeze dried for display
4. HORN-MTD; CRANIUM PARTIAL
horns mounted on a plaque; the horns are attached to part of the cranium
5. SSS-TAN; STOMACH-ALC; SKELETON PARTIAL; SKULL DAMAGED; MANDIBLE MISSING
skin (tanned), skull, skeleton; stomach in alcohol; partial skeleton; skull that is damaged (e.g., cranium partially crushed), mandible cannot be located
6. SN-FLAT; SL-MTD; EMBRYO; UTERUS-ALC
skin (flat); skeleton (skull plus axial skeleton) mounted; embryo(s) retained (always preserved in alcohol); uterus in alcohol

specimens for which the development of codes is not necessary or practical. This does not lessen the importance of such data, nor lessen its need to remain associated with the specimen record. However, the frequency of searching the database for this type of data will probably be low. Thus the need for strict consistency in terms is not as pressing as it is for data that are recorded, used, and searched for frequently.

SUMMARY

The nature of specimen codes presented are additive. The root or primary descriptor refers to the physical entity and the preparation method or secondary descriptor is appended when necessary. Frequently, with such a hierarchical structure, searching the database for a particular part of specimens can be done by using one or several search terms. For example, to search for all skulls (dry preparations) one would search for all occurrences of the substrings "SS", "SK", and "SL", and not "ENCL". The substring "ENCL" excludes specimens with the skull encased by the skin as in mummified, freeze dried, or mounted specimens.

There are two difficulties in this system arising from its attempt to make a compromise with codes traditionally used at the ROM. First, skeleton has two connotations. "SL" means skull plus post-cranial skeleton and the third "S" in "SSS" means post-cranial skeleton. Using the codes SS and SSS compromise with tradition. For optimal retrieval these codes should be broken into the individual primary descriptors "SN; SK" and "SN; SK; SL", respectively. "SL" should refer to the post-cranial skeleton only. With this modification, searching for all skulls would be simplified to searching for the substring "SK" and not "ENCL".

Second, the "ALC" and "-ALC" codes (and, similarly, the "GLY" and "-GLY" codes) are somewhat redundant. Using "ALC" and "GLY" compromise with tradition. As a solution to this redundancy problem, a single primary descriptor for "whole specimen", such as "WS", could be used; the appropriate fluid preparation method would then be described by the secondary descriptor (e.g., WS-ALC; SK).

The coding system presented here standardizes terms, syntax, and punctuation. It is concise, flexible, expandable, relatively easy to learn and apply, and an advantageous compromise between tradition and computer needs. Entry time is shortened by the concise content and straightforward conventions. The code is precise and short, thus meeting the space requirements for printing understandable and legible specimen labels and cards.

This paper is intended to communicate solutions to problems encountered commonly. It is hoped that the code presented here will permit and encourage standardization of terminology, syntax, and punctuation for important specimen-related data. In turn this will facilitate sharing of data between institutions (Roberts, 1985; Cole, 1970).

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BOOK REVIEWS

MATERIALS FOR CONSERVATION, 1987, C. V. Horie (Butterworths, London, 281 pp.). As one of the latest in the Butterworths Series in Conservation and Museology, Velson Horie's *Materials for Conservation* is a welcomed addition to the growing library of reference material designed for the museum professional. Its primary audience is conservators, but anyone responsible for collections care or researching material interactions would find this publication informative. The author states his purpose is providing background information on "the properties of organic consolidants, adhesives, and coatings as they effect the treatment of objects." The book takes the complicated field of Polymer Science and clarifies it, not through simplification but through organization. Presented as a review of resins traditionally used in conservation, the book is a valuable resource for information on history of use, stability, solubility, testing, and interpretation of manufacturer's data.

The first portion of the book deals with an overview of the physical and chemical properties of polymer chemistry. This portion of the text provides information especially critical to the understanding of later sections of the book. Here, sections cover such subjects as mechanical properties of resins, glass transition temperature, molecular weight and size, testing and identification of representative polymers. Additionally, health hazards, solubility parameters, and relevant working properties of resins are discussed. Subjects are covered clearly and do not require a strong background in chemistry to be understood.

