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On the Dissection of a Female Asian Elephant (Elephas maximus maxiums Linnaeus, 1758) and Data from Other Elephants

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Cover Page Footnote

This elephantine project would have been virtually impossible without the tremendous help received from the Ringling Bros. and Barnum & Bailey Circus, various departments within Wayne State University, the numerous individuals involved, and the anonymous donors. The officials and other individuals at the Ringling Bros. and Barnum & Bailey Circus (Irvin and Kenneth Feld, Daniel C. Laughlin, Franz Tisch, Jim "Chico" Williams) were generous, very understanding and accommodating. With regard to the departments within the University, the following deserve special credit: Department of Biological Sciences (John D. Taylor, Chairman; John W. Cosgriff, Vice Chairman, and William L. Thompson, Director, Natural History Museum); Wayne State Fund (Calvin D. Bogart, President, and Joseph L. Gualtieri, Acting Manager); College of Engineering (John Hayden and Dean Stanley K. Stynes); Center for Instructional Technology, Photographic Services (Kathy Morehead, Chief Photographer and very able worker, Rick Bielaczyc, and Tom Roberts, Chairman); Anatomy Department (Harry Maisel, Chairman, Nicholas Mizeres, Vic Lakits, Mortuary Supervisor, and Jim Niedbala); Department of Mortuary Science (W.D. Pool, Director, and Gordon W. Rose, Chairman); Staff of the Science Library (especially Richard C. Manikowski). Among the individuals involved, the following deserve a special note: Sandra Lash toilingly organized the teams while we drove with Iki from Florida, and Mildred Hurt, with her special drive and ability, accomplished things which none of us believed could be achieved. Michael Baccala, Rick Bielaczyc, Marlene Bulgarelli, M. Pam Bedore, Anthony Helinski, Kathy Morehead, George Overbeck, Sue Raymer, and Eyal Shy devoted long hours beyond expectation. Lee Peterson and Al Wilson (Science Shop, Department of Biological Sciences) skillfully made the surface integrator. Vic Lakits was helpful during embalming and subsequently in obtaining human brain weights before and after preservation. And last but not least, Dick Frederick, the able crane operator of L.W. Connelly Company, whose skillful maneuvering of the carcass enabled us to complete the unloading successfully. In addition, we wish to acknowledge the help received from the Knoxville Zoological Park, Knoxville, Tennessee, and M. Donald McGavin, D.V.M. of the University of Tennessee in obtaining organs and tissues from Ole Diamond and Hazel for comparison. We also wish to acknowledge the help received from Rex Williams of the Circus Vargas, the Veterinary staff (W.P. Barclay, G.A. Beroza, J.J. Foerner, and T.N. Phillips) at the Illinois Equine Hospital and Clinic, Naperville, Illinois, and D.C. Laughin, D.V.M. for informing us and letting J. Shoshani participate in the necropsy of Shirley and collect organs and tissue samples. L.D. Kintner of the University of Missouri-Columbia, sent us the eye of Toose for obtaining the dry weight of the lens, and Phillip T. Robinson sent us the reprint and slides about the tumor found on the vagina of Iki when she was alive. Axel Gautier and Darryl Atkinson provided us with detailed information on Iki's life while performing at the circus; Darryl also donated photographs of Iki when alive. Dry weights of the bones of Iki were taken with the help of Deborah Ady, Mary Ann Vaerten, and Francis Zoch. Elephant trainers Lee Keener, Raymond ("Tiny") Turvey, Bucky Steele, and Jody Craigmile were very helpful during the water consumption experiment (see Appendix V). Members of the class "Mounting a Mastodon" and friends participated in this experiment and collecting other data - particular thanks to Diane and Rene Blakeman; Anne and Burt Knox; Mary Ann, Sue and Robert Vaerten; Linda and Gordon Wyllie; Pat and Frank Zoch; Steve Cool; Mary Kelty; Sandra Lash; Jules Pierce; Karen Spodarek; and Toby E. Styles. Diane Blakeman (10 years old) carefully measured the time in seconds that it took the elephants to drink. Meticulous notes were taken by Mary Ann Vaerten. The Detroit Zoological Park provided us with specimens of exotic animals on which we made measurements. Bucky Steele was helpful in providing us with a specimen (Tulsa), a space and support for the dissection. We also wish to acknowledge the following individuals who participated in the dissection of Tulsa: Larry Banks, Joe Brown, Steve Howard, Pegi Jordy, Daniel Prikryl, Dennis Stanford, Robert Steele, and Lucille Sweeney. Dennis Stanford is particularly acknowledged for his help, without which the senior author would not have been able to partake in the dissection of Tulsa. We also wish to acknowledge the many anonymous individuals and the following persons who reviewed this paper and made constructive comments: Irven O. Buss, Richard M. Laws, Lawrence D. McGill, and Sylvia K. Sikes. Finally, the senior author would like to express his earnest appreciation to M. Pamela Bedore, Zirka S. Clark and Eileen D. Koglin for patiently typing and editing the many versions of this paper.

ON THE DISSECTION OF A FEMALE ASIAN ELEPHANT (Elephas maximus maximus Linnaeus, 1758) AND DATA FROM OTHER ELEPHANTS

by Jeheskel Shoshani et al.*

ABSTRACT: A 46-year old female Asian elephant (Elephas maximus maximus Linnaeus, 1758), named "Iki," died on July 8, 1980, at the Ringling Brothers and Barnum & Bailey Circus, Circus World, Haines City, Florida, USA. She was transported to Detroit and was dissected by the Elephant Interest Group (EIG) and friends, Department of Biological Sciences, Wayne State University. The purpose of this continuing study has been to collect data supplemental to that of previous workers, and to enrich knowledge of elephant anatomy, particularly in areas not thoroughly investigated in the past. Some of these findings were compared to those observed in other elephants: "Shirley", "Tulsa", and "Toose" and to the organs of "Ole Diamond" and "Hazel" (see Appendix II).

Measurements and weights were taken and samples were collected, including 218 skin samples for histological studies. Most of the observations, not only on Iki but also on other elephants, correlate with those of previous workers. To our knowledge, some of the data collected on Elephas maximus in these dissections have not appeared in literature. Following is a list of the new anatomical and pathological findings:

1. The presence of the trachea-oesophageal muscle was noted in one (Shirley) of the four elephants examined (Iki, Shirley, Tulsa and Ole Diamond); this muscle was identified under the microscope as a striated or voluntary muscle. The trachea-oesophageal muscle was described by Harrison (1850a). Watson (1872a) and Miall and Greenwood (1878) searched for this muscle unsuccessfully.
2. The intercommunicating canals uniting the right and left nasal passages of the trunk and the associated fibrous arches were absent in Iki and Tulsa, the only two elephants examined for this structure. These arches and canals were described by Anthony and Coupin (1925).
3. The volume of the nasal passages of the embalmed trunk of Iki when filled with water was 2.19 liters, and the computed volume of the trunk of Tulsa (computed from measurements at cross sections soon after death) was 3.08 liters. These measurements were compared to the trunk water-holding capacity of three live elephants, large, medium, and small whose maximum capacities were 10.47, 4.18, and 3.57 liters, respectively (Appendix V).
4. The dry weights of the eye lenses of Iki, Shirley, Tulsa, and Toose were measured. Data obtained so far indicate that the older the

(continued)

*Only the senior author has been credited because it is impractical to list all 76 co-authors on this paper (see * in the LIST OF PARTICIPANTS, Appendix I).

elephant the heavier its eye lens is (Table VI). The dry weights of the eye lenses of known-aged Asian elephants will be used to construct a growth curve similar to the curve constructed for the African elephant (Laws, 1967).

5. The percentages of dressed (skinned) forelegs weights to the total body weights of Iki and Tulsa were 5.72% and 4.43%, respectively.

6. The percentages of dressed hindlegs weights to the total body weights of Iki and Tulsa were 7.28% and 5.66%, respectively. The range for female African elephants as derived by Laws et al. (1967), is 5.3 - 5.8%.

7. The oculomotor nerve originated in Iki's and Tulsa's brains anterior to the caudal cerebral artery. In man, horse, cow, sheep, pig, cat, guinea pig, and chinchilla this nerve originates posterior to the caudal cerebral artery.

8. There were two branches arising from the arch of the aorta in Iki, Shirley and Tulsa, namely, the innominate (brachiocephalic) and the left subclavian arteries. The innominate artery gave rise to the right subclavian and the two carotids, an arrangement found by at least five other workers. Other researchers assert that there are three branches: the right subclavian, a trunk common to the two carotids and the left subclavian.

9. The maximum capacities of the stomach and intestinal tract when filled with water are 76.6 and 616.76 liters, respectively. These figures for the maximum capacity may be different from the true capacity. Our measurements are included for future comparisons.

10. The ratio of the total length of the intestinal tract (small and large intestines and caecum) to the body length, excluding trunk and tail of Iki was 11.69. (An error appears in <u>Elephant</u>, 1(4):45 - it should read "excluding trunk.") Corresponding ratios were calculated for other elephants, see Table V. These ratios were compared to other mammals and found to fall between the ranges of carnivorous, omnivorous and the lower ranges of herbivorous non-ruminant mammals.

11. The wet weight of Iki's skeleton comprised 16.48% of the estimated body weight at death. The total dry weight of bones, 20 months after death, indicated a 39.19% water loss.

12. A small ossified structure (possibly a sesamoid bone) was found at the proximal end and on the posterior side of the humerus between the common tendon of insertion of the <u>teres major</u> and <u>latissimus dorsi</u>, and the humerus.

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13. Two small "joint mice" were found in the elbow joint between the humerus and ulna. "Joint mice" are common features of chronic arthritis in humans and animals.

14. Deep grooves were observed on the femuro-tibia and on the humero-ulna and -radius articular surfaces. The two "joint mice" and the deep grooves are believed to be associated with arthritis.

15. Severe endometritis was reported to be the ultimate cause of death. To our knowledge, this is the only reported case of endometritis in elephants.

16. Suggestions and guidelines for further research are included in the CONCLUDING REMARKS.

Further examination of Iki's and other elephants' organs and tissues will enhance knowledge of elephant biology and will be useful in comparative studies. This elephant (Iki) was being studied for chronic arthritis (Clark et al., 1980). The pathological findings, especially with respect to the "joint mice" and the grooves on the articular surfaces, which appear to be associated with chronic arthritis, may be of special interest since they occur in humans and in animals large and small. This interest arises because the elephant has a mean life span similar to that of man.

INTRODUCTION

Authenticated reports of elephant dissections have been traced to Aristotle (384-322 B.C.), Galen (130-200? A.D.; see Galen, 1550), Moulines (1682), Blair (1710), Hartenfels (1723), Camper (1802), Cuvier and Laurillard (1810), Armandi (1843), Mayer (1847), Harrison (1847-1850), Gilchrist (1851), Vulpian and Philipeaux (1856), Hunter (1861), Watson (1872-1875), Miall and Greenwood (1878), Evans (1910), and Sunamoto (1931-1932). A brief summary on the works of these early anatomists is given in Benedict, 1936:7-13, and Miall and Greenwood, 1878:6-7. [see also Cole (1975).] The extensive list of references in Benedict (1936) and in Miall and Greenwood (1878) include many more pertinent references. General literature published since 1936 dealing with elephant anatomy includes: Osborn (1936-1942), King et al. (1938), Deraniyagala (1955), Frade (1955), Shindo and Mori (1956a - 1956c), Carrington (1958), Shimizu et al. (1960), and Sikes (1971).

This report summarizes our findings on the dissection of a female Asian elephant (Elephas maximus maximus) named Iki and compares these findings to the data collected for other elephants. Throughout this paper, descriptions of organs and tissues refer to Iki, unless stated otherwise. The purpose of this continuing study has been to collect data to compare with previous works, thereby, hoping to enrich knowledge of the anatomy of the elephant, particularly in areas not thoroughly investigated in the past. The dissection and the embalming of two legs and the head lasted five consecutive days and was conducted by the Elephant Interest Group (EIG) and friends, Department of Biological Sciences, Wayne State University, Detroit, Michigan, USA. A total of 136 persons was involved in the dissection project in one way or another, of which 76 individuals actually helped in the dissection (see Appendix I). An estimate of 1,000 working hours was calculated for the five days during which the operation lasted. A rough estimate of cost runs between US $6,000 and $7,000 (excluding dissectors' manhours).

Life History of Iki

Iki was born in Sri Lanka about 1934, transported to West Germany at about 2 years of age, and then to the United States (Ringling Brothers and Barnum & Bailey Circus) at 10 years of age. She performed in the circus in many shows until shortly before her death. Axel Gautier and Darryl Atkinson, who knew Iki for many years, informed us that she was a good natured elephant and never known to be pregnant. Iki had a history of progressive chronic arthritis and was treated accordingly. A benign tumor whose origin was not identified was observed on Iki's vagina (Fig. 1). The tumor was removed surgically (see Robinson and Meier, 1977). She moved more slowly the last two years of her life as her arthritis worsened. A few blood samples were collected during the last three years before she died and one within minutes after her death.

Iki died on July 8, 1980 at the winter quarters for the Ringling Brothers and Barnum & Bailey Circus, Haines City, Florida, USA. At 10:00 a.m. she drank water but refused food and became progressively more sluggish. Later, she stood in one spot and would not walk. With the aid of another female elephant called "Poopy" she was moved to the barn. At 12:30 p.m. she was breathing heavily, her mouth remained open, and her hind quarters steadily swayed. At 1:00 p.m. she was taken to the hay shed where she fell down and died between 3:15 and 3:30 p.m. The animal was covered with ice and insulated with hay and wet blankets. At her death Iki was estimated to be 46 years old and weighed 5,000 lbs. (2,267.95 kg).

DISSECTION, EMBALMING, AND DATA COLLECTING

Necropsy, Brain Removal and Transportation to Detroit

Wednesday, July 9, 1980, 6:30 a.m. - The elephant carcass was cold. About 1,000 ml (over one quart) of a white gelatinous/viscous substance was seen at the tip of the trunk. The necropsy was conducted by Daniel C. Laughlin, D.V.M. (who arrived from Illinois). Samples were collected for pathological analyses. Initial observations revealed a very inflamed uterus with numerous pendulous protrusions internally. The lungs seemed affected. Preliminary findings were summarized: "Probable cause of death is attributed to severe endometritis with a secondary lung infection". Subsequent laboratory analyses by L.D. McGill and E.D. Stoddard confirmed these findings. (See Appendix III for further details).

The brain was removed by Franz Tisch, Hezy Shoshani (who arrived from New York) and other people. A chain-saw was used to cut through the thick skull and tissues. Small sections of the brain were damaged, particularly at

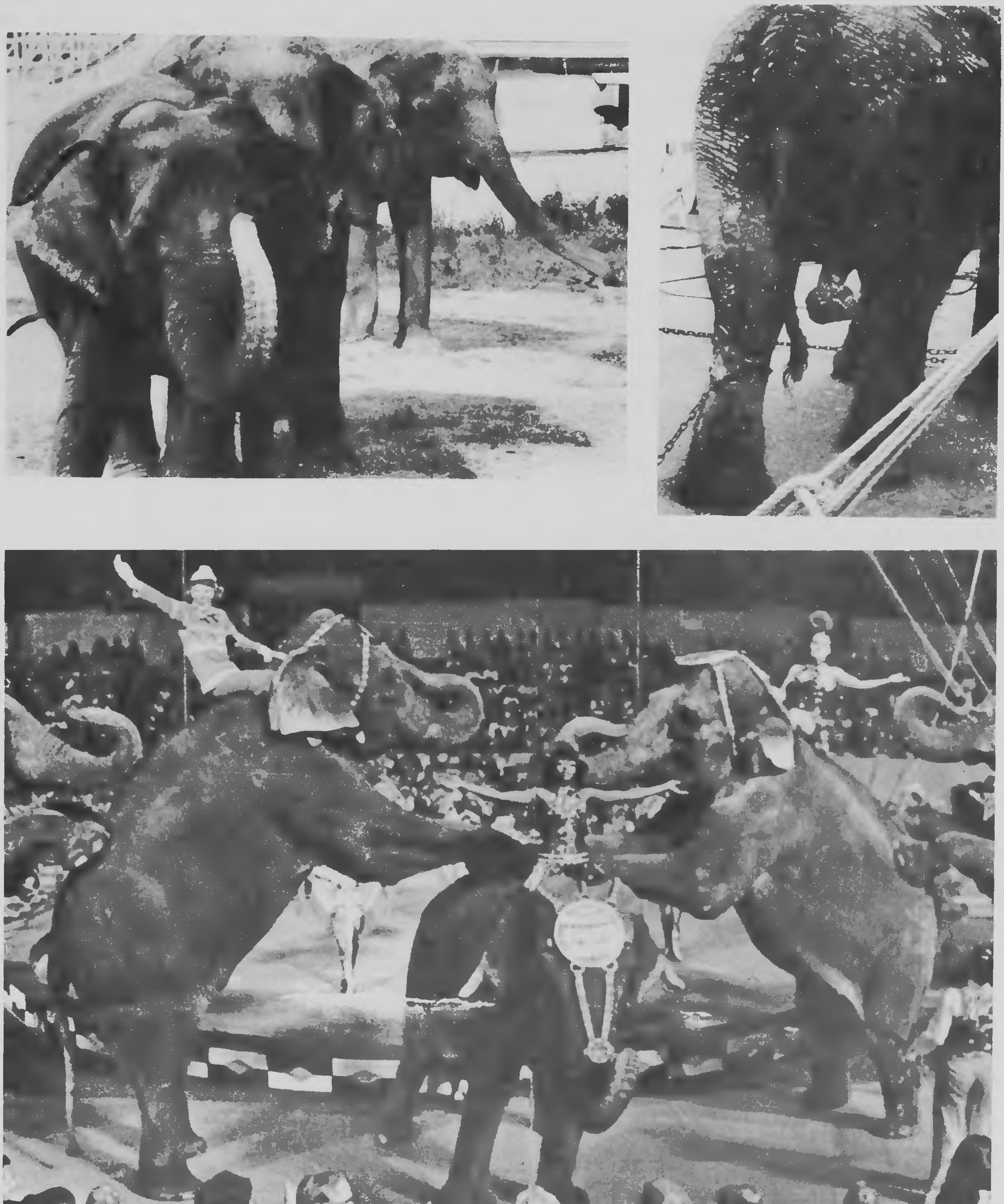

Fig. 1. Iki when alive. Top left: Iki, Targa, and Puppi, at Circus World, Haines City, Florida, 1979. Top right: pendulous benign tumor on Iki's vagina prior to removal. Bottom: Iki (center) during performance with the Ringling Bros. and Barnum & Bailey Circus.

the olfactory region. Necropsy, brain removal and loading onto a truck were completed at 2:30 p.m. The carcass was covered with 1,070 lbs. of ice and insulated with hay and wet blankets. The intestinal tract, brain, and other organs (held in separate plastic bags and surrounded with ice) were placed in large plastic barrels and the elephant was transported in a truck driven by Michael Baccala (who flew in from Detroit) and Hezy Shoshani. The truck departed at 4:00 p.m. July 9, 1980 and arrived at Wayne State University, Detroit, Michigan, at 7:30 p.m. the next day. Preparations for the elephant's arrival in Detroit were directed by Sandra Lash and Mildred Hurt.

At the time of arrival of the truck at the Engineering Building of Wayne State University, Health Officers and other officials had the carcass and barrels sprayed with Airkem Disinfectant and Odor Control (this product contains: dimethyl benzyl ammonium chloride, tetra sodium ethylene diamine tetra-acetate, essential oils, and inert ingredients) and Purina Odor Control, a deodorant and sanitizer (containing: isopropyl alchohol, essential oils, n-Alkyl dimethyl benzyl and ethylbenzyl ammonium chlorides, ethyl alcohol, and inert ingredients). We also decided to pack the animal and tissues with well-insulated dry ice, "to rest overnight and to start fresh the next morning."

Dissection at the Engineering Building, Wayne State University

Friday, July 11, 1980, 7:30 a.m. - Unloading and work on the intestinal tract was begun (Fig.'s 2, 3, 4). Some of the tissues were frozen and had to be thawed with water. There were three pieces of small intestine, five pieces of large intestine (colon), and two pieces of rectum. Measurements, weights and volumes (maximum capacity when filled with water) were taken; tissue samples were collected. Work on the intestinal tract including the stomach was directed by Eyal Shy and Susan Raymer.

The crane and its operator Dick Frederick arrived at 9:30 a.m.. Unloading of the carcass and placing it inside the building lasted over two hours. The animal was lying on its left side. Skinning began soon after external measurements (directed by Mike Baccala) were taken. Right fore- and hindlegs were dismembered and teams started to deflesh them, keeping track of the parts from which the muscles were removed. Respective weights of skin pieces, muscles and bones were recorded. In the process of defleshing the bones of the right foreleg, Dave Sabo and Sue ann Berbenchuk discovered two small ossified structures at the distal end of the humerus. The next day, Kathy Morehead discovered an additional small ossified structure. The latter was found at the proximal end on the posterior side of the humerus between the common tendon of insertion of the teres major, latissimus dorsi and the bone. It was bean-shaped, 17 mm long, 8 mm wide and 5 mm thick (Fig 5). The other two ossified structures were found close to each other on the distal-lateral and posterior end (corner) of the humerus within the area of the joint capsule. Both are oval-shaped, the larger measured 21 x 7 x 10 mm and the smaller 11 x 5 x 7 mm.

Other noteworthy findings on the skeletal system observed on later dates include bone-to-bone contact at the articular surface between the humerus and

Fig. 2. Unloading Iki at the Engineering Building, Wayne State University, Detroit, Michigan.

Fig. 3. Top: small intestine being filled with water to measure maximum capacity as shown in center bottom. Left to right: S.L. Raymer, J. Skoney, J. Shoshani in top; J. Skoney and S.L. Raymer at bottom. Bottom left: close up of a loop of small intestine,with blood and lymph vessels and nerves exposed. Bottom right: close up of lining of stomach.

Fig. 4. Omental bursa or greater omentum (a saclike mesentery which wraps around parts of intestines and stomach). Spider-web pattern represents blood and lymph vessels and nerves. Left to right: G. Overbeck, M. Bulgarelli, A. Helinski, S. Lash, J. Shoshani, H. Rossmoore, J. Engelhard, E. Shy, S.L. Raymer, J. Koenig, E. Efthyvoulidis, and M. Baccala. Inset: close up of omental bursa.

ulna and radius and an even more pronounced condition between the femur and the tibia. In the latter case, the distal-lateral condyle of the femur had ground against the tibial articulating surface so hard that the cartilage had worn off and the bones had five grooves on them, the deepest one being 2.25 mm in depth. This condition is known as chronic arthritis. We also found small chips of bone at various articular surfaces. These chips varied from tiny particles (1 mm) to large chips (1.7 cm). They were found, for example, on the distal end of the femur, in the knee joint, and on the articular surface between the first rib and the sternum. In addition, thoracic vertebrae 3, 4, 5, 6, and 7 were ankylosed at the spinous processes and partly on the ventral borders of the bodies of these vertebrae.

The ribs from the right side were disarticulated from the thoracic vertebrae and sternum in order to allow access to the lungs and heart. At the same time, the abdominal region was cleaned and organs were removed. The kidneys were badly decomposed as were the uterus and to some extent the

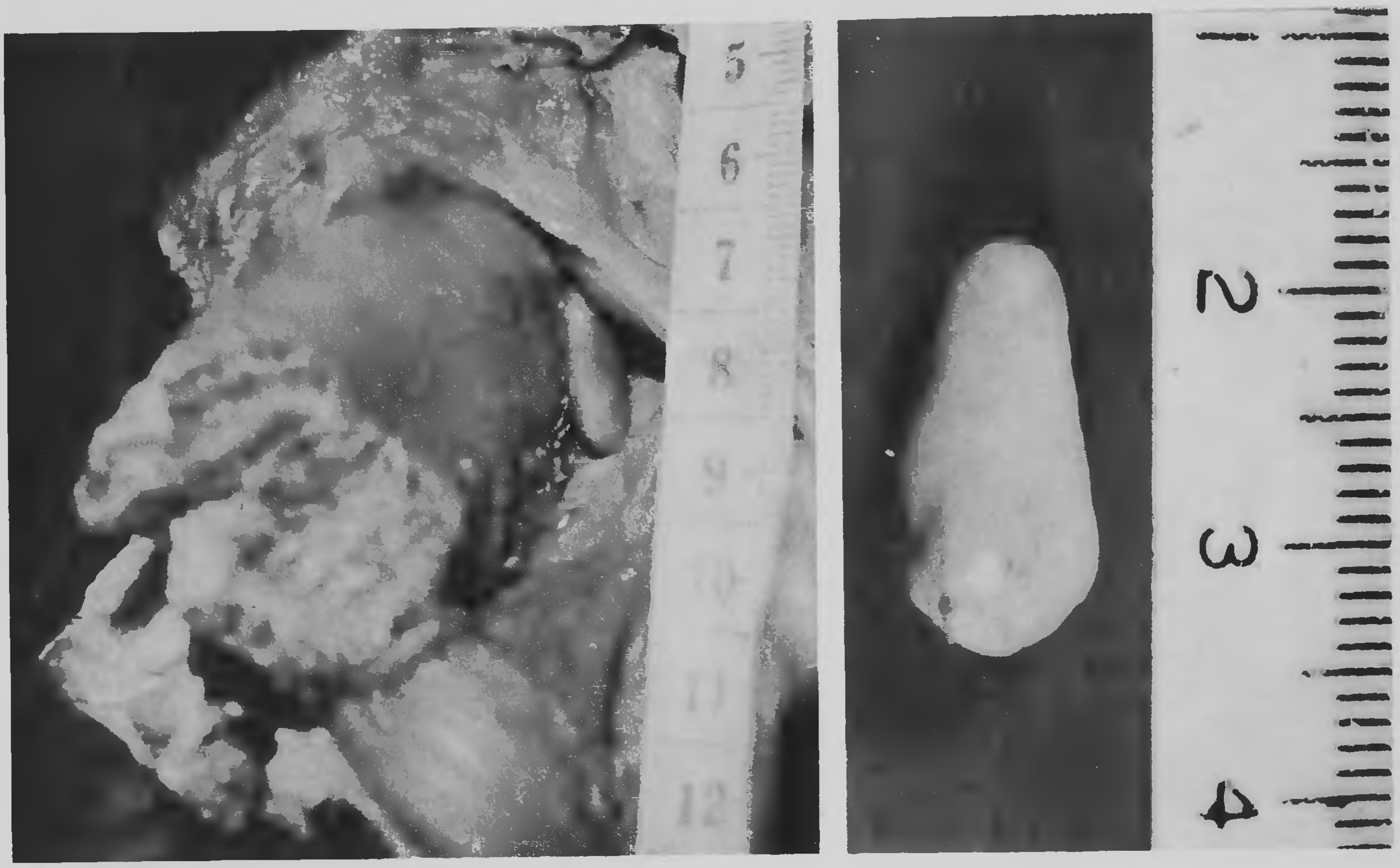

Fig. 5. Ossified structure (probably a sesamoid bone) in Iki. Left: structure *in situ* under the common tendon of insertion of *teres major* and *latissimus dorsi* at the proximal end of the humerus. Right: structure photographed to expose entire length.

liver. The liver had two lobes, the right being the larger. No gall bladder was seen. The spleen and pancreas seemed to be in good condition. The lungs had two lobes. Most of the lungs' surface appeared to adhere to the thoracic walls; there was no distinguishable pleural cavity. Similar observations were made by Watson (1872a), Miall and Greenwood (1878), Short (1962) and Sikes (1971). The trachea and esophagus, most of the diaphragm, and some parts of lung tissues were removed intact and preserved in 10% formaldehyde. Subsequent examination of the close connection between the trachea and esophagus revealed the absence of the *trachea-oesophageal* muscle, one of which was first described and figured by Harrison (1850a). However, this *trachea-oesophageal* muscle was found in Shirley, an Asian elephant. When dissecting Iki, we noticed that muscles in large masses for example, the legs, head, and those attached along the vertebral column were still in good condition. Those muscles in thin sheets as in the abdomen, diaphragm, and others were in various degrees of decomposition.

