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POST-CRANIAL SKELETAL CHARACTERS
OF *BISON* AND *BOS*

BY
STANLEY J. OLSEN

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The original drawings were made by the writer with the aid of a camera lucida. The finished and scientifically accurate art work is the product of Mr. Andrew Janson, staff artist for the Florida Geological Survey, and his excellent work speaks for itself.

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STANLEY J. OLSEN

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POST-CRANIAL SKELETAL CHARACTERS
OF *BISON* AND *BOS*

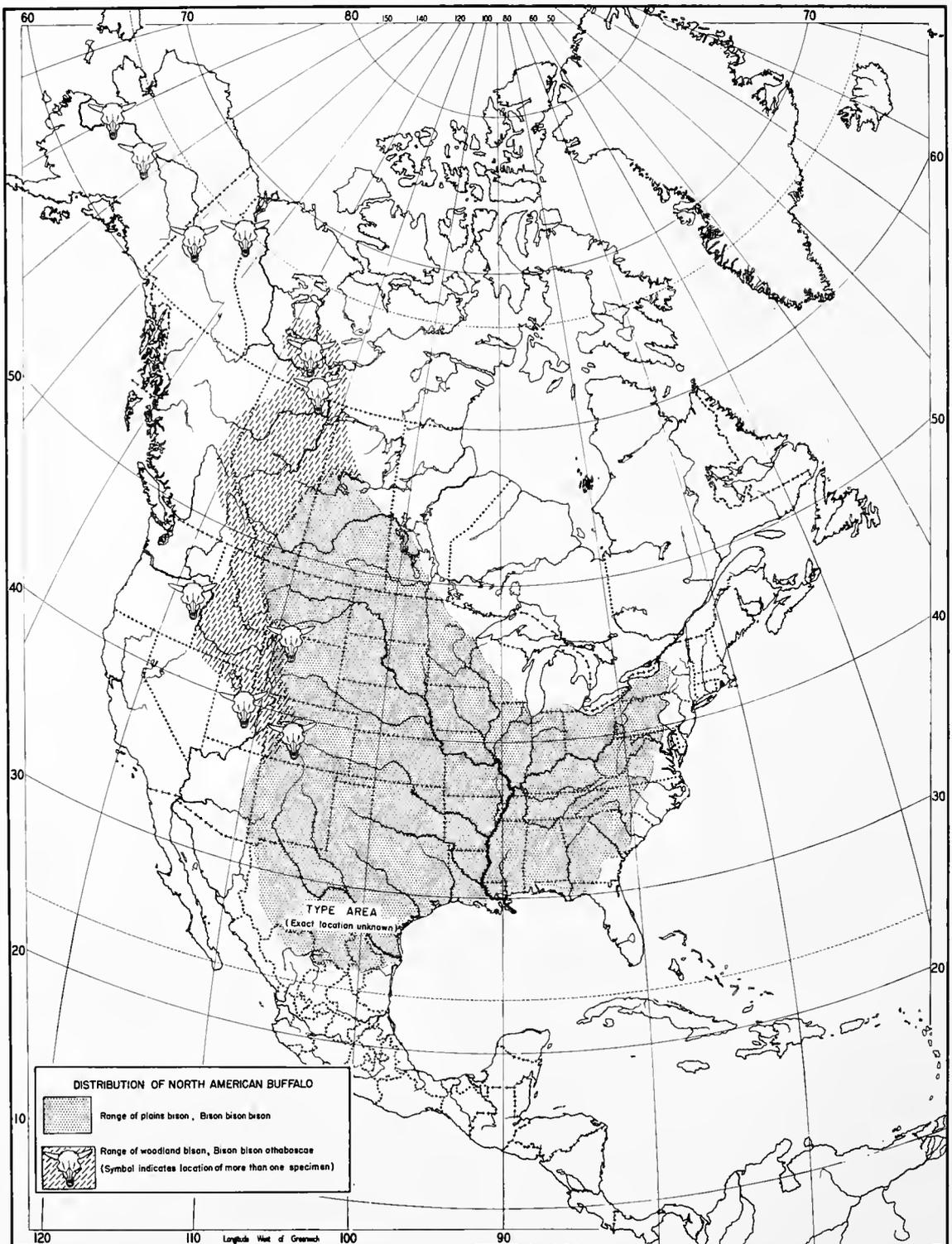


FIG. 1. Map showing distribution of North American Buffalo. Skull symbols, outside of cross-hatched area, indicate probable range of *Bison bison athabasca* during prehistoric times.