The second section is really a survey of the individual polymers likely to have been used in conservation or preparation as consolidants, adhesives or surface coatings. Each material is handled in a similar way. The chemical composition, origin and method of manufacture is described for each generic group. Next, its conservation application is discussed. This is supplemented with adequate literature references to direct the reader to primary sources for further information. Problems and concerns about effects on objects, stability, and reversibility are indicated where appropriate. As a practicing conservator, the author illustrates many points with excellent photographs or examples. Especially helpful is a practical discussion on solvents available for each material.

The appendices for the text are valuable for those likely to use the book for reference. Charts and diagrams related to such properties as elasticity and stability, solubility and solvent properties, labeling for hazards and warnings, and lists of manufacturers are included. References that have been cited are listed fully. The subject index allows the text to be quickly referenced from a number of perspectives.

Throughout, information has been selected with the intention of creating a text which can be easily used and read. There are points, however, where it seems that more specific information is needed, but ample guidance for further reading and research is present.—*Carl Patterson, Rocky Mountain Regional Conservation Center, 2420 South University Blvd., Denver, CO 80208-0508.*

CONSERVATION OF NATURAL HISTORY SPECIMENS: SPIRIT COLLECTIONS, 1989, C. V. HORIE, ED. (The Manchester Museum and Department of Environmental Biology, The University of Manchester, Manchester M13 9PL, UK. viii + 115 pp. £12.50 plus £2.00 postage and £3.00 currency conversion fees if not paid in pounds sterling). This volume records the proceedings of a symposium held on 1 June 1989 at the University of Manchester, under the auspices of the Manchester Museum and the Department of Environmental Biology, the University of Manchester. Comprised of nine papers that deal with aspects of the fluid preservation process and its effects on a range of natural history specimens, the volume includes: fluid fixation and preservation processes (R. W. Stoddart); methods for preserving color of displayed animal tissues (R. D. Lee); historical preservation methods (R. Down); health and safety considerations (F. M. P. Howie); costs and benefits of fluid-preserved collections (J. F. Peake); storage containers (R. J. Lincoln); specimen conservation (S. J. Moore); case study on curation of a small collection (M. Reilly); and a bibliography, unannotated, on liquid preservation of biological material (G. Stansfield). These papers present a fairly good overview of the problems and limitations faced by those dealing with these special collections.

Although most of the papers provide wonderful vignettes elucidating history, problems, and successes of fluid preservation, perhaps no paper exceeds the impact of the opening overview by Dr. R. W. Stoddart, Department of Pathology, University of Manchester. Filled with as much detail as is perhaps possible in a short paper, this is the material everyone working with fluid-preserved specimens is aching to read. Elaborations of fine structure of plant, animal, and fungal tissues and the interactions with chemicals utilized in fixation and preservation, are fairly easy to follow once one dusts off one's physiology/biochemistry dictionary. It is unfortunate the course could not go on to delve into rooms whose doors are cracked ajar by this paper.

Of special note, too, is the paper on conservation of specimens by S. J. Moore, Department of Zoology, British Museum (Natural History). Providing information on treating specimens which have undergone deterioration, this should stand as a "must-read" for all those who, like myself, may have in the past, upon encountering a jar of limp glop in the collection, simply raised eyes skyward, while turning said jar down toward the drain. Notes on long- and short-term experiments of fixative and preservative efficacies on mammalian tissues are especially interesting.

Most papers lack a summary, and many lack complete bibliographies. Taken as a whole, however, the papers make excellent reading, complementing each other well. I suspect this work would hold equal fascination for others in any way embroiled in the world of fluid-preserved collections, and serve to place these collections in perspective in the museum setting for those not so afflicted. It would be a logical next step to have individual authors enrich their respective sections and pursue peer review and publication of their work in a more stringent form. This would address the too many typographical errors in one paper (Down), some distracting overstrikes and poor text-figure reproductions in another (Moore), and the vague feeling that pieces of information seem lacking here and there. Horie states the case well in the opening remarks: these "bare bones" [referring to the papers as reproduced here, without the discussion that ensued or the demonstra-

tions presented during the day course] can only be considered an initial step towards "a process . . . that will generate a group of trained conservators specializing in aspects of natural history material." I would further add, these "bare bones" do much to build a more informed constituency of collections staff worldwide.—*Arnold Y. Suzumoto, Zoology Dept., Bernice P. Bishop Museum, Box 19000-A, Honolulu, HI 96817-0916.*

WOMEN ANTHROPOLOGISTS: A BIOGRAPHICAL DICTIONARY, 1988, U. Gacs, ed. (Greenwood Press, Westport, CT, 428 pp.). The book contains 58 biographical essays of international women anthropologists: foremothers born before 1901 and the second generation, born 1901–1934. Among the criteria for inclusion in the book were pioneering accomplishments in anthropology and examples of age, sex, and racial discrimination.