The heart of Iki was in good condition. The pericardium was tough and light colored, almost white. The heart had a distinct bifid apex. Unclotted blood was still found in the pericardial cavity. The heart proper was connected to the dorsal wall of the pericardial cavity by a thin fleshy tissue from just above the bifidal cleft to the middle of the heart. Between this attachment and the aortic arch and pulmonary artery (base of the heart), there was a space or a foramen large enough to allow a human hand to pass through with little distention of the surrounding tissues. In a subsequent examination of the heart, we identified all the blood vessels to and from the heart, including the unusual condition of the paired anterior venae cavae. The bifid apex and the paired anterior venae cavae were previously reported by Evans (1910), Hill (1938), Miall and Greenwood (1878), and Sikes (1971). Various measurements of the heart were taken and the splitting arrangements of the arteries from the aortic arch were compared to other elephants (see Table I and Table IV and under Discussion).

Saturday, July 12, 7:00 a.m. - Work on head, legs and other systems. The head and neck were surrounded by dry ice until they were separated from the rest of the vertebral column. Disarticulation was facilitated by the aid of an overhead winch. The left fore- and hindlegs were also dismembered; the foreleg was attached to the scapula and associated musculature, while the hindleg was attached to the left half of the pelvis (ilium, ischium and pubis bones and associated musculature). The head and neck and left legs were loaded onto a truck, packed in dry ice, and covered with hay and blankets, to await embalming. By late Saturday night the skeletal parts which remained to be cleaned were: the vertebral column with the left half pelvis, the left ribs, the sternum, and the first right rib attached.

Sunday, July 13, 7:00 a.m. - Work on the skin began. Large pieces of skin from the right foreleg, right hindleg, abdominal region and dorsum, thoracolumbar region, and tail were spread out on the concrete parking area and matched up to determine locations for skin sample collection. Workers had a difficult time matching the pieces since the ends were not marked and some were similar in structure and texture. Matching the skins in almost a jigsaw-puzzle manner was completed in over one hour. Teams were designated and 2-3 individuals worked on one piece of skin. Skin parts were measured and skin samples including hair were collected (Fig. 6). A total of 218 skin samples of various sizes was collected from marked locations on the five skin pieces. Of these, 205 samples were preserved in 10% formaldehyde (formalin) solution and the rest were preserved in 1% gluteraldehyde solution. Surface areas of the five pieces were measured with the surface integrator modified after Elting (1926) and made by Lee M. Peterson and Albert Wilson of the Biology Science Shop, Wayne State University. The surface integrator is a simple device having a cylinder of a known area with an attached digital counter. Each complete revolution of the cylinder is recorded as "1" on the counter; tenths of revolutions are also recorded. A surface area is computed by multiplying the number of revolutions recorded on the counter by the known surface area of the cylinder. In our case, the skin surface area as measured by George Overbeck for the above five parts was: $251.4 \times 200 \text{ cm}^2 = 5.03 \text{ m}^2$. The rest of the skin was measured, in parts, at a later date. Thereafter, each piece of skin was weighed (the weights of the samples taken were estimated and added to that weight), salted, and stored in a freezer. Work on the skin was completed at 3:00 p.m. Skin sections were air-dried, reweighed 22 months after death, and the water loss was recorded (see Table I).

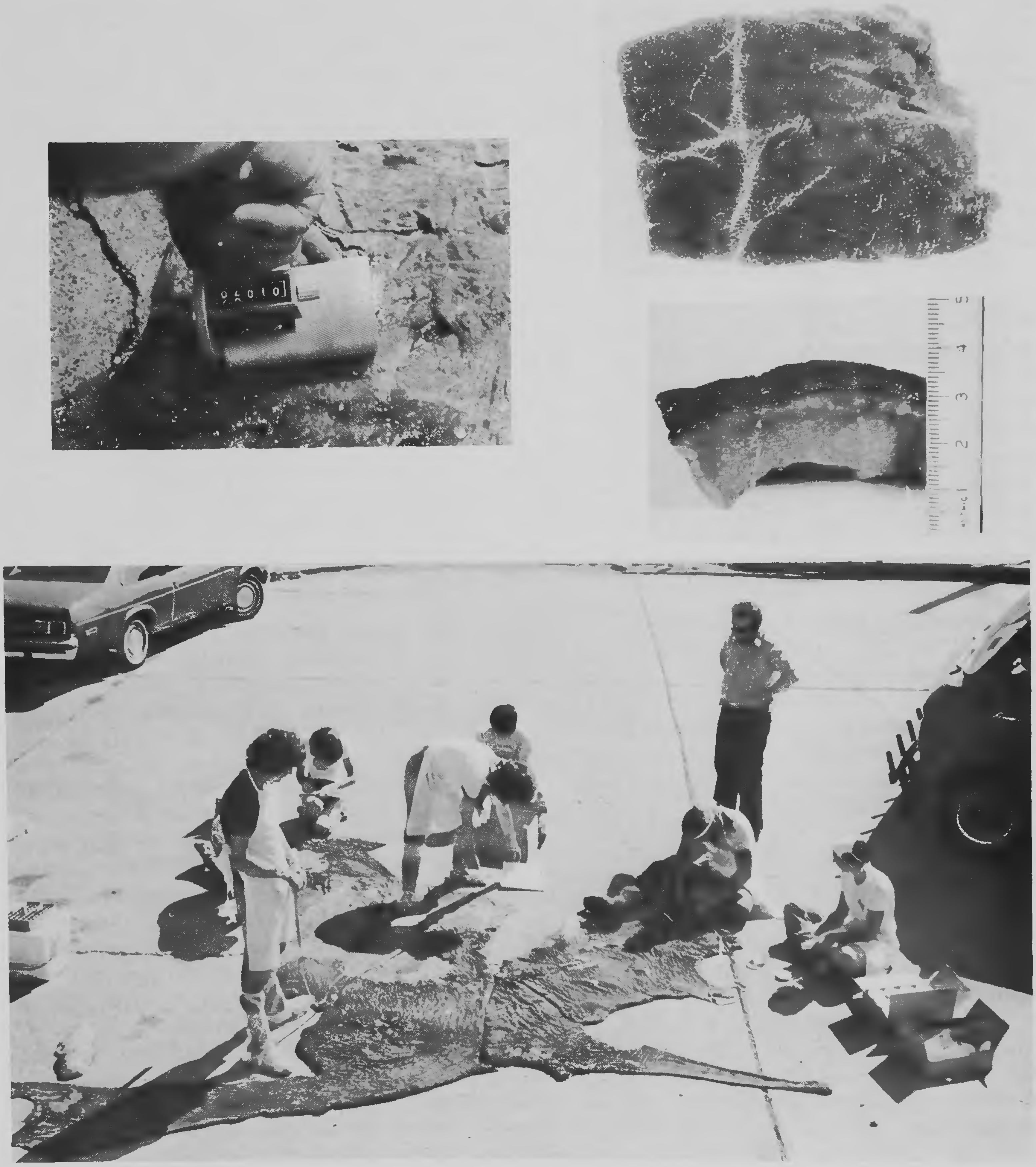

Fig. 6. Hide of Iki. Top left: using surface integrator to measure surface area. Holes in skin represent areas from which samples were taken. Top right: close up of skin, top view of sample below. Bottom: skin stretched on concrete while teams collect samples and data. Left to right: E. Shy, J. Koenig, S.L. Raymer, M. Bulgarelli, M. Baccala (sitting), H. Rossmoore, and S. Lash.

During the day some work was also done on the liver, rectum and anus, vagina and other parts of the reproductive tract and on the bones. The bones were cleaned of muscles and their wet weights were recorded. Subsequently, these bones were taken for final cleaning to the Dermestid Beetle Room of the Natural History Museum at Wayne State University and their weights were recorded 20 months later (see Table II). Once all the bones are cleaned, the group plans to reconstruct the skeleton.

Embalming of Head and Two Legs

Monday, July 14, 8:30 a.m. at the Mortuary, Scott Hall, School of Medicine, Wayne State University.

Left hindleg, left foreleg and head had been on a truck packed in dry ice and insulated with hay since Saturday afternoon. The left hind leg was thawed with water and transferred to the embalming table using an engine hoist and a "Hi-Lo" Power forklift. The deep femoral artery was identified by Nicholas J. Mizeres, and the embalming, directed by Victor T. Lakits, Jr., began (Fig 7).

Fig. 7. Embalming of Iki's left foreleg. Inset: pump used to force (15 lbs/sq. in. pressure) embalming fluid into leg arteries. Left to right: T. Gaskins, M. Bulgarelli, D. Smith behind, C. Heberer, J. Shoshani, and V. Lakits.

The embalming process involves the insertion of an arterial tube into a major artery and subsequently connecting the embalming fluid tube to the pump which was set at 15-pound/sq. inch pressure. The embalming fluid is made up of formaldehyde (1 part), phenol (1 part), glycerine (1 part), alcohol (5 parts), and water (14 parts).

While embalming the elephant leg there were many leakages from the arteries that were severed during leg removal. The severed arteries had to be clamped with hemostats to allow free fluid flow to the distal end of the leg (Fig. 7). Application of fluid was continued until the tissue swelled and changed to a lighter color. The signs of a good embalming are the swelling and the color change of the tissue and subsequent slow seepage of fluid from the outer surface. In the areas where these signs were not seen (i.e. where circulating fluid had not reached) a trocar was used. A trocar is a long, thin, metal tube perforated at its tip, which is inserted into the muscle tissues and through which the embalming fluid is injected. Total amount of embalming fluid applied to the hindleg was 35 gallons (about 159 liters). The leg was covered with absorbent tissue soaked with embalming fluid, wrapped in plastic sheets, taped and readied for storage. The left foreleg was treated in a similar manner; it took 32 gallons (about 145 liters) of fluid.

Nipples and mammary tissues of both left and right sides were removed with the left foreleg. Both nipples were almost circular in shape and the diameter of the base measured 3.2 cm and the height, 2.0 cm. The left nipple had 12 lactiferous (milk) ducts, eight of which were plugged with white matter (Fig. 8, left). Reddish-white viscous fluid was squeezed out of the remaining four ducts. The right nipple had 10 lactiferous ducts, one was

Fig. 8. Left: left nipple of Iki showing lactiferous ducts. Right: right eye lens of Iki.

plugged. No fluid exuded from the ducts when the mammary gland and nipple were squeezed.

The right eye lens was removed by S. Murphy to be studied by him and by H. Maisel (Fig. 8, right). The left eye and lens were removed by M. Baccala and J. Shoshani from the embalmed head. The left lens was freeze-dried and the dry weight was recorded (see Table VI). The right pinna and part of the external acoustic meatus were removed and studied by A. A. Muraski and D. W. Nielsen. The embalming of the head and trunk presented some problems since many blood vessels were cut in the process of brain removal. Leaks from various foramina were stopped using tapered plastic plugs (trocar buttons) as used in human cadaver preservation. The trunk was embalmed through the right infraorbital artery; it was curled when work began and gradually it straightened, stiffened, changed color, and slowly leaked fluid. It required 13 gallons (about 59.0 liters) of fluid. The rest of the head and neck were trocared with an additional 19 gallons (about 86.3 liters) of embalming fluid. Embalming procedures were completed on Tuesday, July 15, at 6:00 p.m.. Careful notes of these procedures were taken by M. Bulgarelli.

Other Data Collected

The embalmed legs and head (including the preserved brain and trunk) of Iki were studied at later dates. The left foreleg and hindleg were partly decomposed at the proximal end where the blood vessels were severed; the rest of the legs were in good condition except for the soles which were also partly decayed. Normally Iki's sole appeared flaked (Fig. 7). We were able to identify major muscles, blood vessels, and nerves. Rich blood and nerve supplies were observed at the manus ("hand") and pes ("foot") regions. While working on the left foreleg, we noticed additional pathological signs of arthritis to those observed on the right leg bones. These included: a small osteophyte on the lateral side of the glenoid fossa of the scapula, a small osteophyte on the distal-anterior end of the humerus, a fracture of the anterior-medial articular surface of the ulna, and wear marks on the proximal facets of the scaphoid and lunar bones. Similar signs on the left hindleg included: eroded head of the femur and deep grooves between the femur and tibia articulating surfaces (very similar to the grooves found on the right hindleg). In addition, workers found pendulous soft-tissue structures protruding from the surrounding tissues at the knee and acetabular capsules, and feet. See also Benedict (1936:112) for description of the arthritic skeleton of "Bolivar" by H. Fox.

Major subdivisions of the brain and all the cranial nerves were identified. Measurements were taken and noticeable features of the brain were recorded (see Table I and under Discussion).

In the head (Fig. 9 and Fig. 10), most large muscles and all the salivary glands were identified. The glands include the left parotid (18.0 x 12.0 x 9.5 cm), the left sub-maxillary or sub-mandibular (11.0 x 3.5 x 1.0 cm), the sublinguals (Left: 8.0 x 2.0 x 12.0 cm; Right: 5.0 x 3.0 x 12.0 cm), and the buccal glands (a total of 10 distinct aggregates of glands in the

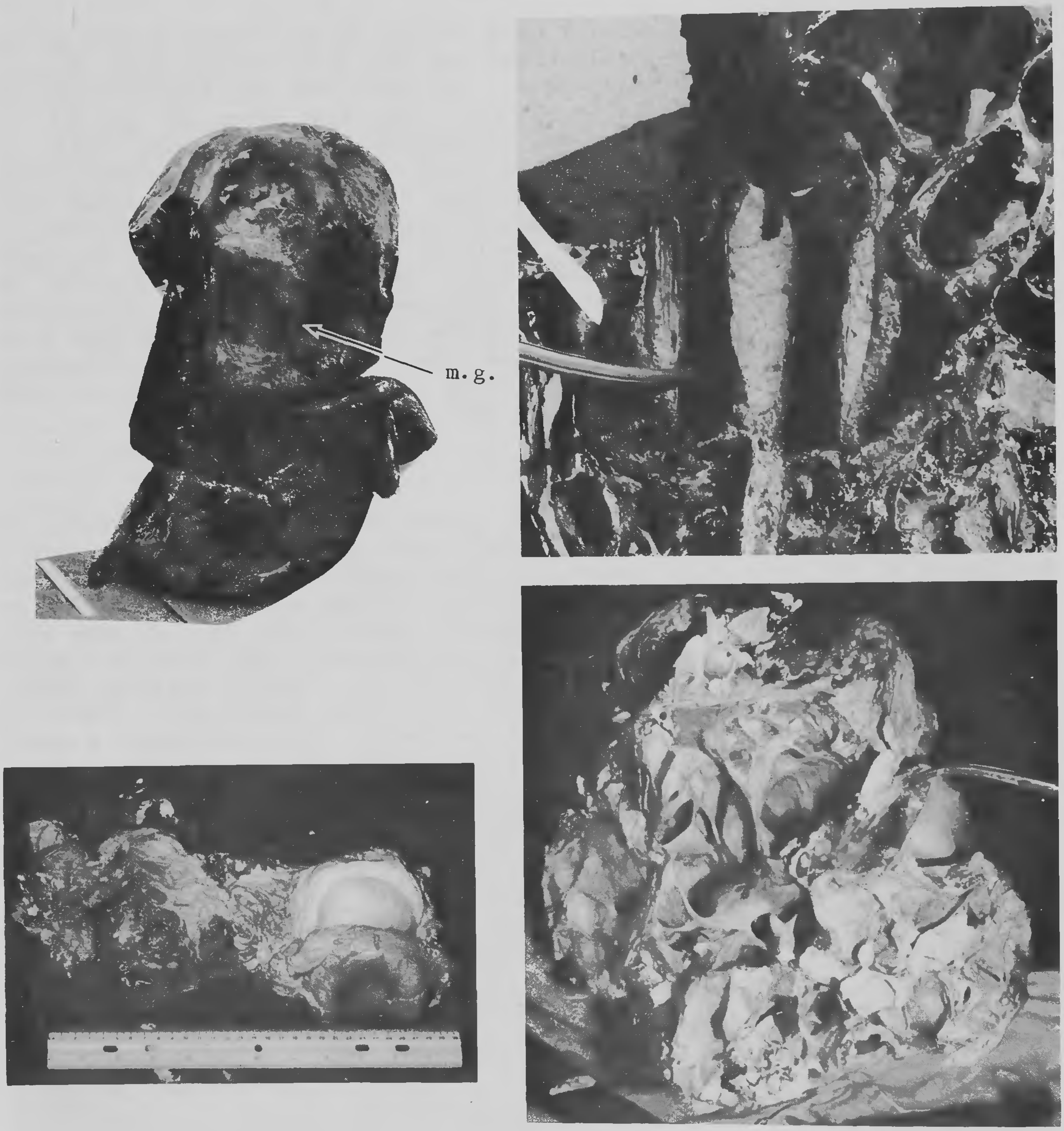

Fig. 9. Top left: Iki's skull and tissues, part of rostrum removed with trunk. Arrow indicates opening to left musth gland (m.g.). Top right: alinasal cartilages and opening at base of trunk. Bottom right: air cells or honey comb pattern at the ear region, characteristic of elephant skull. Bottom left: right condyle of mandible and double concave cushion between condyle and mandibular fossa.

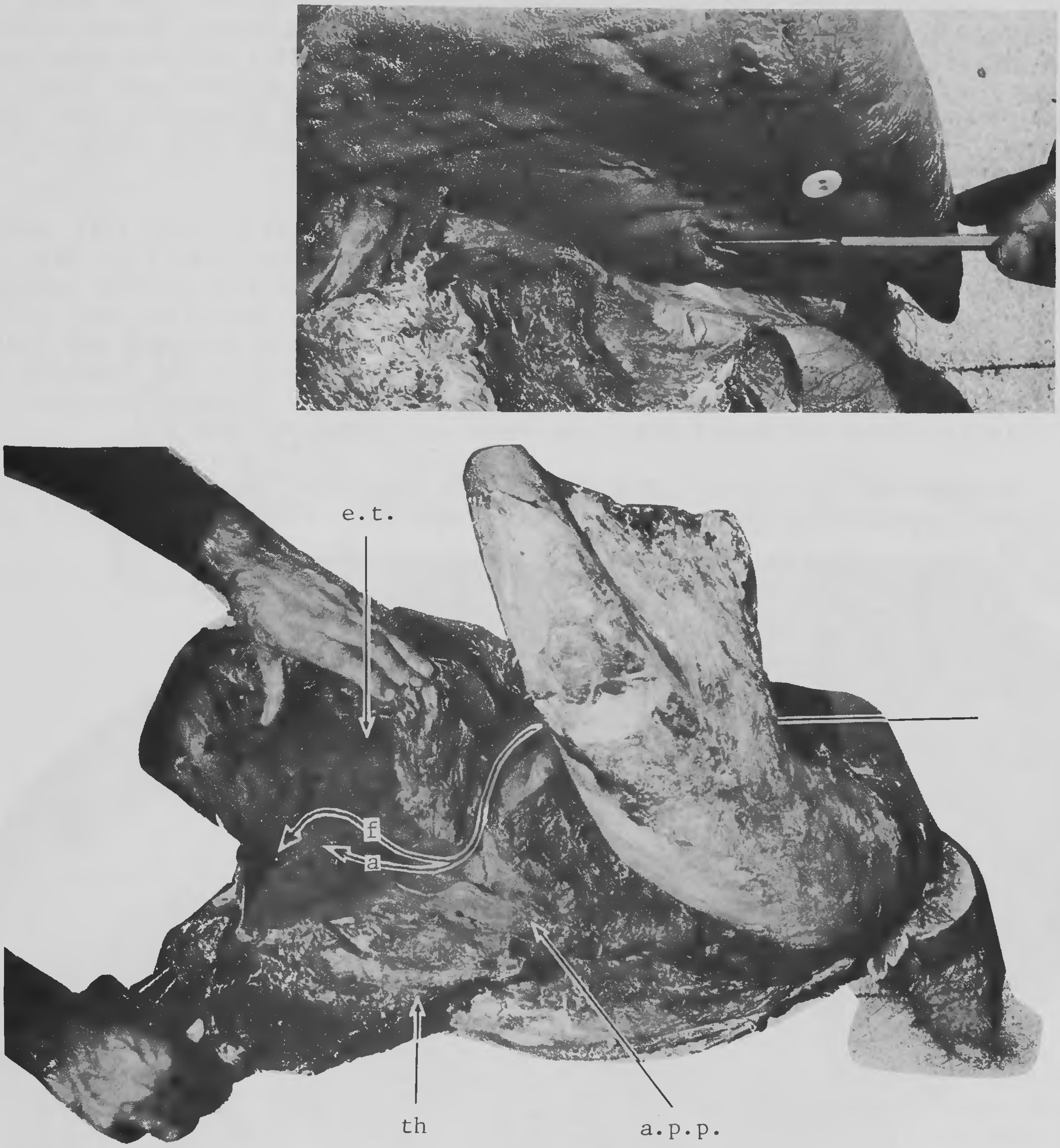

Fig. 10. Top: tongue of Iki. Probe holding papilla surrounding efferent duct of submaxillary gland. The white, round structure above the probe is a trocar button used to seal leakages during embalming. Bottom: mandible and associated tissues, viewed from right side. e.t.=eustachian tube, f=direction of food ingestion, a=direction of air flow, a.p.p.=anterior border of pharyngeal pouch, th=right thyrohyoideum (bone forming part of hyoid apparatus).

cheek measuring 10.0 x 2.0 cm in cross section). All glands were found in the usual position (see Eales, 1926 for descriptions) although Watson (1874) and Miall and Greenwood (1878) searched and did not find the sub-maxillary gland. In Iki the efferent ducts of the sub-maxillary glands were found at the tip of large papillae (1.2 cm long) on the frenulum linguae on each side of the tongue, 14 cm from its tip. Sikes (1971) calls this opening the Wharton's duct (Fig. 10, top).

The musth or temporal glands were relatively small. The left musth gland had a length of 14.0 cm, width of 13.0 cm, and was flat (2.5 cm). It had a central chamber (5.0 x 3.2 x 1.1 cm) leading to the orifice outside (Fig. 9). The orifice measured 2.0 cm long. Musth secretion was still present at the central chamber; it was thick and appeared granular and light brown in color. For additional information on the structure and function of the musth gland, see Schneider (1956), Fernando et al. (1963), Jainudeen et al. (1972), Estes and Buss (1976), and Poole and Moss (1981).

Within the oral cavity and pharynx the pharyngeal pouch and the hyoid apparatus were examined carefully (Fig. 10 and Fig. 11). Watson (1874) and

Fig. 11. Posterior and ventral view of skull of Iki. o.c.=occipital condyles, e=opening to ear, p.g.=parotid gland, es=esophagus, t=trachea, st=stylohyoideum, th=right thyrohyoideum, bh=basihyoid, sl.g.=sublingual gland.

Miall and Greenwood (1878) described and discussed the pharyngeal pouch in detail. The palatal pits were identified, 5 on the right and 6 on the left, at the anterior end of the hard palate (Fig. 12). The palatal pits were described and diagramed for the African elephant by Eales (1926); neither Watson (1874) nor Miall and Greenwood (1878) made mention of these pits for the Asian elephant. Papillae on the tongue were identified according to the 3 known types: circumvallate (5), foliate (Mayer's organ), and filiform papillae.

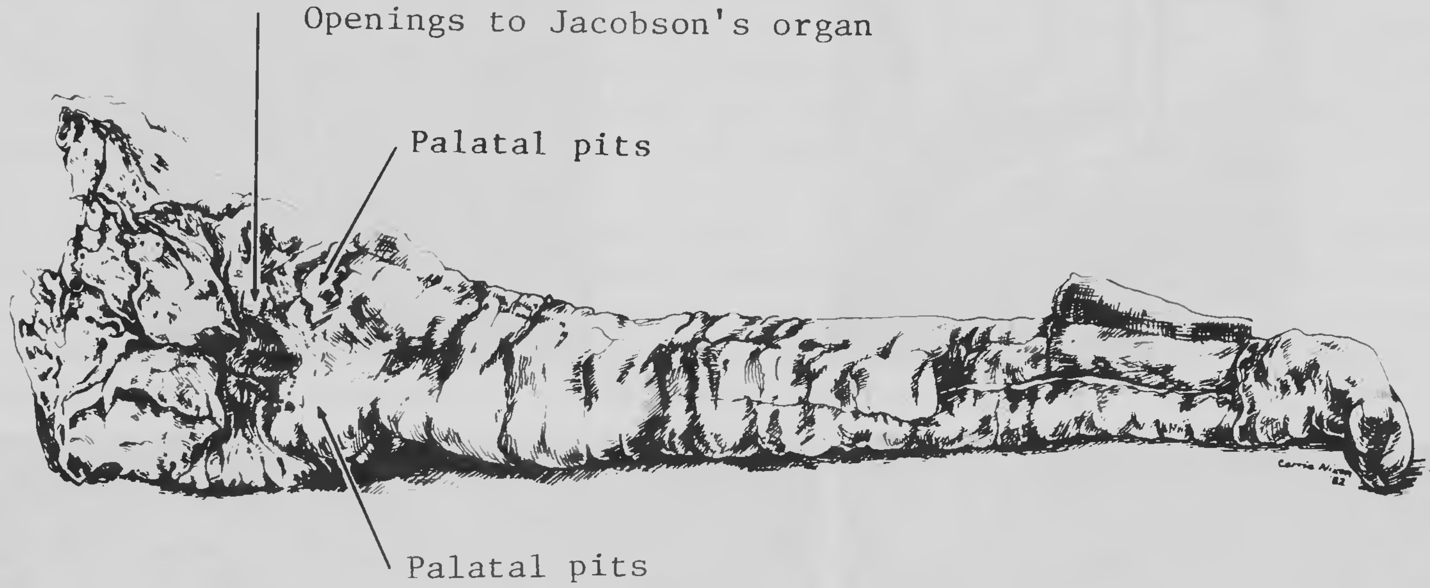

Fig. 12. Drawing of Iki's trunk in ventral view.