DISCUSSION

PERHAPS no forms of life are as symbolic of a free and wild continent as are the Indian and the North American buffalo. Due to the buffalo's wide distribution, great numbers and its importance as a major food source of the Indian, its skeletal remains have been found in almost every important archæological site within the animal's known range (fig. 1). Mr. G. Catlin, prophesying the future of the Indian and the buffalo, declared ". . . they have taken up their last abode, where their race will expire, and their bones will bleach together" (Catlin, 1844, vol. I).

The introduction of domestic cattle into North America took place at two widely separated points at about the same time. Dr. A. H. Sanders (1925, p. 709) summarizes these landings as follows:

The first reliable data as to cattle are contained in a written report found in the Spanish Archives at Madrid, to the effect that Gregorio Villalobos in 1521 went to New Spain (now Mexico) as governor-general or viceroy. Villalobos landed near the present town of Vera Cruz, Mexico, and according to the manuscript "brought a number of calves from Santo Domingo, he being the first to bring them to New Spain." . . .

Four years later, in 1525, Portuguese fishermen landed a few cattle and some hogs on Cape Breton Island, from which they were soon carried to Newfoundland and the adjacent mainland.

The conquistadores, Coronado, Fray Marcos de Niza, Oñate and others who explored the southwestern United States undoubtedly took with them cattle which were the basic stock of the southwest, including Old Mexico, Arizona, New Mexico and Texas. These animals were designated in the reports of the time as "droves of big cattle" with no mention being made of breed. However, they were probably of Andalusian stock, with heavy forequarters and light hindquarters, thick necks, large coarse heads, and possessing unusually long horns. From this first stock came the longhorns of Texas and ultimately the cattle industry of the West. The cattle that were

peculiar to Spain in the sixteenth century were neither as fine as the British breeds nor were they exceptional as either beef or dairy cattle. This is understandable since they were a product of a land where forage was not especially abundant. Hardiness and ability to thrive under primitive conditions were their chief recommendations and they were admirably suited to the new territory taken over by the Spanish Crown in the early sixteenth century.

There is little skepticism among workers having contact with *Bison* and *Bos* remains as to their similarity; in fact, Dr. C. Linnaeus (1788), in the type description of the plains bison, placed the species *bison* in the same genus as the present day domestic cattle, *Bos taurus*. This is due in part to the distinguishing differences between the skeletons of *Bison* and *Bos* which are so subtle that only a combination of these characters make certain bones identifiable and separable (figs. 3 and 4).

Archæologists have long felt the need for osteological keys to aid in determining the various problematical animals that turn up in their excavations, with special emphasis on those fragments that are labeled "cf. *Bison* or *Bos*." This has been pointed out in particular by Dr. J. O. Brew in the introduction to Miss Barbara Lawrence's fine paper on the mammals found at the Awatovi site (Lawrence, 1951) and by many of the people who were present at the discussions held by the Committee on Archæological Identifications of the National Academy of Sciences (Taylor, 1957). Several volumes are available for the student of mammalian osteology (Cornwall, 1956; Flower, 1876; Reynolds, 1913) but, in all instances, these are general texts and are not suited to the special problems or the authors of these works assume that a sufficient library or reference collection is at hand.