Progressing beyond a reiteration of secondary sources, many essayists conducted interviews or corresponded with their subjects. Others contacted colleagues and former students in order to obtain a fuller picture of their subject's private and professional life. A few essayists consulted archival repositories for their subject's papers. The essays were authored by female and male anthropologists, students and museum professionals, and vary in length, emphasis, scope, and quality.

The book is both pleasing and vexing. Positive features include essays on dancer Katherine Dunham and writer Zora Neale Hurston (both of whom also appear in the *Biographical Directory of Anthropologists Born Before 1920*, recently compiled by the Library-Anthropology Resources Group, but who might have been omitted from a traditional compilation of anthropologists), a focus on problems encountered by women during fieldwork, examples of female-female mentoring beyond the traditional male-female mentoring of Boas and Malinowski, and economic issues involving publications and tenure. Unfortunately the book's faults overshadow these features.

Citing the omissions of archaeologists, ethnologists, and Third World women from a work which does not attempt to be encyclopedic may appear overly judgmental; yet one must question why the following women, among others, were omitted: folklorist Martha Beckwith (1871–1959); Anna Gayton, Lowie Museum curator; Sophie Aberle, first woman member of the National Science board; Angie Debo (1890–1988), author of *The Rise and Fall of the Choctaw Republic*, *The Five Civilized Tribes of Oklahoma* and *And Still the Waters Run*; Helen Roberts (1888–1985), a pioneer in ethnographic field recordings; and Elizabeth Colson, the third woman anthropologist elected to the National Academy of Science in 1977 (the first were Frederica de Laguna and Margaret Mead in 1975).

The book's most disturbing feature is its apologetic tone. Examples of language bias include "married to her profession," having "close women friends" but "romantic involvements" with men, and "successfully interacted" with male colleagues. One cannot imagine such language applied to biographies of male counterparts. Excuses are frequently made for unmarried women, whose lives and relationships are trivialized.

Sadly, little attention is directed to interdisciplinary activities. The introduction and essays contain brief references to the wealth of creativity expressed by these

women in their poetry, short fiction, novels, etc. This "aesthetic/scientific" dichotomy is explained as the result of "serendipitous circumstance," the influence of family or friends, or the result of life crises. Given recent publications on the lack of mainstream participation by women in their chosen professions, significant attention should be directed to the outsider stance of many of the foremothers of anthropology.

The two appendices offer general information, such as fieldwork areas and a chronology of birthdates. A strong Western bias is evidenced in the fieldwork areas. For example, North America is subdivided by region, but no similar attention is given to Oceania or Africa.

The index, footnotes, and individual bibliographies are particularly frustrating when relating one essay to another. For instance, *Pioneers of American Anthropology*, edited by June Helm, does not appear in Helm's bibliography, but rather in the bibliography of Nancy Lurie, a contributor to the Helm volume.

The general bibliography is replete with the writings of deceased male anthropologists and neglects important examples of contemporary feminist scholarship in anthropology. Absent are the writings of Sharon Tiffany, Rayna Rapp, Michelle Rosaldo, etc. One wonders how different the biographical dictionary would have been if these women were involved in the book's compilation.—*J. Miller, Field Museum of Natural History (current address: Archives and Special Collections, Medical College of Pennsylvania, 3300 Henry Ave., Philadelphia, PA 19129).*

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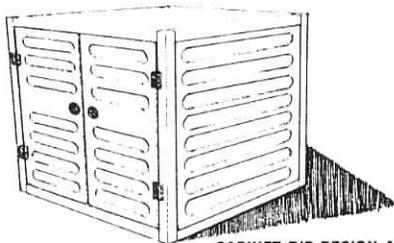
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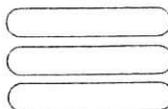
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