At the hinge points between the mandibular fossae of the cranium and the condyles of the mandible, we found double concave cushions that fit snugly on the two convex articulating surfaces (of the mandibular fossae and condyles). These intercondyle-mandibular fossa cushions were made of tough connective tissues and measured (on the right side) 10.5 cm long, 7.5 cm wide and 2.0 cm thick (see Fig. 9, bottom left). Similar cushions between the condyles and mandibular fossae were found in the head of Tulsa.

Examination of the embalmed trunk of Iki for the intercommunicating canal that unites the two nasal passages and the associated fibrous arches ended unsuccessfully (Fig. 13). These structures were sought in an area from the tip of the trunk to approximately 1 m from the tip of the trunk. This intercommunicating canal and the arches were described by Anthony and Coupin (1925); all works previous to that of Anthony and Coupin which we reviewed made no mention of these structures. We also examined the entire trunk of Tulsa and did not find either the canal or the arches.

The trunk of Iki was also skinned, in parts, and cross-sectioned at 80 cm from the tip. At the cross section, major fascicles of the longitudinal and radiating muscles, blood vessels, and the rich nerve supply of the trunk could be easily identified. Seven muscle samples from various locations at

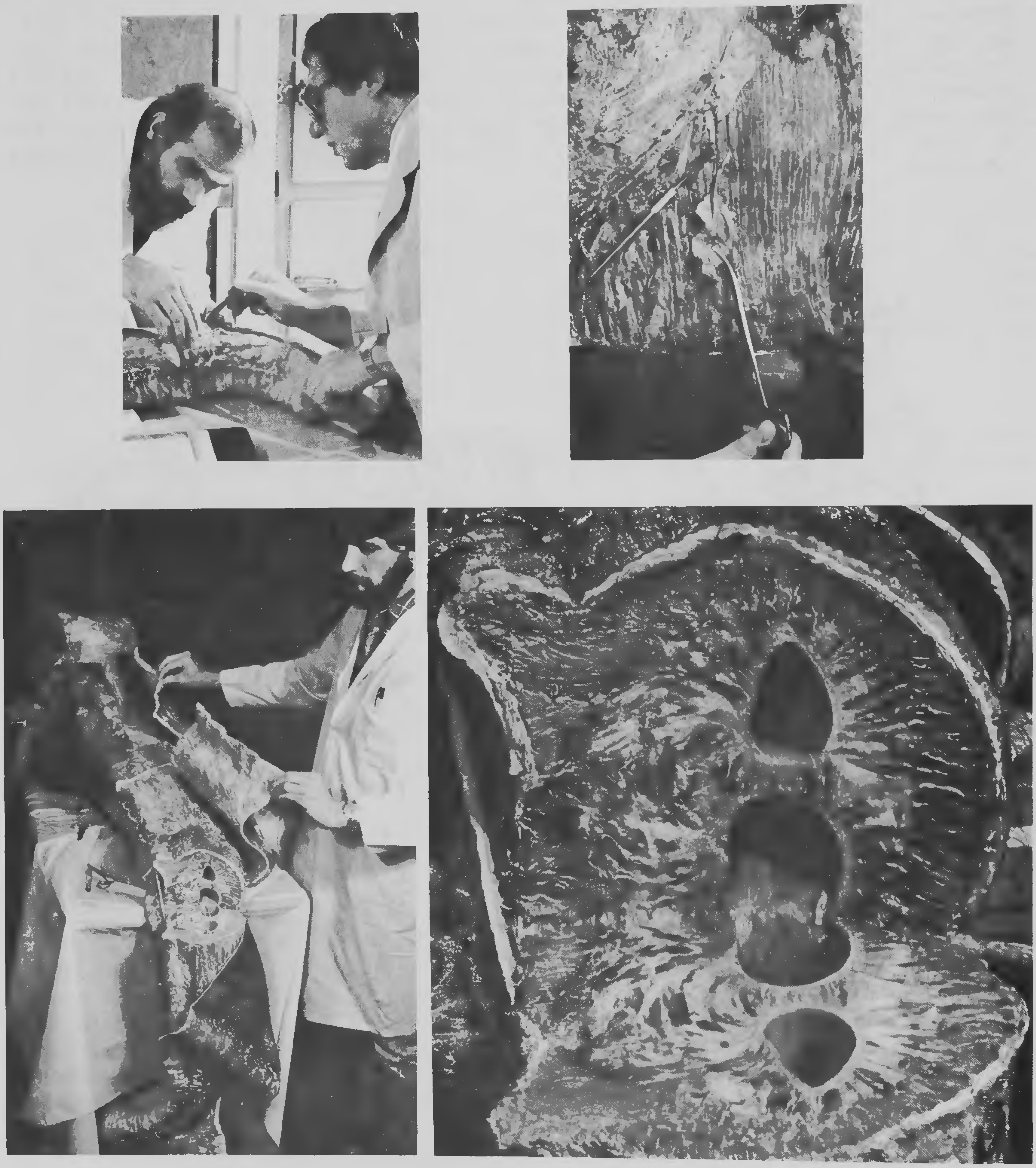

Fig. 13. Iki's trunk (top left), the search for the intercommunicating canal by J. Shoshani and N.K. Mizeres. Top right: close up of external trunk musculature close to the eye. Bottom left: S. Cool holding skin flaps from trunk. Note the increase in thickness of skin from tip to base of trunk. Ventral side of trunk is to left. Bottom right: close up of cross section of trunk showing nasal passages, muscles, blood vessels, and nerves.

the cross section were taken for microscopic examination; all samples were identified as skeletal or voluntary muscles.

Volume of the nasal passages was measured by starting with a known volume of water, filling the embalmed passages, and subtracting the remaining water from the initial volume. This was done in two parts. First, we measured the volume of the right nasal passage at the proximal end from the alinasal cartilage (the place where the trunk is attached to the cranium) to the cross section where we were able to block the water flow. The volume of the other segment of the one nasal passage was measured by pouring water into the tip of the trunk and again blocking at the cross section. The added volumes of the two segments were then multiplied by 2, giving a total volume of the embalmed nasal passages (which are probably smaller than when the animal was alive) to be 2.19 liters or 2.31 quarts.

The trunk of Tulsa was sectioned every 10 cm and various measurements (including the diameters of the nasal passages) were taken at each cross section. Tulsa's trunk was 17 cm shorter than Iki's. Computing the volume of the nasal passages of Tulsa comparable to those measured on Iki gave a total volume for both passages of 3.08 liters or 3.25 quarts.

Following these observations, we became interested in obtaining some measurements on the amounts of water a live elephant can hold in its trunk. On March 28, 1982, we conducted a water consumption experiment on three elephants - large, medium, and small. Our data are included in Appendix V.

DISCUSSION AND SUMMARY

Table I summarizes our data and preliminary findings. Many details were omitted for simplification. The most significant findings of Iki's dissection when compared to other elephant dissections are summarized in the abstract. The listing in the abstract is arranged so that items 1-12 pertain to normal elephant anatomy, while items 13-15 pertain to abnormal or pathological findings. Item 16 refers to suggestions and guidelines for further research. The abstract included with this paper is an updated version of the one in Shoshani et al. (1980). We begin our discussion with the pathological findings since they may be of interest to many readers who own elephants or who are in direct contact with elephants regularly.

Pathological Findings

Examination of a cross section of one of the joint mice (by S. Grabowski and J. Shoshani) under the microscope revealed them to contain organized spicules, canals and blood vessels similar to the spongy bone found in other mammals (Bloom and Fawcett, 1975). To our knowledge, no such joint mice and severe arthritis have been previously reported in elephants (Fig. 14 and 15). However, Siegmund (1973) reports that joint degradation, osseous

TABLE I. A SUMMARY OF FINDINGS ON IKI, THE FEMALE ASIAN ELEPHANT
(Elephas maximus maximus Linnaeus, 1758)

SYSTEM and/or organ investigated	MEASUREMENTS IN METRIC WEIGHT (in kilograms)[a]	LINEAR AND AREA (in meters)[b]	VOLUMETRIC (in liters)[c]	NOTES[d]
1) Head, neck, and trunk	317.70	Length: 3.09	236.88	1) Head includes the brain. The head, neck, and trunk were subsequently embalmed. The intercondyle-mandibular fossa cushions were noted on p. 21.
1a) Brain	4.55	Length: 25.8 cm Width: 25.0 cm Height: 12.5 cm Maximum thickness of dura mater: 1.0 cm	4.569	1a) Volume was measured by displacement of water. The volume of Tulsa's brain is 4.90 liters (see p. 51).
1b) Pinna Left	5.10	Upper base: 33 cm Lower base: 57 cm Height: 55 cm		1b) Shape of ears was assumed to be trapezoids; upper base = part of ear attached to head, lower base = posterior margin, height = dorsal margin. Measurements of the acoustical properties of the external auditory meatus were also made. The lateral side was darker than the medial and had much more hair on it. Blood vessels and nerves were present between the medial side of skin and cartilage.
Surface area of both sides		Area: 0.49 cm^2		
Right	6.40	Upper base: 46 cm Lower base: 60 cm Height: 50 cm		
Surface area of both sides		Area: 0.53 m^2		
Cross section from about middle of ear		Thickness: 1.5 cm of which 5 mm is cartilage sandwiched between two layers of skin laterally (5 mm) and medially (5mm)		

Table I. Continued

SYSTEM and/or organ investigated	MEASUREMENTS IN METRIC WEIGHT (in kilograms)[a]	LINEAR AND AREA (in meters)[b]	VOLUMETRIC (in liters)[c]	NOTES[d]
1c) Eye lens Right Wet weight Dry weight Left Wet weight Dry weight	 1.7042 g 0.7454 g 1.4534 g 0.7714 g	Diameter: 21.0 mm Height: 11.0 mm		1c) The right lens was decapsulated and separated into cortex and nucleus. Each region was processed to isolate its proteins and compare them to those of human, chicken, and frog (see Table VI and pp. 63-65).
1d) Cornea	0.8685 g			1d) Right side.
1e) Musth gland	5.53	Length: 14.0 cm Width: 13.0 cm Height: 2.5 cm		1e) Weight is of right musth gland and associated tissues. Measurements are of the embalmed left gland (see p. 20).
1f) Tongue	4.08	Length: 70.5 cm		1f) Preserved in 10% formalin.
1g) Salivary glands				1g) The following glands were identified and measured: left parotid, left submaxillary, sublinguals, and buccal glands. See pp. 17-20.
1h) Dentition Lower right VIth molar	 2.648	 Maximum enamel loop: 6.8 cm Grinding length: 17.2 cm		1h) The lower molars are maloccluded, having 4.5 enamel loops. The upper molars are normal having 10.5 loops. No other molars present behind these teeth. See pp. 63-65 and Fig. 25.
Upper right VIth molar	1.950	Maximum enamel loop: 7.1 cm Grinding length: 18.4 cm		

Table I. Continued

SYSTEM and/or organ investigated	MEASUREMENTS IN METRIC WEIGHT (in kilograms)a	LINEAR AND AREA (in meters)b	VOLUMETRIC (in liters)c	NOTESd
1i) Jacobson's organ		distance between openings: 9.0 mm		1i) Openings were located on an elevated area.
1j) Palatal pits Left side Right side		 distance range between opening was: 8-17 mm same: 10-12 mm		1j) There were 6 pits on the left side and 5 on the right. They were asymmetrically located on the anterior end of the hard palate at the vicinity of the demarcation line between the trunk and the upper rostrum. On the left they were 32 mm from the Jacobson's organ and on the right 62 mm from it (see Fig. 12).
1k) Trunk	89.0	Length (d): 1.77 Length (v): 1.40	External: 47.40 Nasal passages: 2.19	1k) Weight was taken when the trunk was embalmed and it included parts of the premaxillae, maxillae, nasals, and frontal bones. (d) = length along dorsal edge, (v) = length along ventral edge. Volume of nasal passages was obtained by filling the embalmed trunk with water.
1k.1) The inter-communicating canal between the nasal passages and the associated fibrous arches.				1k.1) These structures were not found in Iki or Tulsa (see pp. 21 and 49-50).

Table I. Continued

Table I. Continued

SYSTEM and/or organ investigated	MEASUREMENTS IN METRIC			NOTES[d]
	WEIGHT (in kilograms)[a]	LINEAR AND AREA (in meters)[b]	VOLUMETRIC (in liters)[c]	
2) Left foreleg attached to the scapula, associated musculature and skin	204.5		Two Fore-legs: 204.90	**2)** and **3)** Number of "toes": left front-5, right front-4, left hind-4, right hind-4. Three "toe" patterns observed in captive Asian elephants are 5 front and 4 hind, 4 front and 4 hind, 4 front and 3 hind.
2a) Left foreleg with skin attached	155.48			2a) The weight of the left foreleg including skin comprised 7.22% of total body weight of Iki. For Tulsa this number was 5.52%.
2b) Left foreleg without skin	123.9			2b) The weight of the dressed foreleg comprised 5.72% of Iki's body weight. For Tulsa this number was 4.43%.
3) Left hindleg attached to half of the pelvis, associated musculature and skin	243.0		Two hind-legs: 235.14	**3)** Thickness of the soles of hindfoot and forefoot near the center, respectively, were: 14 mm and 15 mm. Average thickness of keratinized middle "toe" on hind- and forefoot was: 4 mm.
3a) Left hindleg with skin attached	200.56			3a) The weight of the left hindleg including skin comprised 9.31% of total body weight of Iki. For Tulsa this number was 6.99%.

Table I. Continued

SYSTEM and/or organ investigated	MEASUREMENTS IN METRIC: WEIGHT (in kilograms)[a]	LINEAR AND AREA (in meters)[b]	VOLUMETRIC (in liters)[c]	NOTES[d]
3b) Left hindleg without skin	156.86			3b) The weight of dressed hindleg comprised 7.28% of Iki's body weight. For Tulsa this number was 5.66%.
4) Body		Length: 2.50	370.06	4) Body implies the entire animal minus neck, head, trunk, legs, and tail.
5) Tail	9.03	Length: 1.10	3.37	5) Length excludes the hair.
6) Bones: Total wet weight Total dry weight	 354.97 215.83			6) Vertebral formula: C-7, T-19, L-3, S-5, Cd-27. Total number of bones (excluding sesamoids) is 282. Wet weight of bones constituted 16.48% of total body weight. Water content of bones was 39.19% (see Table II, pp. 40-44).
6a) A sesamoid	2.0 g	Length: 17 mm Width: 8 mm Depth: 5 mm		6a) This sesamoid was discovered by K.M. Morehead at the proximal end of the humerus under a tendon (see pp. 8 and 44).
6b) Pathological findings				6b) These included "joint mice", eroded and grooved articular surfaces (see also under the uterus and pp. 8, 11, 17, 23, 36-40 and Appendix III).

Table I. Continued

SYSTEM and/or organ investigated	MEASUREMENTS IN METRIC WEIGHT (in kilograms)[a]	LINEAR AND AREA (in meters)[b]	VOLUMETRIC (in liters)[c]	NOTES[d]
7) Muscles:				**7)** The 927.52 kg (43.06% of total body weight) is a total of different weights weighed at different times.
Total wet weight	927.52			
8) Skin:				**8)** The skin weighed 9.82% of Iki's total body weight. 218 skin samples taken; thickness varied from 1.8 to 32 mm (see pp. 13, 60). Note that the 5 sections of skin lost 56.45% of their weight as water content in 22 months.
Total wet weight	211.52			
wet weight of 5 sections	102.99			
dry weight of same 5 sections	44.86			
8a) Total surface area of skin, including ears on both sides, tail and soles of feet		11.96 m^2		8a) The five sections of skin were measured with a surface integrator; the rest of the area was computed (see pp. 59-60 for details and alternative methods of measuring surface areas).
8b) Hair		Length: 0.3 to 26.0 cm		8b) Three major types of hairs were noted: thick, short, and curled; black, medium long, straight or curled; light brown to reddish, long, medium thick. Most stood straight out of skin. Hairs up to 1.7 mm thick and 26 cm long.

Table I. Continued

SYSTEM and/or organ investigated	MEASUREMENTS IN METRIC			NOTES[d]
	WEIGHT (in kilograms)[a]	LINEAR AND AREA (in meters)[b]	VOLUMETRIC (in liters)[c]	
9) Stomach (empty)	17.35	Length: 124 cm Width: 69 cm Circumference at midsection: 111 cm	Internal volume: 76.6	**9)**, **10)**, **11)**, and **12)** Internal volume implies the maximum capacity when filled with water. At the cardiac end, there were about 17 folds which almost disappeared when the stomach was stretched (see also pp. 57-59).
10) Small intestine (empty)	42.2	Total length: 15.9	Internal volume: 133.56	**10)** The small intestine was cut into three sections and the large intestine into five sections. (This was done in Florida during necropsy and loading.) The weights and measurements are therefore combined.
10a) Histology		Average length of seven villi: 66.81 m		10a) Measurements of seven villi (Magnified 131.5 times) ranged from 50.00 μm to 76.47 μm, and their frequency at one locus was one villus per 24.37 μm (see p. 59).
11) Caecum	13.2	Length: 0.87 Width: 0.61	Internal volume: 91.19	**11)** Grey sand (1.2 kg) was found in the caecum and part of the colon. The caecum was sacculated.

Table I. Continued

SYSTEM and/or organ investigated	MEASUREMENTS IN METRIC WEIGHT (in kilograms)[a]	LINEAR AND AREA (in meters)[b]	VOLUMETRIC (in liters)[c]	NOTES[d]
12) Large intestine (colon) (empty)	57.2	Length: 11.77	Internal volume 392.01	**12)** That portion of the colon attached to the caecum was also sacculated for about 3.5 meters. This was also observed in Tulsa's colon.
12a) Feces from colon	60.8			12a) Based on ours and Benedict's (1936) measurements, the water content of fresh feces ranged from 60% to 80%.
12b) Omental bursa or greater omentum	10.22			12b) The omental bursa is a saclike mesentary that wraps around parts of the stomach and intestines (see Fig. 4).
13) Rectum including anus and anal flap	8.2	Length: 0.27		**13)** The skin becomes progressively thinner from base of tail toward the anal region, about 1.0 mm thick between tail and anus.
14) Liver	25.2	Length: 80 cm Width: 72 cm A hepatic portal vein measured 35 mm in diameter.		**14)** There were two lobes, the right larger.
14a) Gall Bladder				14a) Not found but enlargement of the bile duct was detected.
15) Pancreas	2.0			

Table I. Continued

SYSTEM and/or organ investigated	MEASUREMENTS IN METRIC: WEIGHT (in kilograms)[a]	LINEAR AND AREA (in meters)[b]	VOLUMETRIC (in liters)[c]	NOTES[d]
16) Spleen	15.0	Length: 100 cm Width: 20 cm		**16)** Measurements are estimated from photographs.
17) Kidneys	7.25	Length: 35 cm Width: 15 cm		**17)** Kidneys were decomposed. Data are estimated based on data from other elephants.
18) Urinary bladder and some attached tissues	16.3	Length (when filled with water): 0.62	Internal volume 18.0	**18)** Internal volume implies the maximum capacity when filled with water.
19) Uterus and associated structures	25.0	Length of uterine body: 100 cm Length of uterine horns: 280-300 cm		**19)** Weight is approximate. The uterus was infected. This may be the only reported case of endometritis in elephants (see also note 6b in this Table).
20) Vulva and vagina	17.16	Circumference of labia majora: 81.0 cm Length of clitoris from pouch to tip: 11.0 cm		**20)** Preserved in 10% formaldehyde.
21) Mammary tissue	2.28			**21)** This constitutes most but not all the mmammary tissue. The right and left nipples had 10 and 12 lactiferous ducts, respectively (see pp. 16-17).

Table I. Continued

SYSTEM and/or organ investigated	MEASUREMENTS IN METRIC: WEIGHT (in kilograms)[a]	LINEAR AND AREA (in meters)[b]	VOLUMETRIC (in liters)[c]	NOTES[d]
22) Lungs (including portions of trachea and esophagus)	98.0	Length: 0.99 Width: 1.22		**22)** There were two lobes, the left larger. The trachea close to the pharynx measured: 9.2 cm and 7.0 cm, dorso-ventrally and latero-medially, respectively. Its thickness was 0.5 cm.
22a) Trachea-oesophageal muscle				22a) Not found in Iki (see pp. 44-50 and Table III).
23) Heart (empty) with portion of the aortic arch	12.71	Length: 0.448 Width: 0.481	External volume: 9.6 Internal volume: 8.0	**23)** Distinct biapex was observed. The body weight can be estimated by considering the heart to weigh 0.5% of the body weight (Benedict, 1936). Thus, Iki's estimated weight = (12.712 x 100)/0.5 = 2,542.4 kg. Splitting arrangements of arteries off the aortic arch are also discussed (see pp. 51-57 and Table IV).
24) Blood, water, and other body fluids	220.0			**24)** The 220 kg weight was estimated as an average of 10.21% of total body weight, an average that was calculated based on measurements of six elephants reported by Benedict (1936:109), Robertson-Bullock (1969:134), and Wilson (1957,

Table I. Continued

SYSTEM and/or organ investigated	MEASUREMENTS IN METRIC: WEIGHT (in kilograms)[a]	LINEAR AND AREA (in meters)[b]	VOLUMETRIC (in liters)[c]	NOTES[d]
24) Continued				see Hanks, 1979:78). Of these 220 kg, we estimated that 80 kg was blood. This was based on our data from Tulsa - 112.60 liters of blood, i.e., 3.5% of her body weight.
25) Embalming				**25**) Embalming formula is: formaldehyde (1 part), phenol (1) part, glycerine (1 part), alcohol (5 parts), and water (14 parts). Embalming fluid was pumped at 15 lbs./sq. in. pressure. Head, including trunk, took 145.3 liters; left hindleg took 159.0 liters; and the left foreleg took 145 liters (see pp. 15-17 for details).
TOTALS				
Length from tip of trunk to tip of tail		6.69		
Length of trunk		1.77		
Length of tail		1.10		
Shoulder height (when lying)		2.27		
Length of intestinal tract		29.24		
Internal volume of intestinal tract			616.76	

Table I. Continued

SYSTEM and/or organ investigated	MEASUREMENTS IN METRIC: WEIGHT (in kilograms)[a]	LINEAR AND AREA (in meters)[b]	VOLUMETRIC (in liters)[c]	NOTES[d]
Internal volume of stomach			76.60	
Surface area of skin		11.96 m^2		
External volume of entire animal			1,050.35	
Weight of skeleton	354.97			Constituted 16.48% of total body weight.
Weight of muscles	927.52			Constituted 43.06% of total body weight.
Weight of internal organs including brain	440.15			Constituted 20.43% of total body weight.
Weight of blood and other body fluids	220.00			Constituted 10.21% of total body weight.
Weight of skin	211.52			Constituted 9.82% of total body weight.
TOTAL WEIGHT	2,154.16			100.00%

a) Some weights were originally taken in Avoirdupois pounds (lbs.) and subsequently converted to kilograms, using 1 lb = 0.453 kg. Weights of eye lenses, cornea, and sesamoid are in grams (g).
b) Unless stated otherwise, cm = centimeters, mm = millimeters.
c) Measurements are of external or internal volumes as stated. Volumes of small organs like the brain and heart were obtained by displacement of water. External volumes of different parts of the body were calculated assuming, for example, the trunk and tail were frustums; the body, head, and legs were cylindrical approximations; ears as trapezoids. Internal volumes were noted under "NOTES" numbers 9-12, 18, and 23.
d) All notes pertain to Iki unless stated otherwise.

Fig. 14. "Joint mice" in Iki. Top left: arrow indicates position of joint mice on the posterior and distal end of the humerus, the upper bone. Right: posterior view of the humerus showing joint mice *in situ*. Lower left: cross section of the larger joint mouse; scale is in millimeters.