Illustrated keys of a sort to be used by archæologists dealing with the skulls and dentitions of mammals, including *Bison*, are rather numerous (Brown, 1952; Burt, 1948; Glass, 1951) but only a few illustrating post-cranial

skeletons have been published (Brainerd, 1939; Hildebrand, 1954, 1955; Hue, 1907) and none of these are concerned with a detailed study of the vertebral column or appendicular skeleton of the *Bison*. Dr. J. A. Allen (1876) in the introduction of his bison monograph states, in relation to the text that follows, ". . . it cannot be considered as an exhaustive essay on the subject, but it is believed that the conclusions reached will not be much affected by future investigations, though many important details respecting particular districts may yet be added." However, Allen does not include any plates illustrating a complete or partially articulated bison skeleton. He devotes all of the figures to illustrating the skulls and dentitions of both fossil and Recent forms, with the exception of a few limited views of metacarpals which appear on plate XI and 3 metatarsals as a part of plate VII. This same criticism holds true for the more recent publication which deals with the revision of the genus *Bison* (Skinner and Kaisen, 1947). This contribution certainly represents a detailed study of the skull and dentition but lists only comparative measurements of some of the elements of the lower limbs, without any figures being given. Mr. F. G. Roe (1951) in his study of the North American buffalo covers nearly every aspect of the history that pertains to this animal, including an appendix on such fringe topics as "Indian Cannibalism," yet only one plate, the frontispiece depicting a buffalo, is included in the nearly 1000 pages of text that constitute this volume and even this meager representation of the buffalo is credited to a worker in Berlin.

Although the North American buffalo was figured by A. Thevet in 1558 and much has been said during the intervening years concerning this animal, no illustrated osteological discussion comparing *Bison* and *Bos* has appeared among the many contributions to the recorded literature. There is little doubt that a published comparative study of the skeletons of the American buffalo, *Bison bison*, and the domestic cattle, *Bos taurus*, is needed by those workers who are engaged in interpreting sites that fall within the ecological range of both of these animals.

The skeletal remains of the Brahman cattle, *Bos indicus*, are very similar to those of the bison and in some cases may be found under

conditions which could lead to confusion when attempting a hasty identification of these remains (Olsen, 1959). A small herd of Asiatic humped cattle or Zebus (*Bos indicus*) were landed in South Carolina in 1849, to be used for domestic purposes. Zebu is a universal term used to designate the numerous breeds of humped cattle as found in southern Asia. This expression includes many breeds of Nellore, Gyr, Guzerat, Krishna Valley, etc. The term Brahman, as applied to cattle, is strictly of U.S. origin and is used to designate the breeds of Zebu or *Bos indicus* that are developed in this country. These breeds are many and varied but tend to be larger, heavier and shorter limbed than do their counterparts of Asia. The descriptions and comparisons of those elements that were deemed diagnostic in the Brahman have been included in this study. Some of the smaller elements such as carpals, tarsals, or caudal vertebræ are usually poorly preserved or exhibit little in the way of morphological features which aid in separating these three similarly developed animals and their descriptions have been omitted.

A field manual of this sort, in order to be of real service, must be well illustrated and nearly self-explanatory so that the archæologist can identify incomplete specimens with a minimum of additional research into other literature or reference collections. This contribution has been designed with this in mind and it is hoped that it will fulfill the needs of the archæologist who has to identify those tantalizing fragments that are usually categorized cf. *Bison* or *Bos*.

When a large series of either *Bos* or *Bison* is examined, individual variations can be noted in the separate elements, particularly between a large bull and a small cow of the same species. However, as Barbara Lawrence (1951) determined, on examination of different breeds of domestic cattle, these differences show up in relative length and diameter of the various bones, but the epiphyseal muscle scar characters and articular surfaces are the same for all of them. When muscle scars are used as key characters (fig. 21, A-1), it is important to remember that the rugosity of the ridges and prominence of the surface for muscle attachment may be age or sex characters, the specific characters being the actual shape or outline of the muscle scar.

DISCUSSION

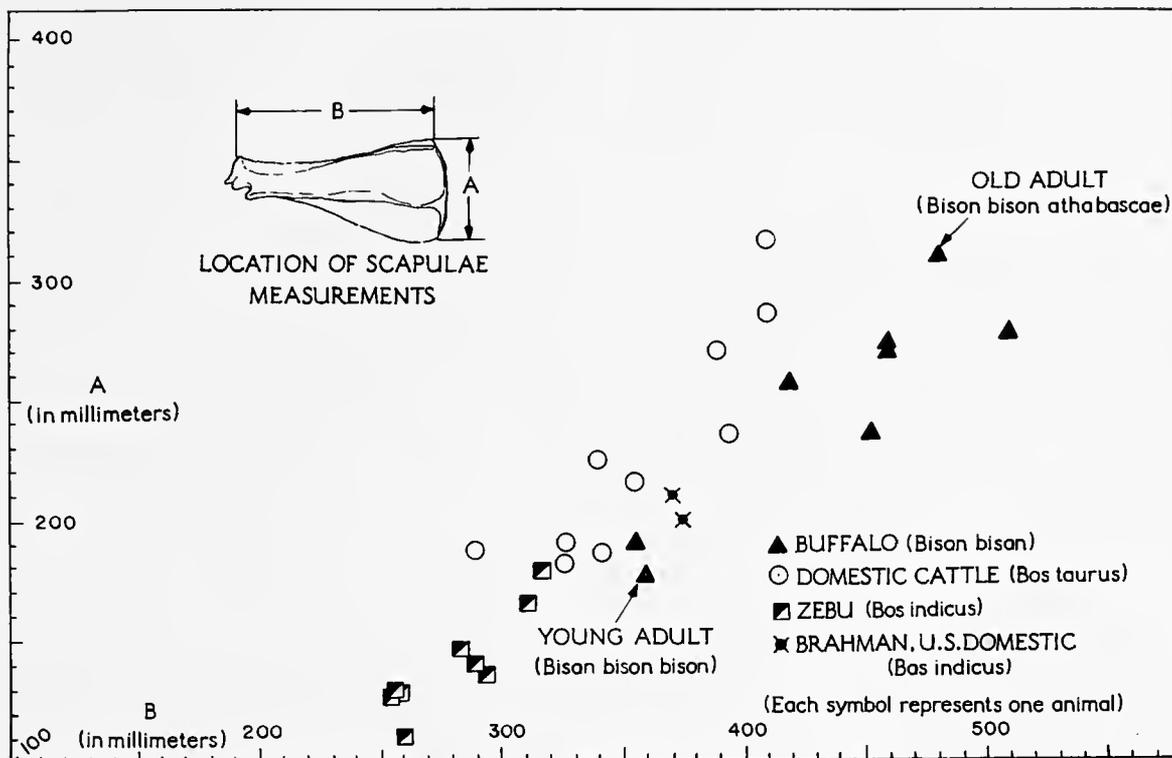


Fig. 2. Proportional linear measurements of scapulae of *Bison* and *Bos*.

Although *single* individual "key characters" may vary and intergrade when a large series of skeletons is examined, making the separation of *Bison* and *Bos* difficult, in no instance was it observed that *all* key characters followed this course and prevented positive separation of the 2 genera. There are sufficient features in a partial skeleton (other than a single bone) to differentiate between the animals in question.

The terminology used by writers in their osteological discussions varies considerably, sometimes very confusingly. For instance, Flower (1876) used *astragalus*, Sisson (1953) used *tibial tarsal bone*, and Ellenberger, *et al* (1949) used *os tarsi tibiale*, all for the same bone of the hind foot. Since this paper is a discussion of only the skeletons of the animals concerned, the nomenclature used by Sisson will be followed, as this work is a widely accepted mammalian anatomy, still in print, and those readers wishing to refer to the musculature or soft anatomy of the bovids may consult this volume. Although the writer believes that the terminology used by Sisson is perhaps

not that which is generally used by palaeontologists or archaeologists, it is perhaps better to follow this text and be consistent rather than to have the more interested readers convert the terms each time the musculature is referred to.

Albeit, after handling a number of skeletons of each of the compared animals, a certain "feel" for the heavier bison bones is acquired, it is essential that at least one skeleton of each of the 3 forms be at hand for the proper understanding of the points discussed. At the present time, it is possible to obtain buffaloes from the Federal government herds when they are thinned out, usually each year, and good domestic cow skeletons (Brahmans included) can be secured from many of the ranches in this country merely for the asking.