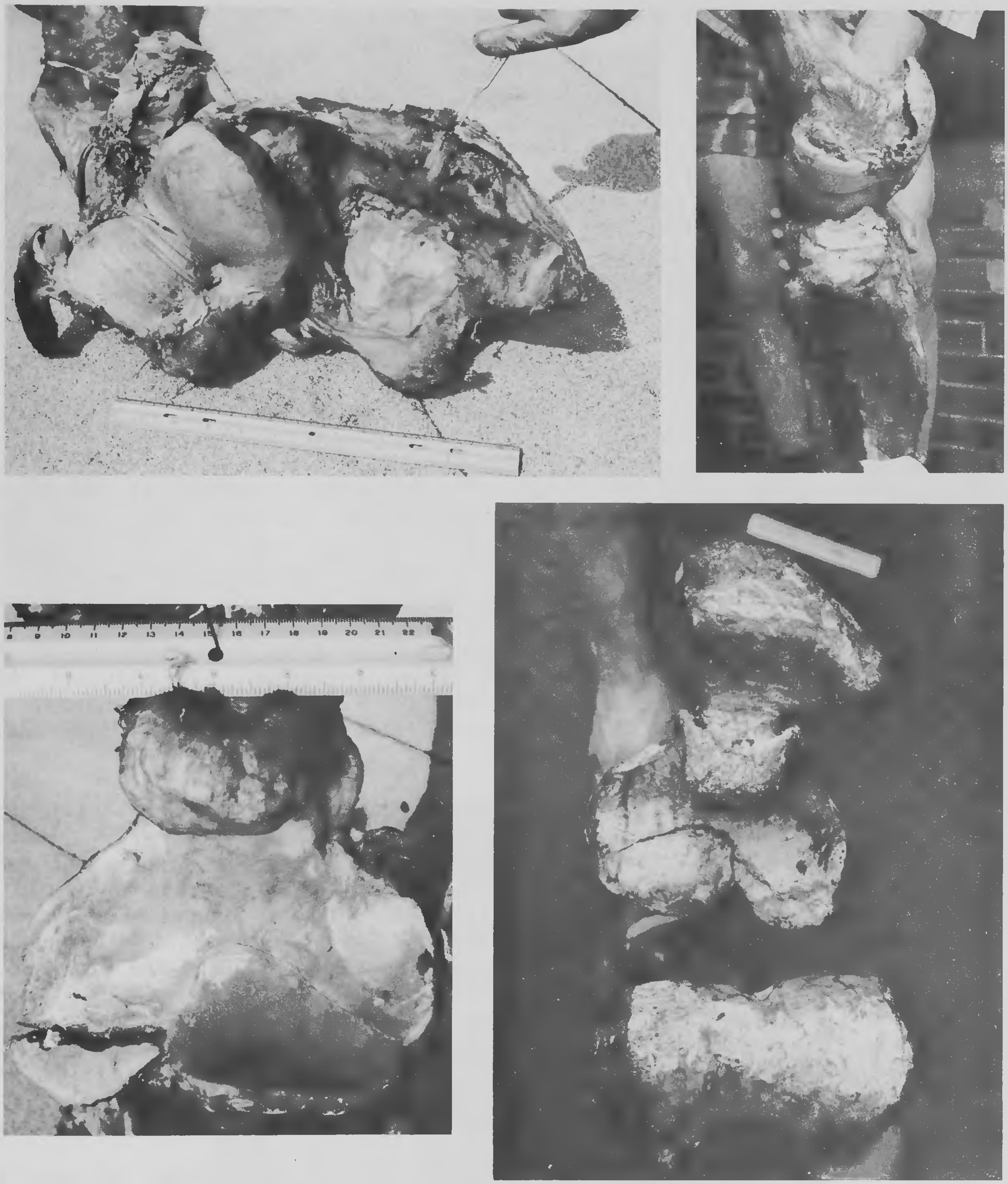

Fig. 15. Pathological findings in Iki. Top left: posterior of left femur, distal view. Note deep grooves on lateral condyle and eroded patella, as well as pendulous soft tissues. Top right: right femur (top) and tibia showing deep grooves on lateral condyle of femur and corresponding fossa on tibia. Bottom right: right ulna and radius (top) and humerus showing eroded articular surfaces and cracked proximal end of ulna. Bottom left: left radius and ulna showing broken proximal and lateral end of bone.

deposition and fractures of articular surfaces occur in other mammals. Fundenberg et al. (1980) report that subperiosteal nodules ("rheumatoid nodules") were found in man. The exact origins of these rheumatoid nodules and joint mice are not known. However, it is possible that when bone particulates derived from erosions and calcium particles are being deposited in and around the articular surfaces, they might serve as nuclei onto which additional deposits attach, enlarging and hardening the original nucleus to form a small ossified structure not connected to the skeleton. The process of benign new growth protruding from a bone, or the osteophyte formation, is called exostosis (Siegmund, 1973; Robbins and Cotran, 1979). Similar exostoses may have taken place in the formation of the two joint mice found in the joint capsule around the humerus and ulna and radius of Iki. The term "joint mice" or endogenous hard foreign bodies is well described in Jubb and Kennedy (1963).

The grooves at the articular surfaces could very well be associated with the "joint mice" found in that particular location; these ossified structures in turn may be associated with aging. Analysis of the white particles found on and around most of the articular surfaces of the limbs of Iki showed that they were calcium deposits. (Effervescence was observed when these white particles were placed in weak hydrochloric acid solution.) The presence of these calcium deposits between two articulating bones and around the joint areas may lead to exostosis which in turn may cause the loss of synovial fluid. The absence of synovial fluid enhances the possibility of bone-to-bone contact especially when additional calcium deposits are present, leading to cartilage degeneration and groove formation. In addition, this phenomenon may also be associated with exercises which elephants, Iki included, have to perform in circuses, exercises and tricks that may employ unusual pressure on a particular joint.

Herbert Fox (cited in Benedict, 1936:108-112) reported on arthritis in a captive, 27 - year old male Asian elephant named "Bolivar." Another observation on arthritis in a 19-year old female circus Asian elephant named "Shirley" (of the Circus Vargas) was made by the veterinary staff and J. Shoshani at the Illinois Equine Hospital and Clinic, Naperville, Illinois. Degeneration of the cartilage was clearly visible in the two elbow joints (Fig. 16) and in the right knee joint. Shoshani searched for the presence of joint mice in of the above leg joints and found none. Evans (1910) noted that "cold is generally regarded as the chief cause" of rheumatism in elephants. "Exposure to wet, damp, cold winds, insufficient shelter,..." were other causes mentioned. Sikes (1971) concurs with Evans (1910) with regard to the above causes. Sikes (1971) added that "captive elephants of either species may be affected." See also Crandall (1964) and Garrod (1875).

It appears that arthritis in elephants occurs independent of age, sex and species; possibly this may be attributed to medical history of the animal, injuries, captive conditions, and/or strenuous exercises, especially at a young age. The arthritis observed in Iki and Shirley may have been a result of combinations of the above mentioned causes.

Fig. 16. Left ulna and radius and humerus (right) of Shirley, with eroded articular surfaces (note prominent eroded surface particularly at bottom center of photograph).

Fig. 17. Endometritic uterus of Iki. Note the pendulous structures within the body of the uterus and the thick wall next to the ruler. Ovary is in upper left.

Generally speaking, there are two major types of arthritis. The first, rheumatoid arthritis, which is a chronic disease of unknown cause is characterized by inflammation, pain, swelling of the joints, and often leads to deformity of these joints. The second, osteo-arthrosis (sometimes also called osteoarthritis or degenerative joint disease, DJD), is associated with the "wear and tear" of tissues (mostly cartilage) at articular surfaces and joints, and hypertrophy of bone at the margins due to aging and/or injuries, and is accompanied by pain and stiffness (see Robbins and Cotran, 1979).

Iki's medical history (Appendix III) indicated chronic progressive rheumatoid arthritis. This condition was confirmed by clinical symptoms and blood tests (Clark et al., 1980). The clinical signs are similar to those found in man, namely, intermittent lameness, lethargy, and inflammation of the joints (particularly the knees and elbows in circus elephants). Blood analysis revealed that Iki had a high rheumatoid factor (a protein which is an anti-antibody associated with autoimmune diseases), elevation of gamma globulin, and a high Mycoplasma complement fixation titer. The search for and discovery of rheumatoid arthritis in elephants was the result of perseverance by Daniel C. Laughlin and his colleagues. The finding of "joint mice" and especially the grooves at the articular surfaces sheds additional light on the evidence of Clark et al. (1979) and Clark et al. (1980) that Iki may have had rheumatoid arthritis. See Appendix III for further details. These data are particularly noteworthy because elephants have a mean life span similar to man. Thus, studying rheumatoid arthritis in elephants in addition to studies on the great apes (Brown et al., 1970 and 1974), may help us to better understand this disease in man.

The ultimate cause of death of Iki was severe endometritis (Fig. 17). This was first determined during necropsy by D.C. Laughlin and J. Shoshani and subsequently confirmed by laboratory testing conducted by L.D. McGill and E.D. Stoddard (see Appendix III). We are not aware of a previous report of endometritis in elephant but it is known to occur in other mammals (Siegmund, 1973). The gross anatomy of the reproductive tracts of Iki and Tulsa is similar to those observed by other workers (see Blair, 1710; Miall and Greenwood, 1878; Shimizu et al., 1960; and Watson, 1872b).

Skeletal System

Table II contains a summary of wet and dry weights of the bones of Iki. Studying the figures in this table show that the wet weight of the skeleton comprises approximately 16.48% of the body weight. Hoffmeister (1967) noted that the skeleton of an elephant comprises up to 15% of body weight. In addition, we learned that Iki's bone contained 39.19% water (see also footnotes to Table II). The wet weights of bones of a female brown hyaena (Hyaena brunnea), in comparison, indicate that they made up 15.94% of her body weight.

The bones of Iki were studied and compared to bones of other Asian and African elephants. The epiphyses on the long bones (and others) were firmly fused. Garrod (1875) reported on a 25-year old female Asian elephant whose epiphyses on the long bones were also firmly fused. However, Blair (1710) noted that in his subject, a female 26 or 28 years old Asian elephant, "the Epiphyses separated from the Bones by Boyling as easily, as those of an Human Subject would have done at the Age of 10 or 12." The work by Blair (1710) is, in our opinion, one of the most thorough works of his time; the text and the presentation of the data have an unique flavor which we would like to share with the reader - see Appendix VI.

Most of the osteological characters examined on Iki's skeleton agree with previous observations. One feature in particular may be noted here - the scapula of Iki (and other Asian elephants) when laid on its medial side on a flat surface, (e.g. the ground) and the tip of the infraspinous fossa is pushed towards the ground, it stays touching the ground (Fig. 18). Under similar conditions, the scapula of the African elephant balances between the infra- and supraspinous fossae. This character was studied in 45 skeletons of elephants and was found to hold in 75% of the cases. (Shoshani and Eisenberg, 1982; Shoshani et al., unpublished data).

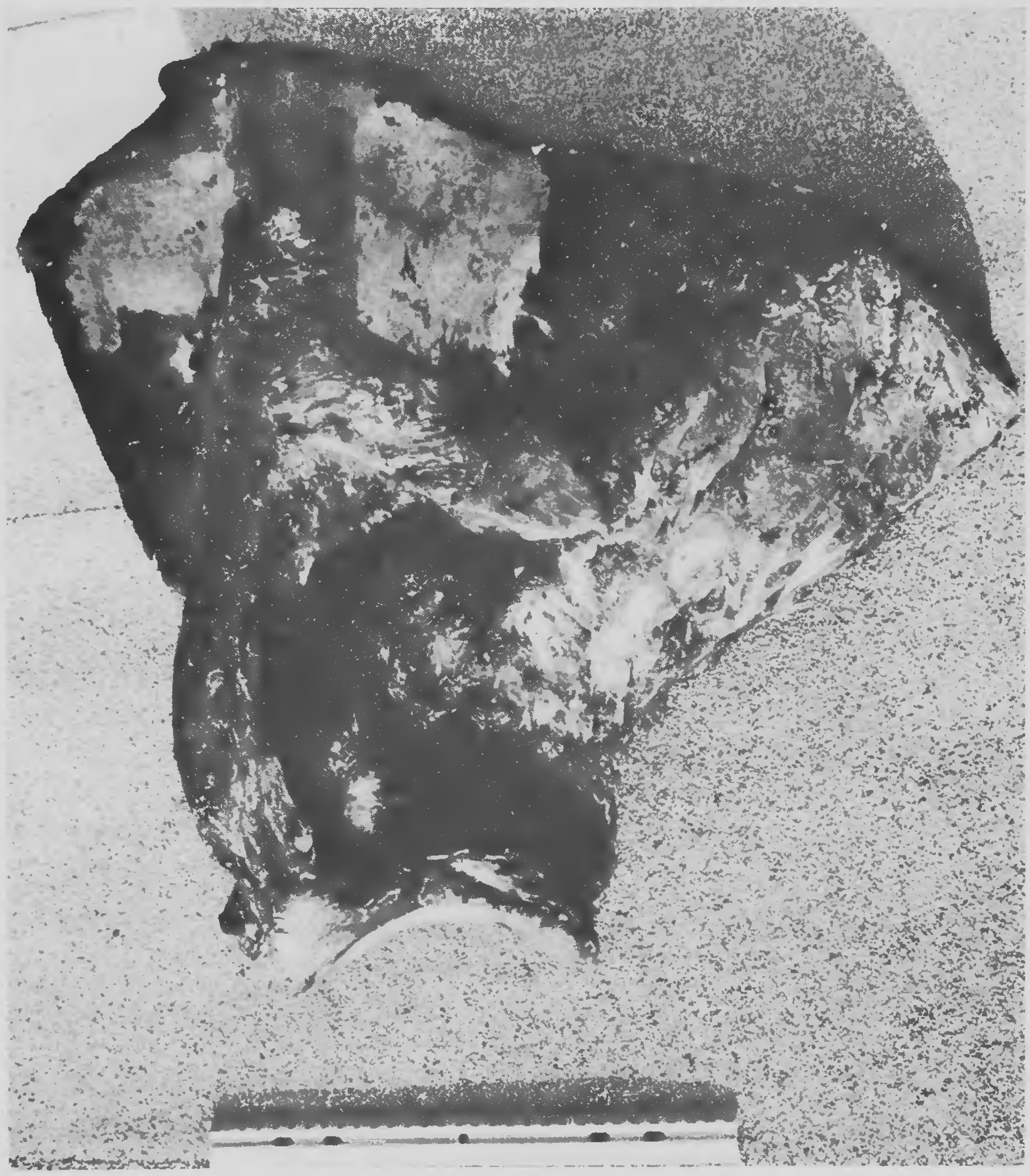

Fig. 18. Left scapula of Iki. Note that the tip of the infraspinous fossa on right touches the ground. In many scapulae of the African elephant, the tip of that fossa does not touch the ground when laid on a flat surface (see text for details).

TABLE II. Summary of wet and dry weights of bones of Iki, *Elephas maximus maximus*.[1]

Name of bone, or complex of bones	Number of bones[6]	Wet Weight in kgs.	Dry Weight in kgs.
CRANIUM[2] Including Molars[3] and hyoid apparatus[4]	49	51.08	23.69
MANDIBLE[2] Including Molars	2	33.52	24.41
VERTEBRAL COLUMN[5] i.e. cervical (7), thoracic (19), lumbar (3), sacral (5), and caudal (27) vertebrae	61	56.15	29.84
STERNUM[5]	4	4.08	1.60
RIBS (19 pairs)[5]	38	45.81	24.49
SCAPULAE[2]	2	20.27	13.77
HUMERI[2]	2	23.16	19.17
RADII AND ULNAE[2]	4	19.80	14.41
MANUS[2,5]	54	30.35	10.36
PELVES[2]	6	28.90	22.50
FEMORA[2]	2	28.38	21.51
PATELLAE[2]	2	1.22	0.91
TIBIAE AND FIBULAE[2]	4	12.47	9.50
PEDES[2,5]	52	18.46	5.20
TOTAL NUMBER OF BONES[6] . . .	282		
TOTAL WEIGHTS . . . . (plus some soft tissues)		373.65	221.36
Subtract 0.5% of the total wet weight and 0.25% of total dry weight.[7]		18.68	5.53
ESTIMATED TOTAL WEIGHT		354.97[8]	215.83[9]

FOOTNOTES FOR TABLE II

1. Bones were kept at room temperature (25° - 27°C), and dry weights were recorded 20 months after death.

2. The head, left foreleg and left hindleg were embalmed. The bones of these parts were placed in the Dermestid Beetle Room approximately 12 months after death.

3. Tusks were not present.

4. Cranium includes the stylohyoidea. The thyrohyoidea and the basihyoid are with the pharynx.

5. Some muscles and connective tissues were still attached onto these parts when weighed, especially on the manus and pedes which included the soles.

6. Cranium includes ear ossicles (6), and the hyoid apparatus (5). Number of bones does not include the turbinals, sesamoid bones (amounting to 40 in the manus and pedes), centralia, and acetabuli. The interparietal, clavicle, baculum (os penis), baubellum (os clitoris) and os cordis are absent in the living elephants. According to Sikes (pers. comm.), a structure similar to the os cordis has been found in some individual elephants. Total number of bones is the same for both *Loxodonta africana* and *Elephas maximus* except for the number of thoracic vertebrae and consequently the number of ribs (*L. africana* has 20-21, *E. maximus* has 19-20), number of lumbar vertebrae (*L. africana* has 3-4, *E. maximus* has 3-5), number of sacral vertebrae (*L. africana* has 4-6, *E. maximus* has 3-5), and number of caudal vertebrae (*L. africana* has 18-33, *E. maximus* has 24-34).

References discussing skeletal system and variations in numbers of bones in elephants include: Blair (1710), Boas and Paulli (1908, 1925), Deraniyagala (1955), Eales (1926), Laursen and Bekoff (1978), Osborn (1932, 1942), Shoshani and Eisenberg (1982), and Sikes (1971). See also Appendix VI for original text and data from Blair (1710).

7. The 0.5% and 0.25% subtractions from the total wet and dry weights, respectively, were done to account for the soft tissues attached to the bones. These percentage estimates were derived by weighing a few bones with and without soft tissues.

8. Note that the estimated wet weight of the skeleton comprises 16.48% of the body weight.

9. Note that water content of bones is approximately 39.19%.

The ossified structure that was found under a tendon (combined tendons of insertion of the teres major and latissimus dorsi) at the proximal end of the humerus, is, we believe, a true sesamoid bone because it was found under a tendon (Fig. 5) and not associated with an articular surface or a joint capsule. Hildebrand (1974) noted that sesamoid bones in mammals are usually found associated with tendons, the patella being the best example.

In further studying the skeletal system we examined a cross section of a tibia and a rib. In cross section, at about the middle of the bone, the tibia resembled an outline of a heart and revealed the absence of a marrow cavity (see Fig. 19). The absence of a marrow cavity in long bones of elephants was reported by Beddard (1902) and Hoffmeister (1967). The center of the bone (where the marrow cavity is found in other mammals) is occupied by a spongy or cancellous bone, whereas the periphery is hard and lighter in color. Examination of a section of the hard periphery of this bone under the microscope showed it to contain the normal components of a compact mammalian bone, namely, the Haversian System, including the lamellae, lacunae, and canaliculi. In the fresh section, blood was clearly seen in the communicating canaliculi.

A cross section of the rib revealed no marrow cavity. It has three distinct parts in the elliptical appearance: two crescent-shaped areas, one medial, one lateral and one large middle ellipse. The midsection appeared darker in color and was softer in texture; the two other areas were lighter and harder.

Trachea-oesophageal Muscle

With respect to the finding of the trachea-oesophageal muscle, accurately described for the first time by Harrison (1850a), it should be mentioned that Watson (1872a) and Miall and Greenwood (1878) have searched for this muscle but found "no trace" of it. Since Harrison's (1850a) paper may not be easily available, we thought it might be advantageous to include his original description with this report:

> "My attention was accidentally directed to it in the course of the dissection of the thoracic viscera. When removing the lungs and heart, I remarked an unusually close connexion to exist between the trachea and oesophagus, and which, on examination, I found depended on a short, thick muscle, which extended from the back part of the bifurcation of the trachea to the fore part of the oesophagus, and along which the fibres descended to tis lower or gastric extremity. The muscle was enveloped in that cellulo-elastic tissue which abounds in almost all parts of this animal, especially in the thorax, where it connects the lungs to the ribs and diaphragm (there being no pleural membranes), and extends from the latter along the oesophagus and trachea, connecting all parts intimately together. On dissection through this tissue, the muscle in question was exposed: it may be described

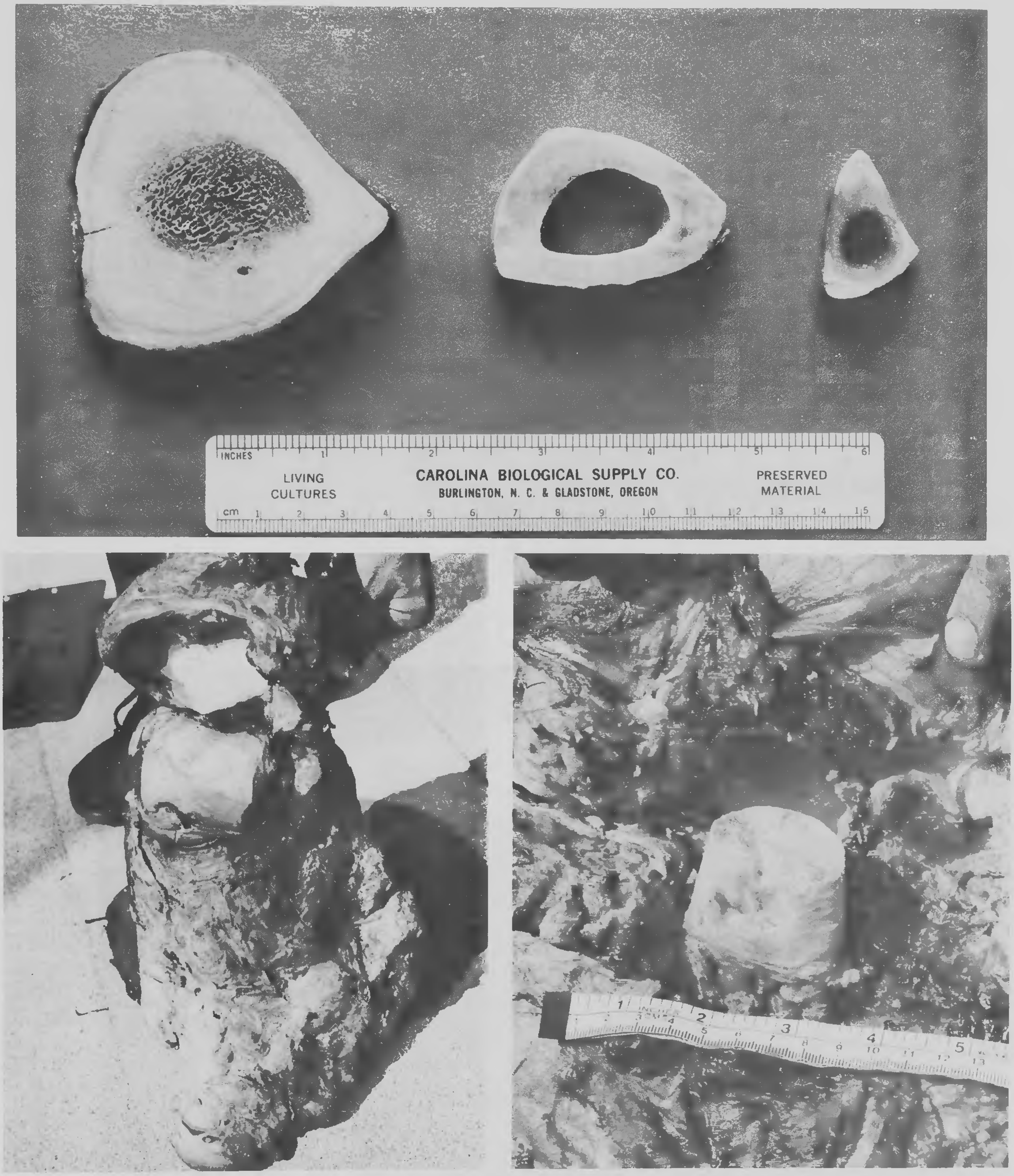

Fig. 19. Top: cross sections of right tibiae (shinbones) of Elephas maximus, Bos taurus, and Homo sapiens (from left to right). All bones were photographed in dorsal view, and anterior of animal is toward top of picture. Lower left: front view of left hindfoot, showing eroded articular surfaces between the tibia (top) and astragalus (bottom). Lower right: posterior view of right forefoot showing the central tendon.

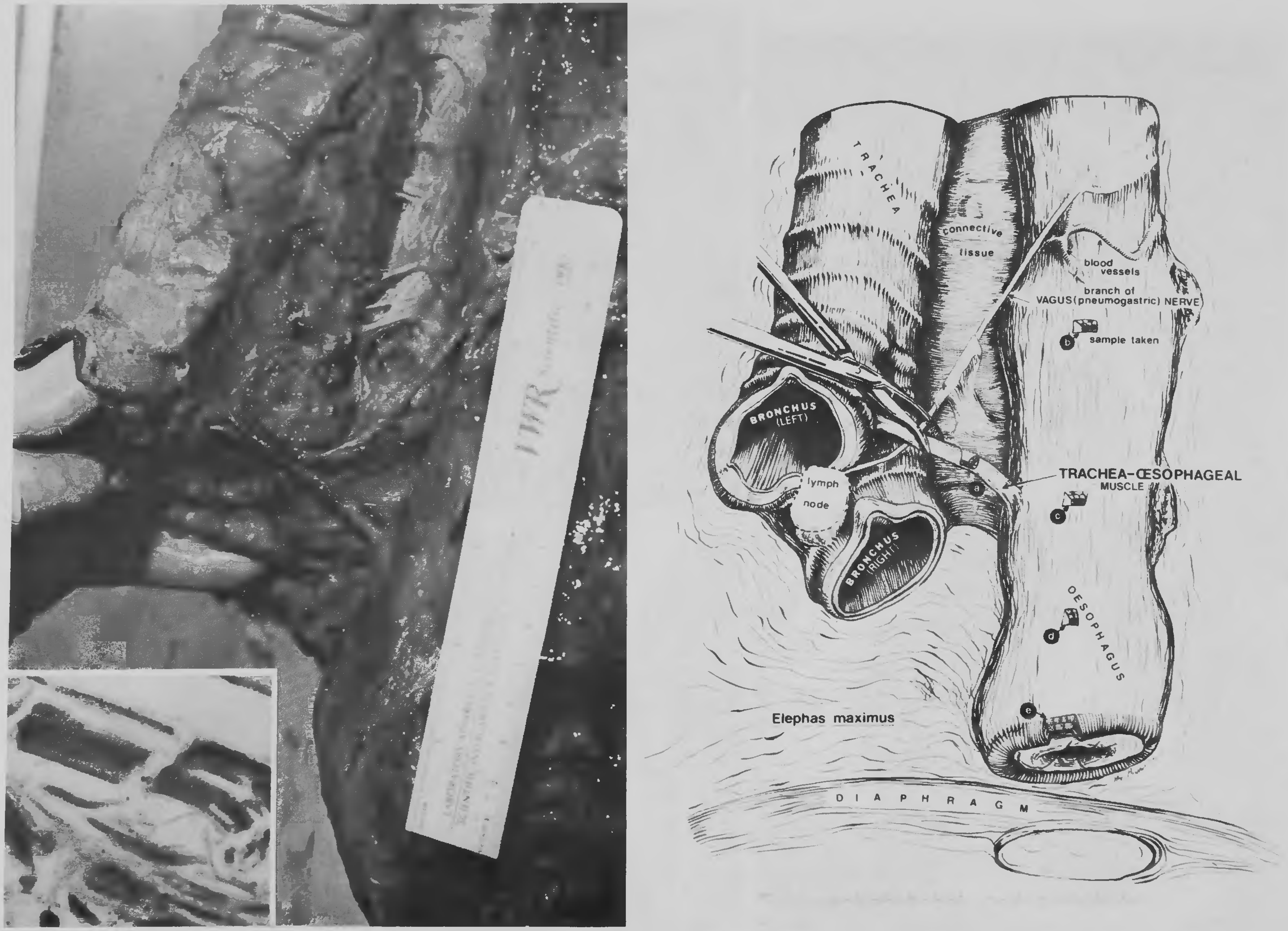

Fig. 20. Shirley's trachea-oesophageal muscle. Left: actual specimen. Right: drawing. Inset: photograph taken through light microscope of sample (magnified 160 times) at position a in drawing, showing bands characteristic of striated muscle.