There are 2 recognized subspecies of North American buffalo, the plains bison, *Bison bison bison* and the woodland or "woods" bison, *Bison bison athabascae* (Miller and Kellogg, 1955; Skinner and Kaisen, 1947). The plains bison was a former inhabitant of the Great Plains area and the woodland race was found

farther north as dwellers of the mountainous country. This last named form was darker in color and grew to a larger size than did those of the plains race (fig. 2).

However, for this osteological study no particular emphasis is given size alone; rather, the articular surfaces, muscle scars and proportional measurements are shown to be the diagnostic reference points and, consequently, no attempt will be made to isolate these 2 subspecies on osteological evidence alone. It is seriously doubted if, in many cases, these subspecies could be separated where identifications were based on living animals, particularly in those areas where the habitats of the 2 groups overlapped.

The 18 specimens of *Bison bison* which were available for comparison were animals collected from the wild herds of the 1870's.

Nine skeletons of *Bos indicus* (Zebu) were also checked and compared. These were of undesignated breed and represented the smaller types of Asiatic cattle (fig. 2). Skeletons of *Bos taurus* representing the breeds of Holstein, Jersey, Alderney, Shorthorn, Devon and Aberdeen-Angus were used in this study.

One of the discouraging things that came to light during the course of this study was the absence of an adequate representation of domestic animal skeletons in the collections of our larger museums. None of the collections examined contained skeletons of the North American Brahman. The specimens used for comparison and illustration were collected in Florida and are representatives of the Guzerat breed, one of the largest animals maintained in this country.

SKELETAL CHARACTERS OF *BISON* AND *BOS*

CERVICAL VERTEBRÆ

Atlas and Axis (fig. 5). The first 2 cervical vertebræ display several differentiating characters that key out or separate these elements as belonging either to *Bison* or *Bos*. When viewing the anterior notch, from a ventral aspect, the atlas of *Bison* presents a curved or cup-shaped margin (A-3). In both *Bos indicus* and *Bos taurus* this same edge tends to square up and form right angles (B-3 and C-3). The wings of the atlas in the buffalo form a square outline at their terminus (A-3) while these same processes in the Brahman are more rounded (B-3) and those in the domestic cow have a tendency to be pointed (C-3). In the specimens of old adult buffalo bulls that were compared, the vertebral foramen of the atlas approached a triangle in outline (A-2) when viewed anteriorly, as compared with the more rounded or oval form of this same opening in the specimens of *Bos* that were examined (B-2 and C-2).

The axis of the buffalo has a dens (A-1) that differs from that of *Bos indicus* (B-1) and *Bos taurus* (C-1) in that it forms an acute angle when viewed laterally. In both species of *Bos* this same margin has a definite break or angle occurring between the anteroventral angle of the dens and its terminus at the anterior base of the spinous process. The lateral

margin of the anterior articular process also forms a nearly right angle with the long axis of the body of this second cervical in both species of *Bos* (B-1 and C-1), a condition not present in the buffalo (A-1). In old adult buffalo bulls the dorsoanterior angle of the spinous process assumes a position directly over the forward tip of the dens (A-1). This latter process in the examined species of *Bos* was observed to be well in advance of the spinous process.

Fifth Cervical (fig. 6). The outline formed by the tips of the anterior articular processes and the ventral branches of the transverse processes of the cervicals, when viewed from a posterior position, is rectangular in shape in the *Bison* (A-1) and more nearly square in both species of *Bos* (C-1). The lateral branch of the transverse process in *Bos indicus* has a ridge connecting it with the ventral branch of the transverse process (B-1 and B-2), a condition at times present in *Bos taurus* but not so in the examined skeletons of *Bison bison*. The summits of the spinous processes of the cervical vertebræ of the buffalo are very little expanded (A-1) as compared with a definite flaring of these same processes in both *Bos indicus* and *Bos taurus* (B-1 and C-1).