> as an azygos muscle, placed horizontally in the median line, about two inches in its long axis, that is from the trachea to the oesophagus, and about an inch in its vertical diameter; its anterior end arises from the posterior surface of the bifurcation of the trachea, by short tendinous fibres; these soon end in fleshy fasciculi, and form a thick, strong muscle, which passes backwards and bends a little downwards to the fore part of the oesophagus, along which the fibres descend, expand, and become continuous with its longitudinal and spiral fibres, and can be distinctly traced to the cardiac orifice of the stomach; the upper margin of the muscle is round, thick, and well defined; the lower margin is concave, and held in connexion with the diaphragm, and with its oesophageal opening, by the elastic tissue before mentioned. The pneumogastric nerves descend one along each side of this muscle, and give small branches to it. (See Plate)."

As of this writing we (M. Bulgarelli, S. Lash, W.W. Mathews, N.J. Mizeres, J. Shoshani, and J. Skoney) were fortunate to examine four specimens: three _Elephas maximus_ (Iki, Shirley, and Tulsa) and one _Loxodonta africana_ (Ole Diamond), in search of the _trachea-oesophageal_ muscle. We also searched for this muscle in each of the following species and found none: fox squirrel (_Sciurus niger_), long-tailed chincilla (_Chinchilla laniger_), domestic rabbit (_Oryctolagus cuniculus_), brown hyaena (_Hyaena brunnea_), domestic cat (_Felis catus_), man (_Homo sapiens_), South American tapir (_Tapirus terrestris_), domestic pig (_Sus scrofa_), Peruvian llama (_Lama peruana_), and blesbok (_Damaliscus dorsas phillipsi_). With respect to _Homo sapiens_, according to Henle (1866:151), Hyrtl (1844) was the first to report the presence of _broncho-oesophageus_ and _pleuro-oesophageus_ muscles in man. Mizeres (1981 and pers. comm.) has not seen these muscles in humans and he believes that the latter two muscles are inconstant in man.

Of the four elephants examined, only Shirley's tissues possessed the _trachea-oesophageal_ muscle. It measured 6.2 cm in length, 1.2 cm in width, and 0.7 cm in thickness (see Fig. 20). In Iki, Tulsa, and Ole Diamond we found connective tissues in the same locations but not the muscles themselves. These connective tissues varied in texture and strength; in Ole Diamond and Tulsa they were loose and relatively weak, while in Iki the connection between the trachea and esophagus was very tight, being composed of a number of short and tough connective tissues.

The function of this _trachea-oesophageal_ muscle is not well understood. Harrison (1850a) discussed the functions of this muscle from two points of view.

> "...first, supposing the trachea to be its fixed point, it might have some influence in raising the diaphragm, and thereby assisting in expiration; or it might raise the cardiac orifice of the stomach, and so aid this organ to regurgitate a portion of its contents into the

> oesophagus..." "Secondly, if we regard the oesophageal extremity of this muscle as the fixed point, and which we are entitled to do from its close connection to the diaphragm and to the surrounding elastic tissue, it may then exert a twofold action on the trachea; first, it may dilate the thin and dilatable portion at its bifurcation, and thus assist in forming a reservoir of air previous to its forcible expulsion; or secondly, by depressing and fixing the trachea during the act of expiration, it may perhaps contribute to the more powerful expulsion of the air, by enabling the expiratory agents to act with concentrated energy on the lungs and on the air passages above, in those violent expiratory acts which the animal so frequently performs..."

Tennent (1867) believed that the ability of elephants to withdraw water from their stomachs depends on two factors: the ability of the stomach to hold water in its folded cardiac portion [the structure of the stomach was figured by Camper (1802), and described by Miall and Greenwood, 1878 and others; the folds at the cardiac portion were also found in Iki, Shirley and Tulsa] and the ability of the trachea-oesophageal muscle to withdraw some of this water. The phenomenon that elephants spray themselves with water from within their digestive tract was observed not only by Tennent (1867) but also by other observers (cited in Watson, 1872a) and more recently by Douglas-Hamilton and Douglas-Hamilton (1975). Tennent (1867) observed elephants who placed the tip of their trunk in the mouth and "...withdrew a quantity of water, which they discharged over their backs, repeating the operation again and again, till the dust was thoroughly saturated. I was astonished at the quantity of water thus applied...". Douglas-Hamilton and Douglas-Hamilton (1975), in the process of fitting a collar with a radio transmitter on an adult male African elephant, noted that "He put his trunk deep inside his throat and sucked out some water which he then splashed on the back of his ears and shoulders." In that same page (113), the authors mentioned three other occasions whereby young and adult elephants demonstrated "this remarkable capability" under stressful conditions.

Miall and Greenwood (1878) noted that the folds at the cardiac wall of the stomach are "too shallow to serve as water-cells"; they concluded that the pharyngeal pouch described by Watson (1874) may serve as a source of internal water for the elephant in time of stress. However, this receptacle is large enough to hold less than one gallon of liquid (Watson, 1874; Miall and Greenwood, 1878), thus there is still no adequate explanation for the "quantity of water" sprayed by elephants, "repeating again and again" as described by Tennent (1867). Further investigation of this phenomenon and the associated structures may provide the answer(s).

Based on our observations, as to the size, structure, and location of the trachea-oseophageal muscle, we believe that the major function of this muscle is to dilate the trachea at the region of bifurcation and thus assist in respiration and perhaps in vocalization. This muscle may also act to anchor the trachea to the esophagus in addition to the connective tissue present.

Of the 10 mammalian species examined, only elephants possess the trachea-oesophageal muscle. Furthermore, it was found only in two of the seven reported cases (Table III). This raises the question "how essential is this muscle for the survival of the elephant?" This is a particularly relevant question in view of the function attributed to this muscle with regard to water retrieval under stress conditions (see also Sikes, 1971, for discussion). It would be premature to attempt to answer this question before additional specimens are examined.

TABLE III. Known searches for the Trachea-oesophageal muscle in elephants.

RESEARCHER(S)	YEAR	SPECIES	SEX*	OCCURRENCE
Harrison	1850a	Elephas maximus	M ?	Yes
Watson	1872a	Elephas maximus	F	No
Miall and Greenwood	1878	Elephas maximus	F	No
Shoshani et al.	1980	Elephas maximus ("Iki")	F	No
Shoshani et al.	1980	Elephas maximus ("Shirley")	F	Yes
Shoshani et al.	1980	Loxodonta africana ("Ole Diamond")	M	No
Shoshani et al.	1981	Elephas maximus ("Tulsa")	F	No

*M = Male, F = Female

Trunk: General Anatomy

We have not completed our dissection on the trunk of Iki but from what we have examined hitherto and what we have learned from other workers (e.g. Harrison, 1847; Miall and Greenwood, 1878; and Shindo and Mori, 1956c), the following general statements may be made. The trunk is an elongation of nose and upper lip combined; the nostrils are at its tip. The dorsal end at the tip possesses a "finger-like" process and at the ventral end there is an area as wide as the trunk itself. The trunk is composed of skin, muscles, blood and lymph vessels, nerves, and a little fat; bones are absent. The alinasal cartilages are situated at the origin of the trunk adjacent to the external naris. The trunk is highly sensitive, innervated by the maxillary division of the trigeminal nerve and the facial nerve. These two nerves reach the trunk via the infraorbital canal along with blood and lymph vessels. Nerves and blood vessels can be observed best in cross section (see Fig. 13).

Muscles in the trunk are voluntary and are divided into two major sets: 1) longitudinal and 2) radiating and transverse. The longitudinals are mostly superficial and they are further subdivided into anterior, lateral and posterior. The anterior longitudinals, or levators proboscidis, arise from the frontal bone and extend the entire length of the proboscis along its anterior surface and continue into the finger-like process at its extremity. The posterior longitudinals, or depressores proboscidis, arise from the premaxilla and from the posterior surface of the proboscis; these muscles do not reach the extremity of the trunk but disappear just before. The depressores plus the set of lateral longitudinals are very intimately connected with the integument, especially in the lower two-thirds of the organ. The deeper muscles are best seen in a cross section of the trunk; they consist of numerous distinct fasciculi of the radiating and transverse muscles (Miall and Greenwood, 1878). Many writers claimed that the trunk is manipulated by as many as 40-60,000 muscles (e.g., Lewis, 1971; Rabb, 1974). On the other hand, Harrison (1847:394) commented that "some have attempted to count the number of these muscles, but such an attempt is totally useless."

As mentioned previously, we were unsuccessful in searching for the intercommunicating canal between the nasal passages and the associated fibrous arches as examined in Iki and Tulsa. These structures were described by R. Anthony and F. Coupin (1925); all works previous to that of Anthony and Coupin which we reviewed made no mention of these structures. The senior author has corresponded with the Museum National d'Histoire Naturelle (Paris) in order to shed light on the discrepancies between R. Anthony and F. Coupin and our findings. In response, J. Anthony has kindly sent us two photographs of the tip of the trunk examined by R. Anthony and F. Coupin. Unfortunately, these photographs do not clearly depict the intercommunicating canal as described in the 1925 paper. Michael Beden has also responded to our letter but was unable to help. Further investigations are underway.

Trunk: Water-holding Capacity

The volume of the nasal passages of the embalmed trunk of Iki is 2.19 liters or 2.31 quartes, and the corresponding volume for Tulsa's trunk is 3.08 liters or 3.25 quarts (see Page 23). The numbers are smaller than the numbers given in the literature; Benedict (1936), Freeman (1981), and Sikes (1971) stated that an adult elephant can drink about 50 gallons (approx. 190 liters) per day and that a trunkful of elephant can hold 5 liters (1½ gallons) of water. (Sikes, 1971, quoted 4-10 kg of water per trunkful). We therefore measured the water-holding capacity in three live elephants to arrive at a range of measurements (see Appendix V).

As can be seen from the data in Appendix V, the amount of water drunk by an adult "large" elephant is 55.90 gallons, and the average amount of water that this elephant can hold in its trunk is 2.23 gallons. These numbers for "medium"-sized elephants are 15.89 gallons and 0.93 gallons, and for a "small" elephant are 8.39 and 0.76 gallons, respectively. Should the water temperature have been warmer than 9°C (48.2°F), the elephants may have consumed more and held more water in their trunks.

Brain

Iki's brain was removed in Haines City, Flordia 22 hours after death. With the absence of preservative, we packed it in plastic bags and covered it with ice. Upon arriving in Detroit, Michigan, 53 hours after death, the brain, partly frozen, was placed in 10% formalin solution. Considering the decomposability of the brain and the time elapsed between death and preservation, we were pleasantly surprised two months later to see the brain firm, well preserved (except for the olfactory region that was damaged during brain removal) and easy to study for gross anatomy (Fig.'s 21 and 22). The preservation of the brain is of particular interest since it is known that the central nervous system (including the brain) is one of the fastest decomposing tissues in the body.

Harrison (1847) studied the brain of a young elephant, nine or ten years old, and noted that the ratio of the brain weight to the body weight is 0.0019, or the brain weighs about 1/500th of the total body weight. In humans, the brain weighs between 1/45th and 1/50th of the body weight. The weight of Iki's brain is 4.55 kg, which is also about 1/500th of her total body weight. Tulsa's brain (5.22 kg) is about 1/600th of her total body weight.

Other observations with regards to Iki's brain include: thick dura mater (maximum of 10.0 mm thick in parts of the dura mater covering the cerebellum); very well vascularized arachnoid and arachnoid villi; well convoluted cerebrum and cerebellum (specialized or derived characters); exposed cerebellum when observed dorsally (i.e., the cerebrum does not cover the cerebellum as is the case in man; exposed cerebellum from dorsal view is an unspecialized or primitive feature - Beddard, 1902); proportionally large temporal lobes; large cerebral peduncles; small and unspecialized hypophysis; well defined Circle of Willis; very large (19 x 8 mm) trigeminal cranial nerve, arising, as in most mammals, from the pons; small (3 x 2 mm) oculomotor nerve. The last nerve, as in most mammals, arises from the cerebral peduncle (Fig.'s 21 and 22). In man this nerve is located posterior to the caudal cerebral artery; in Iki and Tulsa this nerve originates anterior to the caudal cerebral artery. Another difference between man and Iki's brain, as noted by Jose Rafols, was the absence of arachnoid granulation as much as it can be noted with a naked eye. Aside from the above difference, on superficial examination, the elephant's brain resembles that of man (Blair, 1710; Sikes, 1971; Rafols, pers. comm.) or that of Cetacea (Harrison, 1847).

Heart

The bifid apex of the heart and the paired anterior venae cavae were observed in the hearts of Iki, Shirley, and Tulsa. These features have been previously reported in elephants (Evans, 1910; Hill, 1938; Miall and

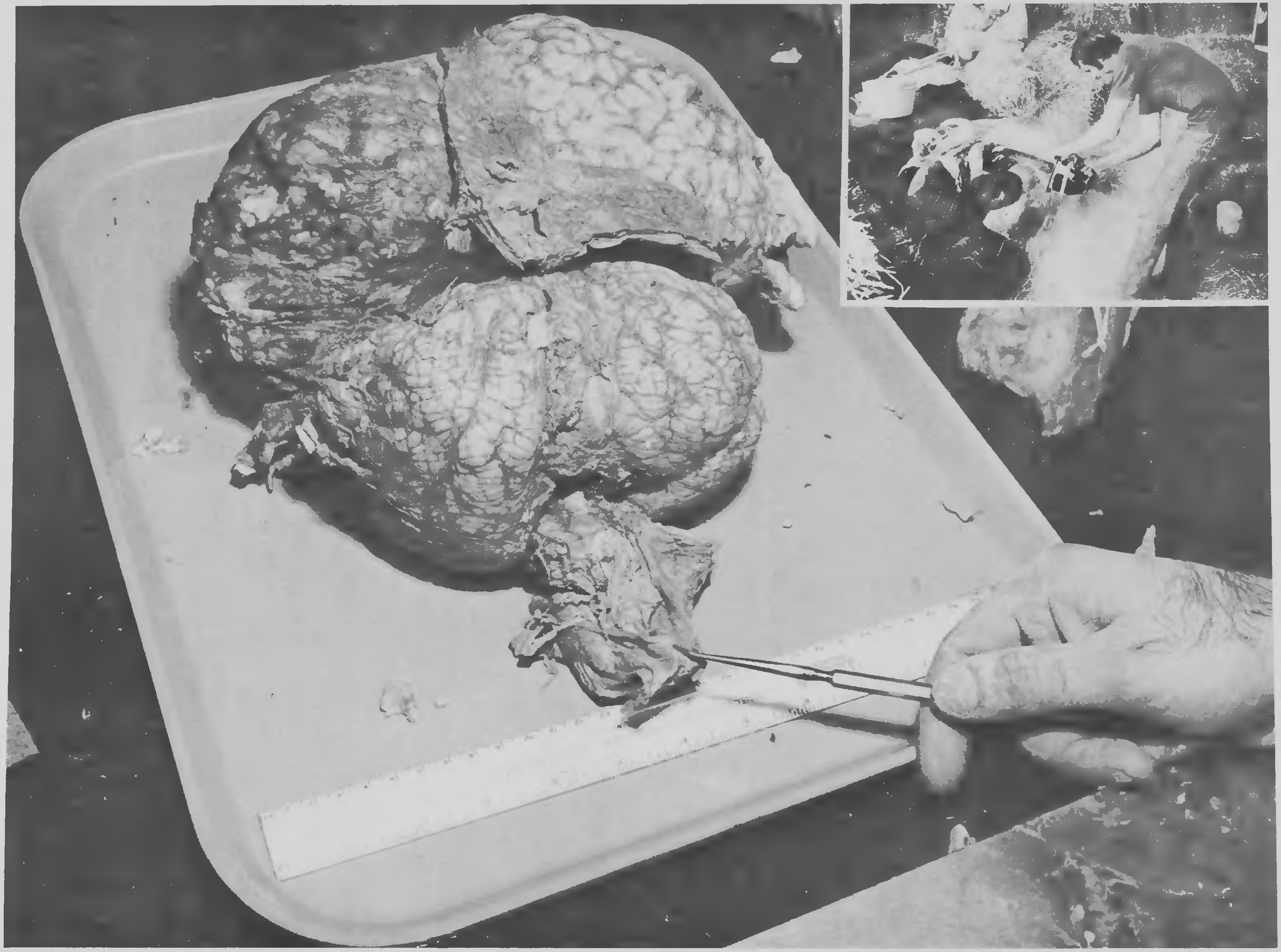

Fig. 21. Dorsal and posterior view of Iki's brain. Dura mater has been removed except for the L-shaped portion at top center. Probe is holding spinal cord onto tray. Brain weight: 4.55 kgs. Inset: Franz Tisch using chain saw to cut through the thick skull to remove brain at Circus World.

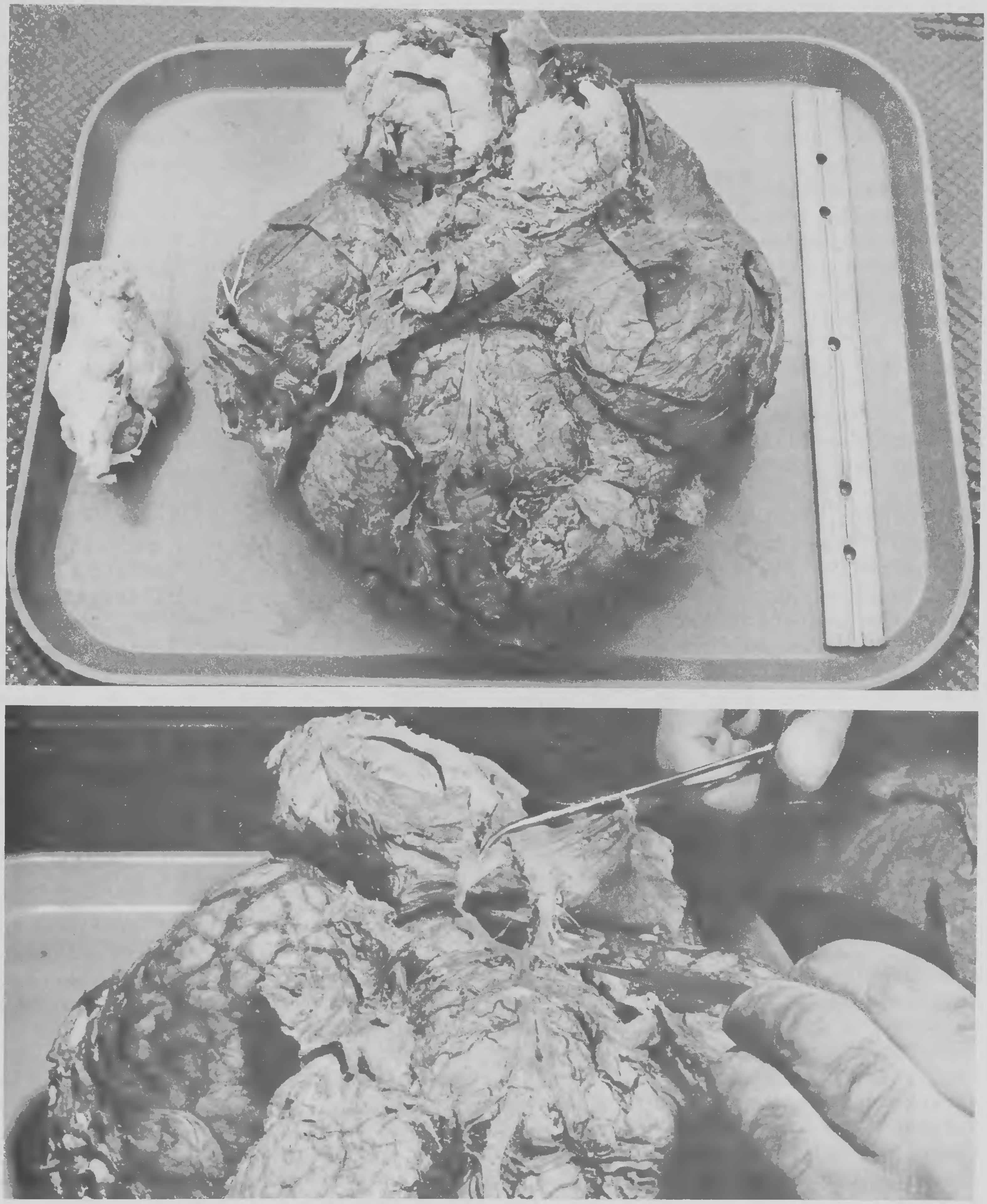

Fig. 22. Top: ventral view of Iki's brain, anterior at top. Pencil lies under trigeminal nerve. Sheep brain at left for comparison. Bottom: close up of the Circle of Willis, hypophysis and oculomotor nerve (held up by the probe).

Inset: Franz Tisch using chain saw to cut through the thick skull to remove brain at Circus World.

Greenwood, 1878; Sikes, 1971; Vulpian and Philipeaux, 1856; Watson, 1872a). Sikes (1969) reported that the hearts of sirenians (manatees or sea-cows and dugongs) also possess apical bifurcations and paired anterior venae cavae. Walker (1975) pointed out that rabbits and sheep also exhibit the paired anterior venae cavae. See also Getty (1975). The paired anterior venae cavae, left and right, are in addition to the posterior venae cavae. Watson (1872a), Miall and Greenwood (1878), and Evans (1910) noted that some cetaceans (whales, dolphins and porpoises) also have hearts with bifid apexes. The unusual conformation of the elephant heart "... led some ancient writers to believe that the elephant had two hearts, but this is incorrect" (Carrington, 1958).

It should be noted that the bifid apex of the heart (Fig. 23) and the paired anterior venae cavae are primitive and not derived or specialized characters (Beddard, 1902; Hildebrand, 1975; Walker, 1975). Walker (1975) states: "The two cranial venae cavae represent the common cardinals plus the proximal portion of the anterior cardinals" (e.g. of the dogfish, Squalus sp., and mammalian embryo). The opening observed at the base of Iki's heart (p. 13) was also observed in the hearts of Shirley, Hazel and Ole Diamond.

Other primitive features possessed by elephants include: simple, bilobed liver and lungs; exposed cerebellum; absence of or reduced third trochanter on the femur; and the presence of five phalanges (Beddard, 1902). Additional elephantine characters that might be considered primitive include: the large number of vertebrae in the vertebral column (up to 73), the large number of ribs (up to 21), the functional Harderian gland instead of the lachrymal (tear) gland, the relative length and structure of the intestinal tract and stomach, and the permanent position of the testes in the abdomen (near the kidneys).

The most distinguishing specialized (derived) features of elephants are located in the head. These include the trunk, the teeth and the structure and mode of articulation of bones in the skull (Beddard, 1902; Flower and Lydekker, 1891; Harrison, 1847-1850; Maglio, 1973; Mitchell, 1905, 1916; Osborn, 1936-1942; Shoshani, unpublished; Watson, 1874).

Dimensions of Iki's heart and other measurements in frontal sections are given in Table IV. Similar measurements were taken on the hearts of Hazel and Ole Diamond. These measurements are provided here for comparison. Measurements of an adult male Asian elephant, "Bolivar", as reported by Herbert Fox and cited in Benedict, 1936, are also included (Table IV).

Discrepancies appear in the literature with respect to the splitting arrangements of the arteries from the arch of the aorta. Tiedeman and Vulpian (?1856), Hunter (1861), Watson (1872a), and Hill (1938) report that there are only two main branches, namely the innominate (brachiocephalic) and the left subclavian arteries. The innominate artery gives rise to the right subclavian and the two carotids. The second possible arrangement is that all three arteries (right subclavian, a trunk to the common carotids, and the left subclavian) branch directly from the arch of the aorta. This three-branch arrangement was reported by Cuvier (1802) and Mayer (1847). In

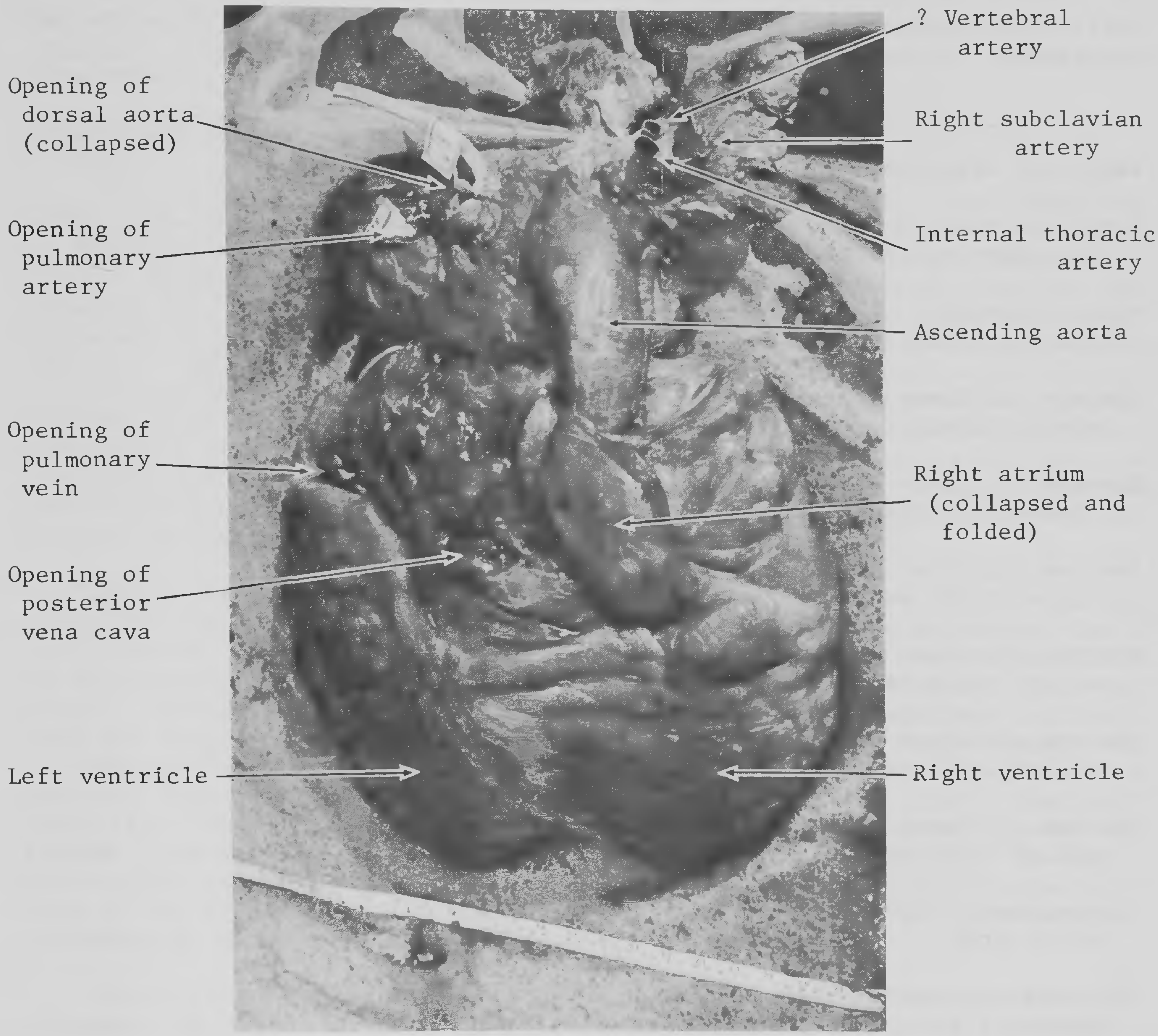

Fig. 23. Iki's heart in dorsal view. Note the bifid apex of the heart at the bottom. The brachiocephalic (innominate) and the left subclavian arteries are not visible in this view. Heart weight: 12.71 kgs. See also Table IV.

TABLE IV. Comparing data of hearts of four elephants.

Measurement (All linear measurements are in cm.)	Animal "Iki" (female Asian)	"Hazel" (female African)	"Bolivar"[1] (male Asian)	"Ole Diamond" (male African)
Weight in kilograms[2]	12.712	12.743	19.1	21.09
Length of heart (anterior-posterior)	44.81	39.0	56.0	57.0
Width of heart (lateral-medial)	48.14	38.5	32.0	41.0
Maximum thickness of interventricular wall	7.0	5.9	-	9.4
Minimum thickness of interventricular wall	5.7	5.6	-	9.2
Maximum thickness of the wall of right ventricle	1.9	2.5	2.0	2.7
Minimum thickness of the wall of right ventricle	1.0	0.9	1.5	1.0
Maximum thickness of the wall of left ventricle	2.8	6.0	8.0	11.1
Minimum thickness of the wall of left ventricle	1.2	2.2	6.0	3.5
Circumference of the aortic arch	32.0	27.5	-	35.0
Circumference of the pulmonary arch	22.5	22.8	-	28.0
Thickness of the aortic arch	1.4	1.3	-	1.7
Thickness of the pulmonary arch	1.1	0.9	-	1.2

1. Measurements by Herbert Fox, cited in Benedict, 1936.
2. All weights are without blood, a portion of the aortic arch intact.

Iki, Shirley, and Tulsa, we observed the two-branch arrangement. (We were unable to examine these blood vessels in Ole Diamond and Hazel because they were severed during removal of the hearts). In our opinion, the discrepancies in the reports could be a matter of interpretation since the splitting of these arteries, especially the right subclavian and the carotids, are close to the base of the aortic arch. Compare drawings in Mayer (1847), Watson (1872a), and Hill (1936, 1938).

Stomach and Intestinal Tract

The maximum capacity of the stomach (76.6 liters) and the intestinal tract (616.76 liters, total for the small intestine, caecum and colon) is, to our knowledge, the first time such figures for elephants are available in print. These figures for the maximum capacity may be different from the true capacity for two reasons: (a) measurements were taken outside the animal's body allowing the organs to expand without restraint from surrounding abdominal wall and other viscera, and (b) possible loss of contractibility of the muscles of the stomach and intestinal walls due to the time elapsed between death and data-collecting. Our measurements are included for future comparisons with respect to ability to store undigested or partially digested food and also with regard to a relative indication of the amount of surface area available for absorption. These figures are significant when one studies adaptation of a particular system of a species.

Getty (1975) noted that the capacity of the stomach of a cow ranges from 95 to 230 liters (average 115-150 liters), and that of a horse ranges from 8 to 15 liters. Benedict (1936) calculated the efficiency of hay digestibility in an elephant to be 44% (as compared to 50-70% in cow, steer, sheep and horse). The poor digestibility of vegetable matter in an elephant implies a need for larger quantities of food when compared to other large mammals who are more efficient in digesting their food. Elephants have a single, not a ruminant stomach; they often eat on the move, chewing their food only partially. Thus, "storage" is needed before the food is acted upon by the gastric juices and subsequently passed into the duodenum. Having a distensible stomach, therefore, is an advantage to the elephant especially when it has to consume large quantities in a short time and move in search of more food or to escape enemies.

McKay (1973) reported the observations he made on feeding habits of elephants in Sri Lanka: "I have frequently observed elephants, feeding in lush grassy areas such as Lahugala Tank (p. 58), to look quite slender as they begin feeding; but after as few as five to six hours of intensive feeding, these same individuals have extremely bulging bellies. It would appear reasonable that if the rate at which an elephant can ingest food greatly exceeds the rate at which the intestines and caecum can process it, there would be a distinct advantage to the possession of a very elastic stomach." The huge maximum capacities of the small intestine, caecum, and large intestine (616.76 liters) may also function in holding large quantities of partially digested food before it proceeds to the next section of the intestinal tract. Also, it may function as expanded surface for water absorption. It may be noted that Mitchell (1905, 1916) has pointed to the primitive nature of the elephant's intestine. This unspecialized nature of the intestine, in conjunction with the relatively short intestinal tract of the elephant (see below), may account for the need for expandable tissues to hold large quantities of food.

It is known that the length of the small intestine, when compared to body length, is considerably greater in herbivorous than in insectivorous or carnivorous mammals (Orr, 1976). Benedict (1936) in his discussion on intestinal contents or ballast noted that the ballast of a carnivore (dog) would weigh significantly less than that of an herbivore. He also stated "...that the intestinal contents represent a far smaller proportion of the total body weight in the case of the elephant than has commonly been noted with large ruminants." With these ideas in mind, we were interested in computing the ratio of the length of intestinal tract (small intestine, caecum and colon) of elephants to the body length. Body length includes head to base of tail. The head was measured from the base of the trunk (the demarcation line between the trunk and the upper lip, at about the level where the tusks protrude form the upper lips). The trunk and tail were excluded from these measurements because the trunk is a structure unique to elephants and the length of the tail varies among mammals and even among elephants of the same species. Computing these ratios for Iki, Shirley, Tulsa and Ole Diamond, we got the following ratios as shown in Table V.

TABLE V. Ratios of intestinal tract to body length in four elephants.

Species	Sex*	L_i=length of Intestinal tract (small & large intestine & caecum)	L_b=length of body excluding trunk and tail	Ratio of L_i/L_b
Elephas maximus (Iki)	F	29.24 m	2.50 m	11.69
" " (Shirley)	F	28.40 m	3.61 m	7.86
" " (Tulsa)	F	29.87 m	3.83 m	7.79
Loxodonta africana (Ole Diamond)	M	28.15 m	5.24 m	5.37

*F=female, M=male

The large ratio for Iki as compared to Shirley and Tulsa may be explained by the fact that Iki was a small animal and also by the possible loss of contractability of the muscle of the intestines, thereby, their length when measured (65 hrs. after death) may have been larger than if measured sooner after death.

We also calculated the ratios of intestinal tract to body length for 13 other mammals and got the following ratios: carnivores (N=2): 2.94-7.41, omnivores (N=3): 5.61-12.73, herbivores-nonruminants (N=5): 9.92-13.99, Camelidae (N=1): 23.07, and herbivores-ruminants (N=2): 15.60-23.20. For comparative purposes we also calculated these ratios for the domestic fowl (N=2) and got a ratio of 4.5.

Studying the ratios for elephants and comparing them to those of other mammals we examined, one notes that the ratios for elephants fall in a range between the range of carnivorous, omnivorous, and the lower range of non-ruminant herbivorous mammals. The low ratios for elephants may be evaluated keeping in mind the generalized (primitive) nature of the elephant's intestine when compared to more specialized herbivores (Mitchell, 1916). Additional measurements must be done on a larger sample of elephants, of both species and sexes, to arrive at the degree of differences of these ratios for elephants.

When dissecting the intestinal tract of Iki we found sand in most parts especially in the caecum and the segment of the colon following it. The sand was grey in color and localized. From the caecum we collected 1,209.0 grams of sand. What function(s) the sand plays we do not know. It could be that it was inadvertently consumed with food when in the circus in Florida. Alternatively, it may have been eaten for its salt and/or mineral content (see Wheelock, 1980). Horses in Florida are known to consume sand accidentally with their food (Overbeck, pers. comm.). Hanks (1979) reports a case in which an elephant raided garbage cans and ate many undigestible natural and man-made objects.

Examination of tissues from the small intestine under the Scanning Electron Microscope (SEM) by S. Grabowski and D. Montezinos showed the structure of the villi to be preserved better than expected. About 70 hours had passed between death and preservation of tissues (in 1% gluteraldehyde), a lapse of time considered to allow decomposition of most soft tissues. A specimen (Sample Number 10) of the small intestine taken at 8.8 m from the stomach was examined under the SEM (magnified 131.5 times) for the structure of villi, following techniques described by Hayat (1970). Measurements of seven villi were taken: length ranged from 50.00 μm to 76.47 μm, average 66.81 μm; width at base ranged from 11.76 μm to 29.41 μm, average 17.64 μm; total length from first to seventh villus 170.58 μm, a frequency of one villus per 24.37 μm. One has to take into account that these measurements were taken at only one locus and shrinkage of the tissue may have occurred, resulting in higher numbers of villi per unit length than expected.

Surface area-to-mass

The surface area-to-mass relationship in animals has been used to determine the metabolic rate of a particular species including elephants (Dale, 1970; Benedict, 1936). This was done using the mathematical relationship of a solid object to its volume and relating the amount of heat dissipated from the surface. We were interested in obtaining a measurement of the surface area of Iki in order to compare it to previous measurements of elephants (Benedict, 1936, 1939). Some parts of the skin were measured with a specially designed surface integrator (modified after Elting, 1926). The embalmed skin parts were measured at later dates, giving an estimated total surface area of 11.96 m^2.

An alternative method for computing surface area was derived by Benedict (1936, 1939). His formula is $S = 10 \times W^{2/3}$ (based on Vierordt's formula, $S = K \times W^{2/3}$, where S = surface area in cm^2, W = weight in grams and K is a coant equal to 10 in Benedict's calculations). Calculating Iki's surface area from this formula we get: $10 \times 2{,}154{,}160^{2/3} = 16.68\ m^2$. Yet another method of estimating the surface area is by computing it as the total sum of the different surface areas of all parts of the body. Thus, the trunk is assumed to be a frustum, the neck and head, body and legs as cylinders, ears as trapezoids and tail as a cone. Using these estimators, the computed sum for the surface is 13.33 m^2 for Iki. More measurements must be done on elephants of known weights of different age and sex so that we may be able to determine the constant K for elephants.

Skin

The thickness of Iki's skin varied. On the medial side of the ear it measured 1.8 mm thick, on the medial side of the leg 1.0 cm thick and on the dorsum 3.2 cm thick (see Fig. 6, top). Thickness of skin included dermis and epidermis. Skin samples were examined under light and Scanning Electron Microscopic (SEM) by S. Grabowski, J. Rothstein, and J. Shoshani, in search of sebaceous and sweat glands. Only a limited sample has been examined. So far, no sweat or sebaceous glands have been encountered. Sikes (1971) reported that "histologists have failed to demonstrate the presence of sudoriferous or sweat glands." She cited several references with regard to skin studies (Perrault, 1734; Smith, 1890; Neuville, 1917, 1918; Eales, 1926; Frade, 1955; and Horstmann, 1966).

While examining the skin under the SEM we viewed on the surface of the epidermis regular, delineated structures roughly hexagonal in shape (Fig. 24 top) resembling, on a much smaller scale, the geologic hexagonal columnar joints of basaltic lava origin found in a number of countries around the world. Horstmann (1966) described these hexagonal structures as "epidermal columns or 'studs' 0.2-1 cm thick and 0.3-0.7 mm high. The surface appears bark-like and warty. Hair follicles open irregularly into the inter-columnar fissures. Each main column or stud consists of several lesser columns linked together, each of which is 0.1-0.2 mm diameter and formed of numerous cornified keratinized cells." (Direct quote from Sikes, 1971.)

The skin was basically devoid of hair except for the following regions, listed in approximate decreasing amount of hair present: around the chin, around the external openings of the ear, around the vagina, on the tail, on eyelids, on the knee, elbows and trunk.

Hair

Three basic types of hair were encountered: thick, short and curled type; black, medium long, straight or wiry type; and whitish brown to reddish, long and medium thick type. Most of the hairs stood out from the skin. In all cases examined, a single hair protruded from a papilla. Hair length varied from 0.3 to 26 cm (the 26 cm hair was on the trunk). The tail hairs measure up to 1.7 mm thick.

Fig. 24. Top: piece of skin from Iki as seen through the Scanning Electron Microscope. Note the approximately hexagonal epidermal columns or 'studs' and the two hairs protruding from between them. Each bar represents one millimeter. Magnified 22.2 times. Bottom: a close up of the hair at top right showing the imbricate scale pattern. White bar represents 0.1 mm. Magnified 745 times.

Under the microscope, the hair shows scales comparable to those of other mammals (Fig. 24, bottom). The scales are arranged in a circular manner resembling the bark of a palm tree or a cycad, a situation similar to that found in man. (The structure of human hair is depicted in Bloom and Fawcett, 1975.) This type of scale arrangement is called imbricated (Hausman, 1920, 1930; Stoves, 1942). Many hair samples were collected and density of hair per particular region will be determined later.

A transverse section of a hair from the trunk under the light microscope showed it to be almost circular in shape. It contains light and dark brown pigment granules, regularly arranged in groups resembling small spheres. These spheres are in turn arranged in concentric circles, one within a larger one, a total of one central and two concentric circles. A transverse section of a hair from the tip of the tail under the microscope looks oval in shape and it possesses a number of small unpigmented areas (white as opposed to the dark color elsewhere in the section). So far, we have not found a bristle with a foramen in the middle, a phenomenon noted by Smith (1890).

Estimation of Weight

According to Benedict (1936), elephant heart weight is equal to about one-half of one percent (0.5%) of the total body weight. See also King et al. (1938). The calculated estimated weight of Iki from the weight of her heart (12.712 kg) is 2,542.4 kg. The difference between the calculated estimated weight and the total weight in parts (2,154.16 kg) may be attributed to the fact that Iki had been sick and had lost weight before she died. The calculated estimated weight of Hazel, the African elephant, from the weight of her heart (12.743 kg) is 2,548.6 kg, which is close to her actual weight of 2,394.9 kg.

Another method of estimating live weights of elephants was developed by Laws et al. (1967). They worked with carcasses of African elephants and concluded that dressed or skinned hindleg weight (femur, patella, tibia, fibula, pes and associated musculature) varied between 5.3% and 6.3% of total body weight. Calculating the percentage of the dressed left hindleg weight of Iki (156.86 kg/2,154.16 kg x 100), we got 7.28%. Calculations for the percentage of the dressed right hindleg weight of Tulsa (182.01 kg/3216.00 kg x 100) give 5.66%. Corresponding percentages were also calculated for the forelegs (see Table I). More measurements must be made on Asian elephants of different populations, ages, and sexes before conclusions can be drawn.

Estimation of Height

The circumference of the right forefoot of Iki at its base was 113 cm and that of the left was 108 cm; an average of 110.5 cm. The shoulder height of Iki (measured when lying on her left side) was 227.0 cm, which is close to twice the average circumference of the forefeet (221.0 cm). As a standard method, measurements on Tulsa when standing and lying led us to believe that the actual height of Iki was probably between 221-227 cm. The shoulder height of Tulsa when standing was 248.7 cm and when lying 258.0 cm. The average forefeet circumference when standing was 123.6 cm, and when lying

120.5 cm. Multiplying the averages of the forefeet circumferences when standing by 2 one gets 247.2 cm (123.6 x 2) and when lying, 241.0 cm (120.5 x 2). When comparing the calculated versus the measured heights in both positions, one notes that, while standing, the numbers are closer to each other (247.2 cf. 248.7) than when lying 241.0 cf. 258.0. Benedict (1936:101) provided the "calculated height (from forefeet circumference) greater or less than shoulder height" for 16 elephants. His range of measurements was from 2 to 17 inches (5.08 to 43.18 cm). Additional measurements of shoulder heights and forefeet circumferences in standing and lying positions will be useful in establishing better ratios between forefoot circumference and shoulder height. The relationship that 2 x forefoot circumference at base approximates the shoulder height was previously reported for elephants by Carrington (1958) and for the Asian elephant by Boyle (1929).

Estimation of Age

Upon examining Iki's teeth, we noted the following: the lower molars were maloccluded, each having 4 and 1/2 enamel loops and the widest being 6.8 cm; the upper molars were normal, having 10 and 1/2 enamel loops each, and the widest being 7.1 cm. We have not detected molar teeth behind either the lower or upper molars (Fig. 25). The cause of malocclusion could not be determined; nor could we ascertain what effect this malocclusion had on her mastication, food utilization and health. The maloccluded teeth are not useful in estimating age of elephants but the normal ones will be entered in our accumulated data of known Asian elephants (Roth and Shoshani, Submitted). References discussing age estimation in elephants based on teeth include: Morrison-Scott (1947), Elder and Rodgers (1968), Johnson and Buss (1965), Laws (1966), Sikes (1967, 1971), Hanks (1979), and Fatti et al. (1980).

A method of estimating and confirming age from dry lens weight has been applied to African elephants by Laws (1967). A straight correlation exists between the dry weight of the eye lens and the age of an elephant: as the age of an elephant increases, the dry lens weight is heavier. This is true not only for elephants but also for other species (Bauer et al., 1964; Longhurst, 1964; Lord, 1959; Feldhamer and Chapman, 1980). Since this method has been applied to African elephants and since we had available lenses from four known-aged Asian elephants (*Elephas maximus*), we decided it would be useful to include the wet and dry weights of their lenses for future reference (Table VI). The dry weights of lenses were obtained by lyophilization, or freeze drying.

As more data become available on the weight of dry lenses of known-aged *Elephas*, then it will perhaps be possible to use this method for roughly estimating age and as a back-check technique for other methods, such as molar progressions (Laws, pers. comm.).

Readers who might be interested in obtaining additional information on necropsies of elephants and weights of different organs of elephants, may refer to Benedict (1936:108-113) for the necropsies by Gilchrist (1851), Fox

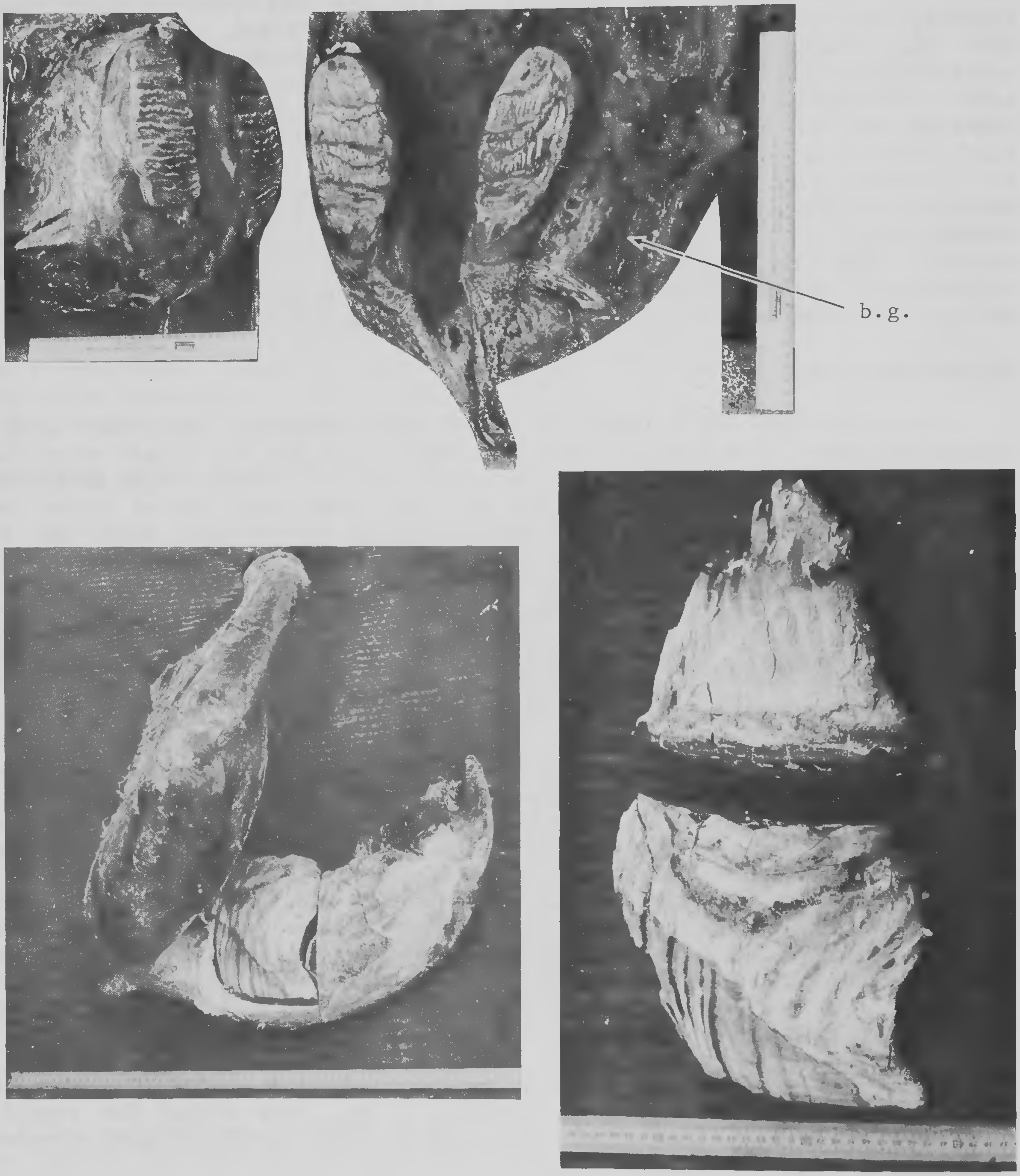

Fig. 25. Dentition of Iki. Top: upper and lower sixth molars *in situ*. Note that the upper molars (left) are normal while the lower molars are maloccluded. Front of mouth is at bottom. b.g.=buccal glands. Bottom left: mandible lying on its right side showing the medial aspect where the bone has been cut away to remove the tooth. Bottom right: medial view of upper and lower sixth right molars removed from the skull.

(1909), and Noback (1932). Additional references include Anderson (1883), Wilson (1957, see Hanks, 1979:78), Robertson-Bullock (1962), Hardouin (1971), and McGavin et al. (1981). Appendices III and IV include reports of necropsies of Iki and Toose, and a section "Necropsy report: 'Shonti'" appears under ELEPHANT NOTES AND NEWS in this issue.

TABLE VI. Wet and dry weights of eye lenses of four female Asian elephants, *Elephas maximus*.[1]

Elephant	Age in years	Eye lens	Wet weight (in grams)	dry weight (in grams)
Iki	46	Right	1.7042	0.7454
		Left[2]	1.4534	0.7714
Tulsa	34	Right	1.1103	0.4923
		Left	1.3170	0.5040
Shirley	19	Right	1.0560	0.4619
Toose[3]	18	Right	1.0814	0.4251

1. All lenses were freeze dried (lyophilized), except the right lens of Iki, whose dry weight was computed based on percentage of water loss in the other lenses.
2. This lens was removed after the head was embalmed.
3. Toose's lens was partly decomposed.

CONCLUDING REMARKS

Obtaining an elephant for dissection or participating in a dissection of an elephant is not a common event. We therefore wish to bring to the attention of future dissectors that, when the opportunity arises, data should be collected on those parts of the elephant anatomy which we were unable to collect and on certain aspects where additional specimens should be examined in search of a particular structure and to obtain range of measurement. The following search checklist is based on observations made on three Asian elephants we examined in detail plus the organs of two African elephants and on observations made by other workers. We do not refer to observations that have been repeatedly confirmed in the literature (e.g. the bifid apex of the heart and the intraabdominal position of the testis) but to observations that need to be confirmed or refuted (see for example items under trunk and thoracic region below). This search checklist is not arranged in order of importance but rather arranged as one studies the elephant by regions from the tip of the trunk to the tip of the tail. However, one must keep in mind that certain organs should be removed and preserved soon after death to avoid decomposition and to retain the original structures. Whenever possible, both male and female, young and adult, Asian and African elephants should be examined. Below is the search and data-collecting list based on observations and data collected:

TRUNK

- Look for the intercommunicating canal between the two nasal passages of the trunk and the associated fibrous arches. Anthony and Coupin (1925:25-30) described these structures in a young (8-9 year old) female Asian elephant, 13 cm from the tip of the trunk. We searched for these structures (pp. 21-23, 49-51) in two adult female Asian elephants and found neither the arches nor the canals.

- Measure the volume of the nasal passages. We have described three methods of measuring this volume: water capacity, computing the volume from the diameter of the passages at intervals, and measuring the amount of water a live elephant can hold in its trunk (pp. 21-23, 50-51 and Appendix V). The trunk water-holding capacity in dead animals, we suggest, should be measured soon after death. The best alternative would be to measure the amount of water consumed by an elephant by providing the animal with a known amount of water and computing the volume drunk by remeasuring the water left in the receptacle.

HEAD

- Obtain the dry lens weights. This can be obtained by lyophilization or freeze drying, as we have done (pp. 17, 63-65 and Table VI), or by using a suitable oven, as was done by Laws (1967). In either case, we suggest weighing the lenses before and after drying to determine the percentage water content of the lenses. We further suggest weighing the lenses two or three times after drying to make sure that the dry weight has stabilized at a constant value.

- Compare in detail the brains of the two living species. In order to remove the brain intact including the cranial nerves and the dura mater, one must damage a good portion of the cranium. A chain-saw and large axe are helpful in penetrating the thick bones. In studying the brain one may note the origins of the cranial nerves in relation to the blood vessels, especially that of the oculomotor nerve to the anterior and posterior cerebral arteries (see pp. 6, 17-21 and 51). In addition to references mentioned in text, the reader may consult the following: Abe (1952), Beddard (1893), Kladetzky (1952), Koikegami and Ozaki (1967), Krueg (1880), and Verhaart (1963).