THORACIC VERTEBRÆ

The vertebræ in a given region have characters by which they may be distinguished from those of other regions and individual vertebræ have special characters which are more or less clearly recognizable. There are 14 thoracic vertebræ (fig. 7) in the bison and 13 in each of the 2 species of *Bos*. This is usually a constant number in *Bos* but 14 may be present or more rarely, only 12. The number remained constant in the examined specimens of *Bison bison*.

The second and third thoracic vertebræ are usually the longest, reaching a length of 20 inches in a large buffalo bull but rarely over 13 inches in *Bos indicus* or over 10 inches in *Bos taurus*. There is a gradual diminution in height of the spines from the third thoracic to the thirteenth or fourteenth with an increase of backward slope. The spinous process of the second thoracic vertebra differs in the bison from those of *Bos indicus* and *Bos taurus* by being more restricted on the anterior outer

edge of the middle of the spine (A-1) and by having a pointed or sometimes squared summit, with no overhang, to this process. In *Bos indicus* this summit has a definite posteriorly curved overhang (B-1) while that of *Bos taurus* has an angle at the anterodorsal margin and is in line with the forward face of the main body of the spine (C-1). The posterodorsal margin of the summit has a pronounced overhang as in *Bos indicus*.

The eighth thoracic vertebra of the buffalo exhibits a forward swelling at the summit (A-2) as opposed to a definite dished margin as is present in *Bos indicus* (B-2) or a pointed tip as found in *Bos taurus* (C-2). *Bos indicus* alone, of the three compared forms, has a notched summit on the eighth thoracic (B-3). This is at times grown over on the dorsal surface to form an eye rather than the bifurcate tip. Both *Bison bison* and *Bos taurus* have the

characteristic widening at the tips of these spines as found in many of the bovids. The last thoracic vertebra is distinguished by the absence of the posterior pair of costal facets, and the confluence of the anterior pair with those of the transverse processes.

The spinous processes of the anterior thoracic vertebrae are largest in the bison due to the position of the animal's head in relation to its spinal column. A. B. Howell (1944) observed that high spinous processes over the anterior thorax are characteristic of those mammals with extremely large heads.

Because of the angle of leverage that the supporting muscles must maintain, this feature is more pronounced in those forms, such as the buffalo, in which the head is habitually held low. The length and flatness of these spines prompted the buffalo hunters to refer to them as "hump ribs."

LUMBAR VERTEBRÆ

The lumbar vertebrae (fig. 8) disclose the same instability in number in *Bos* as do the thoracic series. The usual count is 6 in both *Bos indicus* and *Bos taurus* but may occasionally number 5 (B-1 and C-1). The lumbar series in all of the examined specimens of *Bison bison* remained constant and totaled 5 (A-1). The summits of the spinous processes of the 3 animals exhibit considerable variation as to the amount of overhang which is present, so that no diagnostic features were observed or recorded for these spines. In the buffalo the

transverse processes have a tendency toward finishing off in tapered points (A-2) as compared with a nearly uniform anteroposterior width along the entire length of these processes as observed for both species of *Bos* (B-2 and C-2). The transverse process of the first lumbar vertebra in *Bison* usually has a small pointed projection situated on the anterior margin of the process and is inclined in an anteromedial direction. This spike is not generally as pronounced or is entirely lacking in *Bos* (A-2, B-2 and C-2).

SACRUM

The sacrum (fig. 9) is merely a composite bone formed by the fusion of certain vertebrae. The vertebrae number 5 (A-2, B-2 and C-2) in all 3 animals and form a compact unit having nearly parallel lateral margins. In both *Bos indicus* and *Bos taurus* the lateral border of the anterior end of the body of the first sacral vertebra reaches a point which is in line with the parallel margins of the main body of the sacrum (B-2 and C-2). These same borders of the anterior vertebral end in the bison are located at a considerable distance medially to

the parallel margins of the main sacral element (A-2). The end of the body of the first sacral vertebra, when viewed anteriorly, is more triangular in outline in the buffalo (A-3) while it approaches an ovaloid form in both species of *Bos* (B-3 and C-3). The wings of the sacrum in *Bison* (A-1) are more sharply inclined in a forward direction than are those found in *Bos taurus* (C-1). The sacral wings of *Bos indicus* project laterally with no noticeable forward curve (C-1). In *Bos indicus* the last sacral vertebra may undergo only partial

fusion and terminate in a spool-shaped posterior sacral projection (B-2) unlike those

found in *Bison bison* or *Bos taurus* (A-2 and C-2).