THORACIC REGION

- Search for the trachea-oesophageal muscle. Special care should be practiced in searching for this muscle since it is small and may be overlooked or cut during dissection. We suggest that the pertinent parts of the trachea and of the esophagus (about 20 cm posterior and 50 cm or more anterior to the bifurcation of the trachea) be removed attached and examined carefully outside the carcass. This muscle was found in only 2 out of 7 elephants examined. See Harrison (1850a) and pp. 12, 44-49, and Table III in this paper for further details.

- Examine the dividing arrangement of the arteries from the aortic arch. There are two possibilities: three branches or two branches. In the three-branch arrangement, the sequence is right subclavian, a trunk common to the two carotids and the left subclavian. In the two-branch arrangement, the right subclavian and the common carotids merge into one vessel and the left subclavian remains separate (see pp. 13, 54-57, and Table IV).

ABDOMINAL REGION

- Measure the maximum capacity (when filled with water) of the stomach and intestinal tract (small and large intestine and caecum). This may be measured in two ways. Inside the abdominal cavity, by ligating the cardiac and pyloric ends of the stomach and, if necessary, ligating some parts of the intestinal tract to avoid bursting. This can also be done in a simulated environment (a large vessel about the size of the abdominal cavity of an elephant). Alternatively, the volume may be measured outside the body cavity as soon as possible after death (see pp. 8 and 57-59).

- Calculate the ratio of the total length of the intestinal tract (small and large intestine and caecum) to body length, excluding the trunk and tail. We suggest disconnecting the mesentaries from the intestine close to the point of attachment and laying the intestinal tract in a flaccid position (see pp. 8, 57-59, and Table V).

GENERAL

- Take various external measurements. We suggest collecting enough measurements so that the external volume and surface area can be computed. For example, the body, head and neck, and legs may be viewed as cylinders while the trunk and tail as frustums or cones and the ears as trapezoids. Consequently, a number of girth and length measurements should be taken to reach an average for each "cylinder", "frustum" or "cone", and "trapezoid". Forefeet circumference (average of both feet) and shoulder height may be taken in standing and in lying positions (see pp. 8-23, 59-65, and Table I).

- Weigh the hindleg without skin. It would be helpful to have the skin weighed too, to arrive at a percentage of the hindleg weight (with and without skin) to total weight of the animal (see pp. 8, 62, and Table I). Similar weights may be taken for the foreleg.

- Obtain the total wet weight of all bones to calculate the percentage of skeleton to body weight. Dry weight of bones would be useful in determining the water content of the bones (see pp. 15, 40-44, and Table II).

- Search for sesamoid bones, especially under tendons. We found one at the upper end of the humerus (pp. 8 and 44).

- Note any pathological conditions. Slight erosions on articular surfaces can be viewed best on fresh tissues and should be examined soon after death. Grooves and fractures on articular surfaces cannot be mistaken and should be sought for. Look also for "joint mice" and calcium deposits (pp. 8-11, 17, 23, 36-40 and Appendix III), and any other abnormal signs.

- Never too much. We found it useful to take more measurements and weights than what we originally planned and to record in writing and on film any observation even though it seems superfluous at the time. One never knows; it is better to have it and not to use it than to need it and not to have it.

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APPENDIX I. List of participants

The following individuals have participated in the dissection project of Iki. An asterisk (*) designates a person who has actually helped with the dissection. The rest have helped in various functions, just as important, prior to, during and/or after the operation (see also under ACKNOWLEDGMENTS).

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Joy Koenig*
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Kathleen M. Morehead*
Pamela Moron
Audrey Muczynski
Anthony Muraski*
Sean Murphy*
Jim Niedbala*
Charles P. Otto
George Overbeck*
Cornelius Perkins, Jr.
Lee M. Peterson
Valerie Pfluke
W.D. Pool
Robert Powitz*
Louise Radanovich
Jose A. Rafols*
Susan L. Raymer*
Dennis Reefer
Lisa Rezzonica*
Edward J. Riley
Thomas W. Roberts, Jr.
Gorden Rose
Harold W. Rossmoore*
Lanette Rowland
Laura Rudy
Dave Sabo*
Dallas Schneider
Paul J. Schwikert*
Science Library (Staff of)
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Paul Sklut
Joseph Skoney*
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Charles Storey
Peter J. Sujdak*
Robert Sumner
Curtis J. Swanson
Todd Tarrant*
John D. Taylor
Ron Thielman*
Ronnie Thielman*
William L. Thompson
Franz Tisch*
Linda Walowicz*
Wayne State Fund (Staff of)
Ann Werling
Jim (Chico) Williams*
Albert Wilson
Dorit Yehiel*

APPENDIX II. Summary of information on elephants or parts of elephants examined in this study.

A. Asian elephants, Elephas maximus

Animal (weight in kgs)[1]	Sex[2]	Age in years	Died on	Parts Studied	Last owned by
Iki (2,268)	F	46[3]	July 8, 1980	Most	Ringling Bros. and Barnum & Bailey Circus
Shirley[4] (2,903)	F	19	Dec. 12, 1980	Most	Circus Vargas
Tulsa (3,216)	F	34[3]	March 9, 1981	Most	Bucky Steele
Toose[5] (?)	F	18	Sept. 3, 1981	one eye lens	Circus Vargas

B. African elephants, Loxodonta africana

Animal (weight in kgs)[1]	Sex[2]	Age in years	Died on	Parts Studied	Last owned by
Ole Diamond[6] (7,256)	M	30[3]	Sept. 10, 1980	some organs	Knoxville Zoological Park
Hazel or Sapphire[7] (2,395)	F	19[3]	Dec. 11, 1980	Heart	Knoxville Zoological Park

1. Most weights are estimated.
2. F = Female, M = Male
3. Approximate age
4. See Anonymous, 1980 in the Literature Cited.
5. See Appendix IV.
6. Calculating Ole Diamond's weight based on his heart weight (28.12 kgs) one obtains 5,624.5 kgs. See also Elephant, 1(4):235.
7. See McGavin et al., 1981 in the Literature Cited.

APPENDIX III. **Necropsy report on Iki, an Asian Elephant, Elephas maximus maximus (reprinted with permission).**

CC NC SF

Bac ☐	Hu ☐	NG ☐	Ser ☐
Bru ☐	Imm ☐	Par ☐	Tox ☐
CP ☐	Nec ☐	Ref ☐	Vir ☐
End ☐	Oth ☐		

DIAGNOSTIC LABORATORY
A Service of
New York State Department of Agriculture & Markets
NEW YORK STATE COLLEGE OF VETERINARY MEDICINE
P. O. Box 786
Ithaca, New York 14850
Tel. 607-256-6541

31295
Received: 30 JUL 80
Accession No./Date
H80 5375
Special Number

D:

PLEASE FILL OUT THIS FORM COMPLETELY

YOUR ACCOUNT NUMBER: 4577
Would you like test results reported by COLLECT telephone call? YES ☐ NO ☒

Has previous material been submitted for this problem?
Yes ☐ No ☒ Unknown ☐
Date(s) Accession Numbers

SEP 2 1980 Dept. of Biology

RETURN ADDRESS FOR USE WITH WINDOW ENVELOPE

Veterinarian: Dr. Daniel C. Laughlin
Address: 271 Scottswood Road
Riverside, Illinois 60546
city state zip
Telephone Number: (312 area) 442 — 7344

Client: Ringling Bros. Circus World
Address: P. O. Box 800
Orlando, Florida 32801
city state zip
County: Town:

NYS Ag & Mkts Herd Code: Co. No. Tn No Herd No

ANIMAL IDENTIFICATION
Sex Code M-Male MC-Male (Castrated) F-Female FS-Female (Spayed)
Specify age in Years (Y), Months (M), Weeks (W) or Days (D)

	Name No	Species	Breed	Sex	Age
1.	Iki	Asian		F	46
2.		Elephant			
3.		(Elephas		maximus)	
4.					
5.					
6.					
7.					
8.					
9.					
0.					

Clinical/Differential Diagnoses: chronic cystic endometritis w/ pyometra, septicemia and systemic abscessation; bronchopneumonia

Date specimen(s) taken: July 9, 1980

List tissues submitted: kidney, lung, liver artery, brain, uterine wall, endometrium, ovary

Tests requested: histopathogy

If these tests are to meet export requirements, specify:
(country of destination) / (shipper or exporter)

If SPECIAL or MONITORING fee has been authorized, specify by whom:

HISTORY: A complete history is important. Please give detailed information regarding affected animal(s).

Date of onset of illness: in AFFECTED HERD ; in SUBMITTED ANIMAL(S)

Herd size: 18 Number of animals affected: 1 Number dead: 1

Vaccination History: tetanus toxoid '79 and '80

Additional History: This animal was reported ill about six weeks prior to her death with vague clinical signs including moderate anorexia, decreased thirst and a fever of 2 degrees F. She responded to treatment and was transferred one week later to the owner's central Florida facility from tour. This transfer was made because of a history of chronic progressive rheumatoid disease with arthritis. Clinical signs of illness were not reported during the ensuing four weeks in Florida prior to 7-7-80, when she was noted to be lethargic, with decreased appetite and thirst. On the morning of 7-8-80 she was reported to be ataxic and anorexic with labored breathing. She died at 3:15 P.M. July 8, 1980. History revealed a significant weight loss (approx. 15%) during the preceding six months.

2829
EXOTIC ANIMAL SERVICES
312 442-7344
271 SCOTTSWOOD RD
RIVERSIDE, IL. 60546

Veterinary Reference Laboratory
P.O. Box 30633, Salt Lake City, Utah 84130
Phone: 800-453-4530

DOCTOR: FILE #: 128529 DATE: 7.31.80 AGE: 46
OWNER RINGLING BROS CIRCUS SPECIES: ELEPHAS MAX BREED: ASN ELEPHANT SEX: F
AN.ID: "IKI" SPECIMEN: NECROPSY

MICROSCOPIC:

Examination of the submitted necropsy tissue reveals that the hepatic tissue demonstrates hemosiderosis and fibrosis in centrilobular areas. There is some chronic congestion as well. Many of the hepatocytes contain hemosiderin and bilirubin pigment. The uterine wall demonstrates some edema and congestion. A few inflammatory cells are scattered throughout but they do not appear to be acute inflammatory cells and are apparently due to chronic irritation. Many of the glandular elements are dilated and filled with mucus secretions. Some degenerative process due to autolysis has occurred as well. Several sections of uterine wall were examined and demonstrated the same type of change. The artery wall demonstrated some minimal mucinous change but otherwise it seemed to be fairly normal histologically. The severe changes in the pulmonary tissue demonstrated focal areas of degeneration and suppuration along the bronchioles and in the interstitial areas. Multiple areas of degeneration with hyaline degeneration of the vascular walls are prominent. These changes are rather characteristic of a septic problem and embolic pneumonic change. There is some fibrin and edema in the pulmonary tissue. Several sections of brain tissue were examined. There was a suggestion that some of the tissue may have been degenrate but the specific cause could not be identified. There was some hemorrhage and degeneration with no specific inflammation around it. This could have been the result of a septic problem or vascular problem at this location, but again, due to the small amount of material submitted it is difficult to specifically identify, although we would certainly imply that a septic problem could result in this type of change. Other sections of brain tissue seem to be relatively normal. The several sections of endometrium demonstrate a rather severe dilatation of the glandular elements and some cystic mucinous material with proteinaceous material present. Some inflammatory cells were prominent. There is some interstitial inflammation throughout this endometrium but a severe pyometra does not seem to be prominent in this endometrial section. The section of renal tissue submitted demonstrates interstitial fibrosis of a rather chronic and diffuse nature. There are focal areas of interstitial inflammation in those areas and the inflammatory response is rather diffuse and includes lymphocytes, plasma cells and other chronic inflammatory cells. Some of the tubular elements are dilated. Many of the glomerular tufts are undergoing scarring, although some tubular damage is prominent throughout the tissue. The basement membranes of the glomerular tufts are somewhat thickened and there is fibrosis around it as well.

CONTINUED......

2829
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271 SCOTTSWOOD RD
RIVERSIDE, IL. 60546

Veterinary Reference Laboratory
P.O. Box 30633, Salt Lake City, Utah 84130
Phone: 800-453-4530

DOCTOR:		FILE #:	128529	DATE: 7.31.80	AGE:46
OWNER	RINGLING BROS CIRCUS	SPECIES	ELEPHAS MAX	BREED:ASN ELEPHANT	SEX:F
AN.ID:	"IKI"	SPECIMEN:NECROPSY			

PAGE 2

MICROSCOPIC CONT.

DIAGNOSIS:
1. CHRONIC CYSTIC ENDOMETRIAL HYPERPLASIA
2. SEVERE ACUTE SUPPURATIVE INTERSTITIAL PNEUMONIA (EMBOLIC)
3. CHRONIC INTERSTITIAL INFLAMMATION OF THE KIDNEY WITH GLOMERULOSCLEROSIS
4. MODERATE MEMBRANOUS GLOMERULONEPHRITIS
5. POSSIBLE FOCAL ENCEPHALOMALACIA
6. SEPTICEMIA

COMMENT: In this particular case there is every indication that the individual did have a cystic endometrial hyperplasia and there is a possibility that in some point of the uterus that pyometra was present, although we do not feel that it was specific in the sections of tissue that we had. This probably resulted in the septicemia and pulmonary changes that were identified. Of course, the pulmonary changes are severe enough to have caused the death of the individual. These changes are characteristic of a bacterial infection that you have described. The other possibility with some of the hepatic changes are those of some type of heart problem such as vegetative endocarditis but we are not able to identify that specifically. If there were areas of brain tissue that looked malacic we would certainy wonder about a septicemic problem that resulted in this malacic tissue that we have described. The renal changes are rather severe and do suggest that there may have been some renal problems in the individual, although clinically this was not described specifically.

L.D. McGill, DVM, Ph. D.
Pathologist

LDM:tc
8.13.80

NEW YORK STATE COLLEGE OF VETERINARY MEDICINE —— SURGICAL PATHOLOGY SERVICE

Report for case H80-5378 (DIAGNOSTIC LAB # 31295-1) 8/5/80

ANIMAL:

Owner: RINGLING BROS
Breed: Elephant
I.D. : IKI
Sex : Female
Age : 46 YR

REFERRED BY: 4577

EXOTIC ANIMAL VETERINARY SERVICES,
LAUGHLIN (CONSULTANT),DANIEL C
271 SCOTTSWOOD ROAD
RIVERSIDE, IL 60546
(312)-442-7344

Case Received: 07/30/80
Tissues submitted: Lung; Liver; Kidney; Uterus
Slides prepared: 3
Exam Results entered: 08/05/80
Examining Pathologist: Riley

Pathologist-in-charge: Castleman

Findings for case H80-5378 (DIAGNOSTIC LAB # 31295-1)

SLIDE 1: Lung:
Some of the alveoli are normally expanded and contain foamy eosinophilic material and occasional neutrophils. There are multifocal areas of fibrin exudation and macrophage accumulation associated withbacterial colonies, pyknotic alveolar epithelial cells and a neutrophilic inflammatory response.

Slide 2: Kidney, brain, Uterine wall.
In the kidney there is widespread tubular degeneration and interstitial inflammation. In the pelvis and medulla the collecting tubules are widely dilated and contain necrotic cell debris and inflammatory cells. No lesions were observed in brain or uterine wall.

Slide 3: Endometrium, liver.
There is some fibrosis of the endometrium. The liver shows extensive centrilobular congestion and centrilobular hepatocytes are atrophied and contain brown pigment granules.

HISTOLOGIC DIAGNOSIS: LIVER: CHRONIC CENTRILOBULAR CONGESTION AND BILE PIGMENT RETENTION.
KIDNEY: CHRONIC SUPPURATIVE INTERSTITIAL NEPHRITIS
LUNG: ACUTE MULTIFOCAL FIBRINOPURRULENT PNEUMONIA
UTERUS: CHRONIC ENDOMETRIAL FIBROSIS

FINAL DIAGNOSIS: BACTERIAL INTERSTITIAL NEPHRITIS AND PNEUMONIA

Comment: The changes indicate bacteremia and multiorgan embolic infection.

WC:bjt

** NOTE ** The following information is for DATA RETRIEVAL purposes ONLY **

CODED FINDINGS for case H80-5378 (DIAGNOSTIC LAB # 31295-1) 8/5/80

0 (GENERAL)	:	7140-1200.0	(NEPHRITIS INTERSTIT DT BACT)
0 (GENERAL)	:	3600-1000.0	(PNEU)
370 (Lung)	:	3600-9300.0	(ACUTE PNEU)
600 (Liver)	:	6800-5200.0	(CONGES LIVER)
645 (Kidney)	:	7140-1000.0	(NEPHRITIS INTERSTIT)
645 (Kidney)	:	7100-9570.0	(CHRONIC NEPHRITIS)
720 (Uterus)	:	7820-9000.6	(FIBROSIS UTERUS)

STATE OF FLORIDA **FLORIDA DEPARTMENT OF AGRICULTURE & CONSUMER SERVICES**

DOYLE CONNER COMMISSIONER * DIVISION OF ANIMAL INDUSTRY / KISSIMMEE DIAGNOSTIC LABORATORY
P. O. BOX 460 / KISSIMMEE 32741

PHONE: AC 305/847-3185 ACCESS. NO. 80-8627

DATE REC'D 7/10/80

VETERINARIAN: Dr. Daniel C. Laughlin
P. O. Box 800
Orlando, Fl 32801

OWNER: Ringling Bros. Circus
same

SPECIES Elephas maximus BREED Asian Elephant AGE 46 SEX F FIELD DIAG: pyometra and/or endometritis w/septicemia & systemic abscessation.

SPECIMENS 4 culturette, 1 uterus, 1 kidney, 1 lung and 1 cerebro spinal fluid

TESTS REQUESTED bacterial culture ID & sensitivity

ASSIGNMENTS: NECROPSY___ CHEM___ PARASIT___ PATH___ VIROL___ BACT X SERO___ OTHER___

REPORTS PRELIMINARY ___ PHONE ___ FINAL JUL 14 1980

HISTORY: This animal was reported ill about six weeks ago with vague clinical signs and a fever of 2°F. She responded to treatment but was subsequently transported to Circus World from tour because of a history of progressive chronic rheumatoid arthritis. Clinical signs of acute illness were not reported at Circus World prior to July 7.

RESULTS OF TESTS:

7/14/80 Bacteriology: Lung - Beta Hemolytic Streptococcus
CSF - No growth.
Uterus, kidney - *E. coli*, Beta Hemolytic Streptococcus

(Sensitivity attached.)

Dr. E. D. Stoddard
CASE COORDINATOR

APPENDIX IV. Necropsy report on Toose, an Asian elephant, *Elephas maximus* (reprinted with permission).

University of Missouri-Columbia
College of Veterinary Medicine
Veterinary Medical Diagnostic Laboratory
Columbia, Missouri 65211
Telephone (314) 882-6811
(314) 882-6695

September 11, 1981

Mr. Rex Williams
5150 Candlewood Street
Lakewood, California

Dear Mr. Williams:

This is the Necropsy Report on the elephant which you brought to us on September 3.

The immediate cause of death was a condition called intussusception. Approximately 6 feet of the distal end of the small intestine entered the lumen of the colon. In order to do this, it is a little like a collapsing telescope. The flow of ingesta through the gut stops and the blood flow to the part that turns into the colon swells because blood cannot get back out. The disease is always fatal unless there is surgical intervention.

The specific cause of intussusceptions can seldom be determined. The disease is frequently seen following some hypermotility of the intestine as from digestive upsets, parasitism or inflammation.

The elephant was free of parasites. Cultures of the intestine did not yield any known pathogens. Sometime in the distant past the animal had suffered from severe ulceration of the stomach. Two-thirds of the lining mucosa of the stomach showed evidence of healed ulceration. This lesion was not active at the present time. The cause of the diarrhea which occurred a week or two prior to the intussusception was not determined.

Sincerely,

L.D. Kintner, DVM

/sgt

APPENDIX V. Water consumption by three elephants: large, medium, and small[1]

ANIMAL	Amount of water (in liters)[2] sucked per bout		Time taken (in seconds) from moment of sucking to complete drinking per bout		Number of Trials	Total amount of water (in liters) consumed and time taken	Average amount of water (in liters) per bout
	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM			
Male Asian elephant ("Tommy") 9,800 pounds 37 years old[3]	4.500	10.470	5.0	25.0	25	211.605 (55.90 gals.) in 282.4 seconds	8.464 (2.23 gals.)
Female Asian elephant ("Zola") 6,500 pounds 16 years old[4]	1.750	4.175	3.6	5.6	17	60.095 (15.89 gals.) in 83.5 seconds	3.535 (0.935 gals.)
Female African elephant ("Churchill") 3,000 pounds 8 years old[4]	1.860	3.565	4.0	10.0	11	31.753 (8.39 gals.) in 84 seconds	2.866 (0.762 gals.)

1. Experiment was conducted at the Michigan State Fairgrounds, Detroit, Michigan, March 28, 1982. Elephants were performing with the Shrine Circus. "Tommy" is owned by Tony Diano (of M & M Circus Internationale) and his trainer is Lee Keener. "Zola" and "Churchill" are owned and trained by Bucky Steele. Weights of elephants are approximate.
2. Environmental temperature at the Coliseum was 21°C (69.8°F), and water temperature was 9°C (48.2°F).
3. This elephant was not watered for 15 hours prior to our experiment.
4. This elephant was not watered for 17 hours prior to our experiment but was given a small amount of water 7 hours earlier in the day.

(Numb. 326.)

PHILOSOPHICAL TRANSACTIONS.

For the Months of April, May, *and* June, 1710.

Osteographia Elephantina:

OR,

A full and exact Description of all the Bones of an *Elephant*, which dy'd near *Dundee*, *April* the *27th*, 1706. with their several Dimensions.

To which are premis'd,

1. *An Historical Account of the Natural Endowments, and several wonderful Performances of* Elephants, *with the manner of Taking and Taming them.*
2. *A short Anatomical Account of its Parts.*

And added,

1. *An exact Account of the Weight of all the Bones in this Subject.*
2. *The Method I us'd in preparing the Sceleton.*
3. *Four large Copper Plates, wherein are represented the Figures of the Stuff'd Skin, and prepared Sceleton, as they now stand in the Publick Hall of Rarities at* Dundee; *with the separated Bones in several Views, and other Parts of this* Elephant.

Communicated in a Letter to Dr. *Hans Sloane*, R. S. Secr. By Mr. *Patrick Blair*, Surgeon, *&c.*

Osteographia Elephantina:

OR,

A full and exact Description of all the Bones of an *Elephant*, which died near *Dundee*, *April* the *27th*, 1706. with their several Dimensions. Communicated in a Letter to Dr. *Hans Sloane*, R. S. Secr. By Mr *Patrick Blair*, Surgeon, *&c.*

SIR,

THE *Elephant*, tho' an Animal so considerable for its Bigness and Strength, so remarkable for its extraordinary Endowments and stupendous Actions (if I may so call them,) that it has become the Subject of the most Curious Naturalists of all Ages, and been admir'd by all those who beheld it; yet has its Body been hitherto very little subjected to Anatomical Enquiries. This induc'd Me (when upon *April* 27. 1706. the last *Elephant* that was in *Britain* died near this Place) to bestow some Pains in viewing its Parts at the Opening: But the Time was so short, and Inconveniencies I labour'd under so great, that I was doubtful, whether what I had observ'd might prove worth your Own or your honourable Society's while, until I had address'd your self, and you were pleased to honour me with a return dated *July* the 11th following: Wherein you signify'd, 'You were glad the *Elephant* had fall'n where Notice 'might be taken of its Parts by Dissection, and that the Bones 'would be well worth Observation, for several Reasons; but 'chiefly one, namely, that there have been large Bones, supposed to be those of *Elephants*, found many Feet deep in 'the Ground, and that if there were a Sceleton to compare 'them by, that matter would be more certain: And there- Preface

H 'fore

(54)

' fore (tho' I had told you in mine that I was able to make but ' few of them) you desired me to let you have my Observations. The better to enable me to do which, you favour'd me with two Treatises on *Elephants*, which I suppose to be the only Two hitherto communicated to the *Royal Society*; one whereof gives an Anatomical Account of the *Elephant* accidentally burnt in *Dublin*, *Anno* 1681. written by Dr. *Moulins*; which, tho' it requires a further Enlargement, being very brief both in the Anatomy and Osteology, and the Figures not very exact, yet seems to have been the only Book which undeceiv'd the Author of the other, *viz. Wilhelmi Ernesti Tentzelij Historiographi Ducalis Saxoniæ Epist. de Sceleto Elephantino, Tonnæ nuper effosso, ad Anton. Magliabechium magni Ducis Hetruriæ Bibliothecarium.* This is the Treatise which describes the Bones mention'd by you, found in an Hill near *Erfurt* in *Germany*; wherein the Author earnestly intreats, 'That ' tho' by distance of Place he cannot expect from his Friend such ' a Figure of the *Elephant* at *Florence*, (as *Cyampinus* formerly ob- ' tain'd) yet, that he would, as exactly as possible, take the Di- ' mensions of all the Bones, especially of the Head, Teeth and ' Tusks, their Number, Situation and Origin; and he desires further to know, how old that Sceleton at *Florence* was, how high, and when it was dissected.

Therefore, *Sir*, in Obedience to your repeated Request, in the several Letters you were pleased to Honour me with, and finding the Author of the last nam'd Treatise, has favour'd the Repository of your Society with several Specimen's of the Bones he describes, some whereof perhaps being broke, may come not to be so well known; that I may satisfy you to whom I am so much bound, for the many special and signal Testimonies of your Favour, your honourable and learned Society, for whom I have so great a Veneration and Respect, and to whom I shall be extreamly glad, if by these means I may be capable to do any small piece of Service, and the Learned *Tentzelius* in that he so earnestly desires, and wherein I do not yet understand his Friend has answer'd him: In a word, that I may satisfy the World in such Things as were of Moment in this rare and curious Animal, I shall observe the following Particulars, *&c.*

The Method of Procedure 1*st*, Shew, how the *Elephant* fell in our way.

2dly,

(55)

2dly, Remove some mistakes which have been entertain'd, concerning its Original Names in the Holy Scriptures.

3dly, Give a short Historical Account from Authors of the several Natural Functions and Automatical Performances of this Animal, with the Method of taking and taming it.

4thly, I shall give such a Superficial Anatomical Description of its Parts, as the Inconveniences I labour'd under at the opening would permit.

5thly, I shall give an exact Description of all its Bones, such as is usually given in Treatises of *Osteologie*, with a particular Account of the Dimensions of these in this Subject.

6thly, A true Account of their Weight and Number.

7thly, The Method I us'd in mounting the Sceleton.

To all these I have added the Figures of the stuff'd Skin, mounted Sceleton, separated Bones in different Views, and other Parts of this Animal; all done from the Original, (and represented in several large Copper Plates) as it now stands in the Hall of Rarities in this Place; the Copy whereof the *Royal Society* has been already pleased to approve, as intimated in yours to me in *June* last.

After this Animal had travell'd most part of *Europe*, she came at last to this Kingdom; where, after some stay at *Edinburgh*, they conducted her to the *North*, and in their return came along the Sea-Coast; where being but few Places on the Road for making Advantage, by long and continued Marches they hastned hither; and when they were come within a Mile of this Place, the poor Beast, much fatigu'd and wearied, fell down. They us'd many Endeavours to get her on foot again, but they all prov'd ineffectual. At last they digg'd a deep Ditch, to whose Side she might lean, till she were sufficiently rested; but that proved her Ruin; for shortly afterwards there fell great Rains, which fill'd the Ditch with Water: So that after lying in the puddle a whole Day, she died next Morning, being *Saturday April* the 27th 1706. When the Keepers saw that she was Dead, they came to the Ma- *How the Elephant fell in our way.*

H 2 gistrates

gistrates of this Burgh, and having made Oath they had done her no designed injury, they got an Attestation accordingly, and went off, having first given the Cadaver to an Ingenious Gentleman, Capt. *George Yeman*, since Provost of this Town; by whose Care the People were prevented from carrying it all away in pieces, as they did one of the fore Joints, and we still continue Masters of the Remains; for the Day she di.d, he was pleased to go out himself, and take me along with him, in order to have the Skin flea'd off, which was his chief design, and the Body opened, which was mine. As I was very glad of the Opportunity, so I was concern'd because of the disadvantage I was at, which kept me from prosecuting what I design'd: For there went out a great Multitude, the Day was very hot, and being the last Day of the Week, the Subject could admit of no delay, especially since it lay in the high Way and open Fields: So that I scarce had any convenience to pry into, or so much as to see any thing of moment, much less to enquire so nicely into the Structure of the Parts, as the Subject requir'd. 'Twas One of the Clock in the Afternoon before all were in readiness to go out, and most of the time was spent by the Butchers in fleaing off the Skin. All I got done, was to take such narrow Inspection of the Muscles of the *Proboscis*, (or *Promuscis*, as some call it, in *English* the Trunk) as I could. Afterwards I caus'd the *Abdomen* to be open'd, and then the *Thorax*, and that by the unweildy Hands of unruly Butchers, who at opening the first, would have wholly cut through the *Ossa Innominata*, had I not hinder'd them; and at last, whether I would or not, did so slash the *Sternum*, and mangle several of the *Cartilages*, as to render them useless, cutting and tearing where soever they came. I had not much above an Hour to bestow when Night came on, and that amidst a Throng and Rabble in mighty hot Weather. During that time I view'd the Situation of the *Viscera*, took the Figure and Dimensions of the *Liver*, extracted the *Uterus* and *Bladder*, and caus'd the *Head* to be cut off, which (with some other Parts I design'd to have dissected) were brought to Town. I had a mind to be more fully satisfy'd about the *Intestines*, *Spleen* and *Kidneys* on *Monday*; but when I went out again, the *Intestines* were all dry'd by the Heat; so that their Figure and Structure were quite spoil'd, and the Country People were so earnest to have Parts of it, that they had stole away the whole fore Foot before that time; which, after much Pains and the earnest Care of Provost *Yeman*, we recover'd about 6 Weeks after-

afterwards: So that the time I design'd to have bestow'd in Dissecting the Parts I had reserv'd, was taken up in excarnating, boyling, and taking care of the Bones; which, had not some Physitians and Surgeons gone out and assisted me on the *Monday*, had been all carried off; and the heat of the Weather was such that the other Parts would not keep. This, I hope, will be a sufficient excuse for the Lameness of the following Account.

The Behemoth in Job is not the Elephant.

Because the Names given to the *Elephant* in Holy Scripture have been much mistaken, tho' perhaps it may seem forreign to my Business, yet I hope 'twill not be unpleasing, if from Authors I endeavour to clear them. *Junius* and *Tremellius*, *Franzius*, &c. who comment upon the 40*th Ch.* of *Job v.* 15. and downward, take the *Behemoth* for the *Elephant*; but others, such as the Learned *Bochart*, *Par.* 2. *lib.* 4. *c.* 15. and from him Dr. *Patrick*, are of Opinion, 'tis not the *Elephant* which is meant there, but the *Hippopotamos*, or River Horse; for *Buxtorf* and such others as are acquainted with the Original, agree, that the Word *Behemoth* does not properly signify any thing more than a great Beast; and both in *Job* and *Esdras*, 6 *Ch. v.* 49. (where the *Behemoth* is translated *Enoch* in the *English* Bible) the *Behemoth* and *Leviathan* are nam'd together. *Esdras* makes them the Work of the Fifth Day, wherein Fishe, other Sea Animals, and Sea Fowls were created; by which not the *Elephant*, but the *Hippopotamos* may be meant, which *Bochart* proves by the following Arguments. 1. As in *Job* 39. Land Animals, such as Quadrupeds and Fowls, are spoken of; so in the 40 and 41. *Behemoth* and *Leviathan*, as belonging more properly to the Water, are treated of. 2. The Force of the *Behemoth* is said to be in the Navel of his Belly, whereas 'tis the softest part of the *Elephant*; but in the *Hippopotamos* it is so thick and impenetrable, that it resists both Spears and Darts, which he abundantly proves from Authors. 3. The *Behemoth* is said to move his *Tail* like a *Cedar*; now the *Tail* of an *Elephant* is long like that of an *Ox*, and but small in proportion to the Body; and to move like a *Cedar*, would import some strong round substance, and rather seems to agree with what *Bellonius* affirms of the *Hippopotamos*, that *Caudam habet brevem, crassam & rotundam*, tho' *Bochart* renders it *Retorquet, & non arrigit Caudam*, as *Junius* has it. 4. *Bochart* says, that the Word in the Original will not imply *Nervis Testium ipsius*, as *Junius* has it, but *Nervis Femorum &c.* Not the Sinews of his Stones, but the Nerves of his Thighs are intricate. 5. The *Elephant* seldom lies down, and never in the

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A Table containing the particular Dimensions of the Vertebræ *and* Ribs, *and Weight of all the Bones of the* Elephant.

The Bones of the Head.

	℔
Upper Jaw —	66
Lower Jaw —	45

The *Vertebræ* of the Neck.

Numb.	Weight. ℔	℥.	ʒ.	Length of Spinal Process. Inch.
1	1	13	—	
2	1	6	4	
3		13	4	1/4
4		13	4	1/2
5		14	4	1 1/2
6		14	6	3
7	1		—	5
	7	10	6	

The *Vertebræ* of the Tail.

Numb.	℥.	Length. Inch.	Breadth. Inch.
1	10	2	6
2	8	—	5 1/2
3		—	5
4	6	—	4 1/2
7		—	4
8	5	—	
9	4	—	3 1/2
10		—	3
11	3	—	2 1/2
-13-	2 2/3	—	
14	2 1/2	—	1 3/4
15		—	1
16	1 1/4	—	2 1/2
17	1	—	
18		1 3/4	
-20-		1 1/2	
21		1 1/4	
22		1	2 1/4
23	2/3	—	2
24		—	1 1/4
25	1/2	1/2	
-29-	2/3	—	

The *Vertebræ* of the Back. / The Ribs.

No.	Back Weight ℔.	℥.	ʒ.	Length of Spinal Process. Inch.	Breadth of Extrem. Inch.	Ribs Weight ℔.	℥.	ʒ.	L. of inner Surface. Feet.	Inch.	L. between Extrem. Feet.	Inch.	Breadth of Extre. Inch.
1	2	4		8	2	1	13		1	5	1	4	4
2	2	2		12	3 1/2		12	4		9		8	3
3	2			13	4 1/2	1	1	2		11 1/2		10	
4	1	5					5		2	2	2		
5	1	4	2	12	3 1/2		8	4		6		3	2 1/2
6	1	2	3	11 1/2	3		2	3				3 1/2	
7		15	6	11			1	5		8		3 1/4	2 1/4
8		14		10 1/2	2 1/2		4	6		10		4 1/2	
9		14		10			3					5	
10							15			9		3	
11							14	4		7			
12		13		9 1/2	2		13	4		5		1	
13				9			12			4			
14					1/2		10	6		1/2	1	11 1/2	
15				6 1/2	1 1/2		9					10	1
16				6	2		5	5	1	9		8	
17				5			5			8		7	
18			2	4 1/2			3	2		5		4 1/2	
19			4	3			2	1					
	20	8	7			16	15	6					
						16	15	6					

The *Vertebræ* of the Loyns.

1	13	4	
2	12	7	
3	11		
	2	5	3

	℔	℥	ʒ	∋
3. Weight of Ribs	33	15	4	
Tail	4	2	7	1 ∋

The

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The Sceleton of the Elephant consists of the Bones of

	Number	℔	℥	ʒ	∋
The Head divided into those of the					
Upper Jaw, *viz.*					
Calvaria, or upper and back part	1				
Frons, or upper and fore part	1				
Two *Maxillary* Bones	2				
Two Bones of the Palate	2				
Two *Zygomatic* Bones	2				
Two *Styloid* Processes	2				
Two Tusks	2				
Four Grinders	4	66			
Lower Jaw	1				
Four Grinders	4	45			
	21	111			
The Trunk composed of the					
Spine consisting of the *Vertebræ* of the					
Neck	7	7	10	6	
Back	19	20	8	7	
Loyns	3	2	5	3	
Os Sacrum	5	4	0	0	
Tail	29	4	2	7	1
Ribs, 19 Pairs	38	33	15	4	
Sternum	4	3	00	0	
	105	75	11	3	1
The Fore Extremities					
Scapulæ	2	19	08	0	0
Humerus	2	16			
Cubitus and *Radius*	4	15			
Carpus, Six on each Foot	12	3	12		
Metacarpus	12	3	4		
Toes	24	2	3		
Ossa Sesamoidea	24		6		
	80	60	1		
The Hind Extremities					
Ossa Innominata, viz. *Ilion*, *Pubis*	2	28	00		
Femur, or Thigh Bone	2	16			
Tibia and *Fibula*, or Leg and Spit Bone	4	13	4		
Patella, or Knee Pan,	2		12		
Tarsus	12	5	10		
Metatarsus	12	1	06		
Toes	20	1	02 1/2		
	54	66	2	1/2	
Summa Totalis	260	312	14	7	1

This is the Total Sum of the weight of the Bones.

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thence to the said Bone of the *Metacarpus* with its Toe, where it was fastned.

Connexion of the Femur. The upper *Epiphysis* of the *Femur* having also separated by boiling, it was requisite to perforate its Head four times, for the immission of two folded Wires, which were brought obliquely down the inner and outer side to its Neck, where their Extremities were twisted and secured. Afterward it was perforated in the middle four times more, for two other folded Wires, which were once or twice twisted, and their Extremities put through the foresaid Holes to the inner and outer part of the Neck of the *Femur*, as before, there to be made fast. The *Acetabulum* was perforated in the bottom, and these two Foldings pass'd through it; whereinto was put a Pin, at the back-part of the *Ossa innominata*, to be pull'd out at pleasure, and the Thigh suspended as the *Humerus*.

Of the Tibia *and* Fibula. Two folded and twisted Wires were pass'd in at the *Epiphysis*, on each side of the *Spina*, in the middle of the *Tibia*, and their Extremities brought out at its upper and back part, where they were riveted: Afterward the lower *Epiphysis* at the *Femur* was perforated from the right to the left, and a Pin passed from the out-side, through the Foldings of the Wires from the *Tibia*, to the in-side, (whereby the Flexion and Extension is most conveniently shewn,) to be taken out at pleasure. The *Perone* was fix'd to the *Tibia* at the upper part, by a Pin passing obliquely upward from the one to the other; and the *Patella* fastned to the fore-part of the *Femur*, by a Pin passing directly inward from before to behind.

Of the Hind Foot. The lower part of the *Perone* forming the External *Malleolus*, is perforated from without to within, as is the opposite part of the *Tibia* forming the Internal one; likewise the *Astragalus* is perforated from the right to the left, corresponding to these two Holes, for the Immission of a Pin, whereby the Foot is join'd to the *Tibia*, to be pull'd out at pleasure. The *Astragalus* is join'd to the *Talus* by a Pin, pass'd from the upper and middle part of the one, to the lower part of the other, where it is riveted. The *Astragalus* is thrice perforated before; into two of which Holes a folded Wire is pass'd, which goes forward through the *Os Naviculare* to the Bones of the *Metacarpus* of the second and third Toe from the inside, at whose Extremities they are fix'd. The third Wire runs from the *Astragalus* to the *Os Naviculare*, and the third *Os Cuneiforme*, to the fourth Toe. The said *Os Naviculare* is

is perforated on the inside for a Wire, which runs through the Bone of the *Metacarpus* and inner Toe. The third *Os Cuneiforme* is perforated for a Wire which passes through the Bone of the *Metacarpus* and outer Toe. The three *Ossa Cuneiformia* are join'd to each other by a folded Wire, which runs twice from their outside to the inside, where they are secured.

Sir, By the Opportunity I have had of preparing and joining these Bones, it may be expected I should give some Account of their Structure: But as the design of preserving the Sceleton entire gave me no Liberty to go any further than their External Surface, so it cannot be expected I could dive any deeper in the Knowledge of them. *Tentzelius* says, *Omnia isthæc Ossa porosa sunt & rimosa*; and I may add, *Levia* too: For there is nothing about them to be seen of that Solidity and Compactness, that smoothness of Surface, and Whiteness, which is observable in other Quadrupeds of the larger size, such as Oxen, Horses, Harts, *&c.* or smaller, as Sheep, Dogs, Cats, *&c.* And I should have readily attributed this to the Youth of the Animal, had not *Tentzelius* from his Subject, suppos'd to be 200 Years Old, told the same. And this differs much from the Account of the *Behemoth* in *Job*, whose Bones are said to be as strong pieces of Brass, and Bars of Iron. The *Laminæ* of the Head were thin and solid; the External Table thin and more ponderous; the Teeth exceeding solid and ponderous: So that from the computation of the Weight of the upper part, which was taken off by the Saw, as in *Tab.* 3. *Fig.* 5. and 6. which is only 6 ℔. weight, I may reckon all the Head, which weighs 66 ℔. beside the Teeth, not to weigh above 24 ℔. at most; which well agrees with what *Tentzelius* says, that each of the *Dentes Molares* were 12 ℔. weight, and that of all the 45 ℔. which the Lower Jaw weighs, the rest of the Bone beside the Grinders do not exceed 12 or 16 ℔. For its External Surface seems to be both porous and rimous, as is said; and at perforating the *Condyles* seem'd to be very spongy, as were the Ribs, *Femur*, *Tibia*, *&c.* where, after the Drill had pass'd the External *Lamina*, which was very thin, it would have run forward as if it had been through so much Moss. When the *Epiphysis* came off the Thigh Bone, it resembled very much the *Epiphysis* of the *Femur* in Man; its minute *Cellules* were not so big as those of an Oxe, and the *Laminæ* which circumscrib'd them, not by much so solid. The *Humerus* indeed both above and below was

U 2 much

much harder; it did heat the Drill in paſſing: And there may be ſome reaſon for that too; *viz.* that ſince the Progreſſion of moſt Quadrupeds chiefly depends upon a more frequent motion of the Fore than Hind Limbs, it does much more here, where the Head is proportionably more heavy than in other Animals. And this perhaps is the reaſon too, why the Fore Limbs in this Animal are brought ſo far forward; for meaſuring in a ſtreight Line from the *Humerus* above to the *Carpus* below, and bringing another Line directly backward at the Articulation betwixt the *Humerus* and *Cubitus*, from the perpendicular Line before to the point of the *Olecranon* behind, it is 20 Inches; which is the reaſon why ſome believe my Engraver has made the fore Limbs of the Sceleton to bend too much at the Articulation. The Bones of the *Carpus* are pretty ſolid, and by Perforation they ſeem only to have a little ſpongioſity about the middle: All the reſt of the Bones of the fore Foot are ſpongy. The *Aſtragalus, Os Naviculare*, and *Oſſa Cuneiformia*, are more ſolid; but the *Talus* and other Bones of the hind Foot ſpongious. The Spine was ſpongy, as is uſual; the *Oſſa Innominata* of a middle Conſiſtence; and the *Scapula* very thin, but ſolid toward its Neck. I cannot poſitively determine the Cavities for the Marrow, nor quantity of it; but by comparing the Dimenſions with the Weight and ſmall quantity of Fat to be ſeen at the boiling, we may ſuppoſe it not to have been much in this Animal: I know not how it may be in others of this Species.

I muſt not forget to tell you, that when I weighed the Bones, it was immediately before they were joined; ſo that their weight was much diminiſh'd, in reſpect of what it was when they were newly boil'd. The weight is ℥16. to 1 ℔. and the meaſure, according to the *Engliſh* Yard, 12 Inches to a Foot, and 12 Lines to an Inch.

And thus, *Sir*, I have finiſh'd theſe my Weak Endeavours: The Undertaking, I doubt, will ſeem bold to ſome, and raſh to others, and the Performance mean. But the many Obligations you have laid upon me, and the frequent Marks of Eſteem I have received in your ſeveral Letters, made me paſs over all Obſtacles, Reflections, and Diſcouragements, when to ſerve you and your Honourable Society was my only Deſign. I have rather choſen to addreſs you in a plain and common Stile, than give the leaſt ſuſpicion of Diſingenuity in a finer Language; eſpecially ſince

ſince it is Hiſtory I have written, where Matter of Fact, and not Romance, where Eloquence, is the chief Deſign.

The Copper Plates, which at my own Charges I have cauſed to be engraven here, I acknowledge might have been done finer in *London*; but ſince I had the Original by me, whereby I was able from time to time to correct in the Ingraving what Errors happen'd in drawing the Figures, I rather choſe to have them done by me here: And tho' the Draughts of the Engraver be courſe, yet I have endeavoured what in me lay to have the Figures true and well proportion'd. Wiſhing all Health and Happineſs to your ſelf, Proſperity and Succeſs to your Honourable and Famous Society. I continue,

Sir,

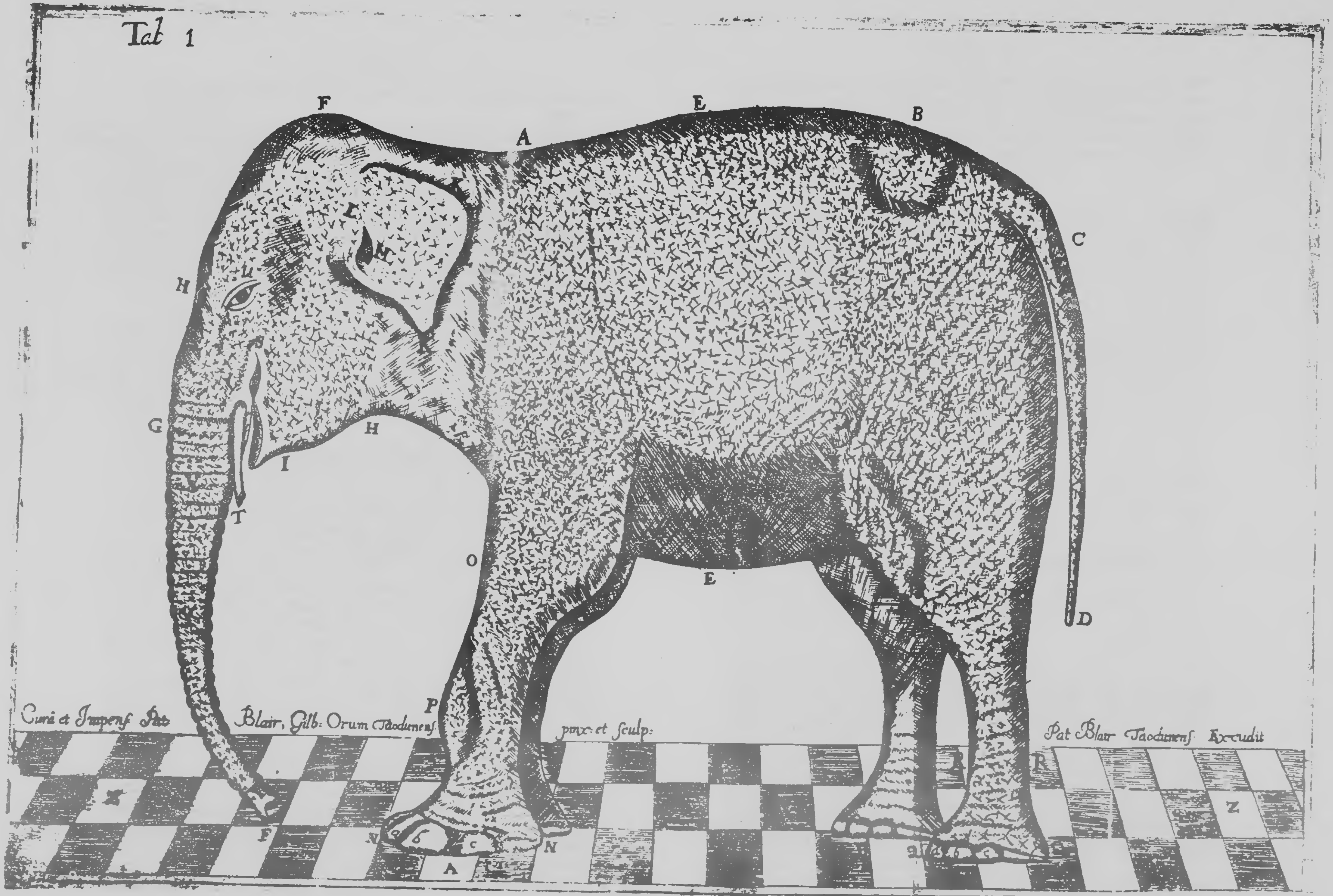
Your moſt humble, and

moſt obliged Servant,

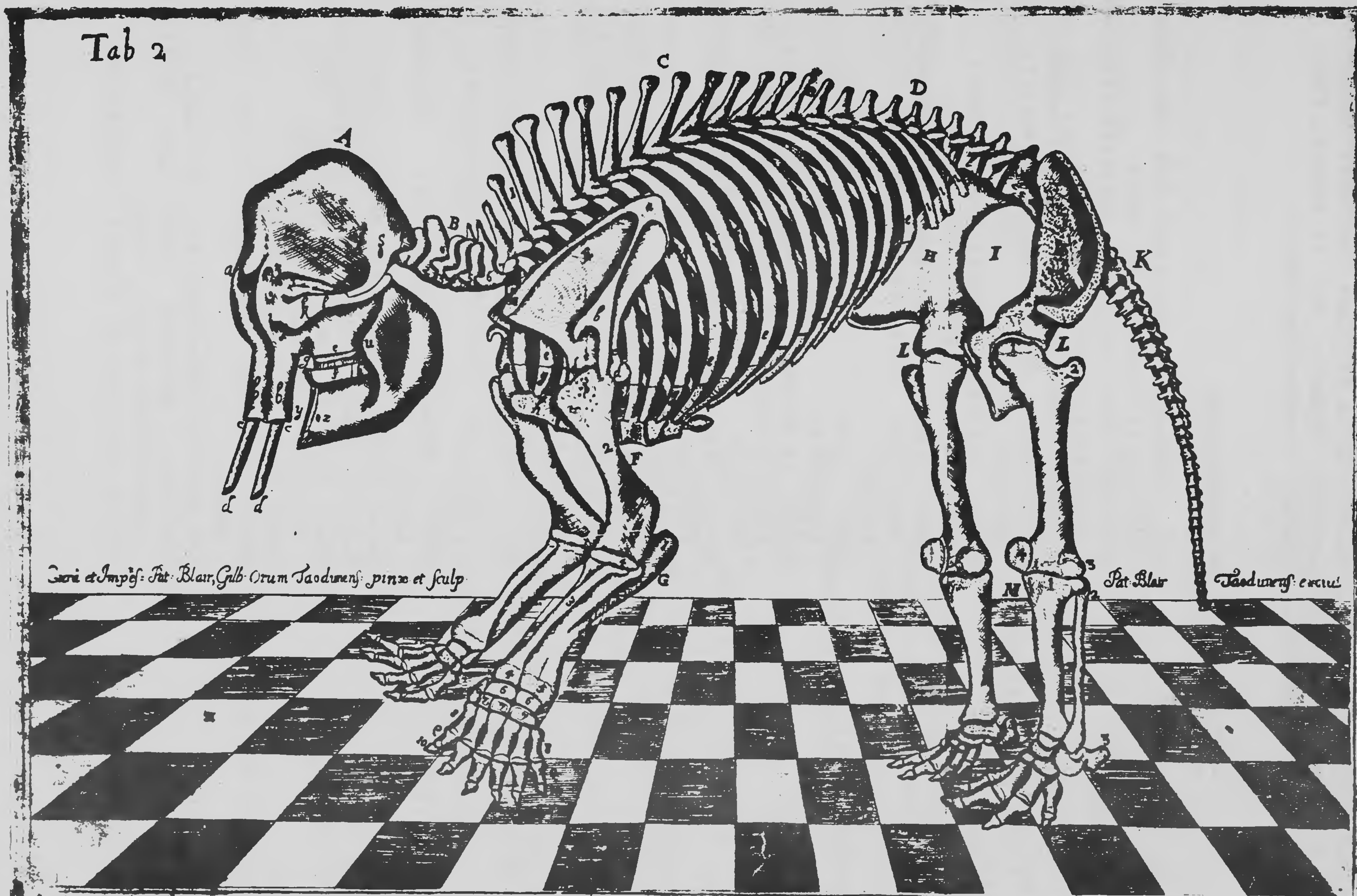
From my Houſe at *Dundee, April* 27. 1709.

PATRICK BLAIR.

The



Tabula I. Represents the stuff'd Skin of the Elephant, as it now stands in our Hall, with an Account of its particular Dimentions (designated by letters).



Tabula II. Represents the Sceleton of the Elephant, as it was mounted by my Direction, and now stands in the Repository of Rarities in Dundee. (Note the position of the scapula and the number of phalanges on the left manus.)