SCAPULA

The scapula (fig. 10) of the buffalo is most readily separated from the other 2 forms by comparative measurements of the blade. In the bison the length from the glenoid fossa to the anterior angle is considerably greater proportionally in relation to the measurement from the posterior angle to the anterior angle (fig. 2). Even in a young adult bison, where the measurement of length approaches that

of *Bos taurus*, the width is noticeably less in the bison. In the examined specimens of *Bos indicus* the anterior angle is nearly a right angle in contrast to a rounded contour as found in the scapulæ of the other 2 animals. The articular surface of the glenoid cavity is nearly round in *Bos taurus* (A-1) while this same surface is more oval in form in both *Bos indicus* and *Bison bison* (B-1 and C-1).

ARTICULATED FORELIMB

The forelimb (figs. 11 and 12) has been figured in articulated, anterior, medial, posterior, and lateral views to enable the reader to compare relative size and position of the various elements comprising this member of the post-

cranial skeleton. Some of the smaller bones such as carpals and sesamoids contribute little in the way of morphological separation of these 3 animals and they have not been separately described or illustrated.

HUMERUS

The humerus (fig. 13) in *Bos* is readily distinguished from that of *Bison* by observing the relationship of the medial and lateral tuberosities to the bicipital groove of the proximal end of the bone (A-1, B-1 and C-1). In *Bos* the medial point of the lateral tuberosity overhangs the bicipital groove (C-1) while in the bison this same projection is directed to form an obtuse angle of the bicipital groove and has no noticeable overhang (A-1). The floor of the bicipital groove, in *Bison*, slopes evenly from the medial wall of the groove to the base of the lateral tuberosity while in *Bos* the bases of the medial and lateral tuberosities are separated by a pronounced swelling (B-1 and C-1). When viewed laterally the larger tuberosity has a single deep notch on the outer margin of this element in *Bison* (A-2) but this same area in *Bos* is not as deeply notched or in most cases has 2 lesser grooves occupying this same ridge (B-2 and C-2). The distal end of the humerus in the buffalo and Brahman have a continuous gentle curve along the ridge connecting the main shaft of the humerus with the lateral condyle

(A-3 and B-3). In *Bos taurus* this ridge has a decided break or angle at its junction with the main shaft (C-3). The fossa for muscle attachment on the lateral condyle is larger and more irregularly shaped in *Bison* (A-3) as compared to nearly round pits for these same excavations in the other 2 animals. The ridge of the medial epicondyle in *Bison* forms a nearly right angle with the most distal margin of the humerus when viewed from a medial plane. The medial epicondylar ridge in *Bos indicus* has a decided outward deflection at its most distal point (B-4) while this same condyle projects well below the distal limit of the medial condyle and in line with the main margin of the humeral shaft in *Bos taurus*.

As stated at the beginning of this summary, most of the morphological differences found in these 3 compared forms are a matter of degree of variation rather than radical, easily seen characters and it is necessary to have at least one skeleton of each of the 3 forms at hand in order to make the final decisive comparisons.

RADIUS AND ULNA

The radius and ulna (fig. 14) of the 3 animals are fused at various points along their surface of contact so that when found they usually comprise a single unit and are discussed here as such. The proximal articular surfaces show too great a variation and change to be considered for key characters. However, scars for muscle attachment on both the lateral and medial sides of the radius have diagnostically separating features. In *Bison* the tuberosity for the attachment of the ligament of the elbow joint (A-1) is less pronounced and more cupped than the knoblike projection found in *Bos* (B-1 and C-1). The scar for the brachialis muscle, though roughened in *Bos* (B-3 and C-3), is far smaller and less excavated than the large rectangular surface

which is present on the proximal end of the radius of the buffalo (A-3). The shaft of the ulna, when considered as a cross section medially, forms a nearly right angle with that of the radius in *Bison* (A-2) while in both species of *Bos* this surface of contact is present as a gently curved plane having no decided break or angle (B-2 and C-2). The distal end of the radius in *Bos taurus* can be separated from *Bison* and *Bos indicus* by noting the relative position of the 2 margins that define the facet for the radial carpal. In *Bos taurus* these margins tend to converge in a posteromedial direction (C-4) while they remain nearly parallel in *Bison bison* and *Bos indicus* (A-4 and B-4).

METACARPAL AND METATARSAL

The metacarpal (fig. 15) of the bison is generally separable from those of *Bos indicus* and *Bos taurus* by noting the degree of fusion between the tubercle and the posterior margin of the articular surface for the fused second and third carpals (A-1). In the buffalo the point of contact is slight, leaving the 2 surfaces nearly separate while in both *Bos indicus* and *Bos taurus* the tubercles are completely fused to the main bone (B-1 and C-1).

The metatarsals are distinguished in each of the forms by observing the relative positions of the articular facets on the proximal surfaces of these elements. In *Bison bison* the articular surfaces for the first tarsal bone are joined to the posterior articular surface for the fused central and fourth tarsal bones by a narrow neck or ridge (A-2) but in both *Bos indicus* and *Bos taurus* the posterior articular surface

for the fused central and fourth tarsal bone is present as a separate raised island (B-2 and C-2). When viewed from an anterior plane, with the bone held in a vertical position, the margin of the anterior articular surface for the fused central and fourth tarsal bones exhibits a curved or at most a widely obtuse angular margin in the buffalo (A-3) while this same edge has a sharp step or break in both *Bos indicus* and *Bos taurus* (B-3 and C-3).

The distal ends of both the metacarpals and the metatarsals in the bison have heavier or more swollen surfaces at the area of contact between the shaft and the articular condyles (A-4). The nutrient foramina are, by comparison, larger and more prominent in the buffalo (A-4).

PHALANGES

The phalanges (figs. 16 and 17) for both the forelimb and hindlimb do not show separable characters so are treated together rather than separately for each limb.

The first phalanx in the buffalo has more

of a curved lateral margin along the distal two-thirds of its length, when viewed anteriorly (A-3). This same margin has a straighter edge beginning at the distal condyle and continuing toward the medial edge of the proxi-

mal articular surface (B-3 and C-3). The dorsal surface of this element, in the buffalo, has a heavier and more pronounced muscle scar on the medial edge of the center of this bone and a more conspicuous tuberosity present on the medial face of the proximal end of the toe, below the articular surface (A-4). Both *Bos indicus* and *Bos taurus* have noticeably deeper pits on the dorsal faces of the proximal ends of these bones (B-4 and C-4).

The second phalanx has a straighter dorsal margin, when viewed laterally, in the buffalo (A-2) while the dorsal prominences on these bones as seen in *Bos indicus* (B-1 and B-2) and *Bos taurus* (C-1 and C-2) give a decided dished appearance to this same surface. The imprint for the tendon on the anterior surface

of the second phalanx of the bison (A-1) is comparatively deeper than this same scar for the 2 species of *Bos*.

The third phalanx or hoof has a straighter plantar margin in the buffalo (A-1) as compared with the broken or curved outline of this same edge in *Bos indicus* (B-1) or *Bos taurus* (C-1). The outer plantar margin of the hoof of *Bos taurus* as well as the inner surface below the anterior articular margin is heavily sculptured or deeply eroded (C-1 and C-2), a condition not found in either the buffalo or *Bos indicus* (B-2). The inner margin of this third element in the bison (A-2 and A-4) is concave in appearance as opposed to a convex margin in the other 2 animals (B-2, B-4, C-2 and C-4).

OS COXÆ

The *os coxæ* (fig. 18) in all three compared forms is separated with difficulty except for noting the marginal outline of the ilium in the vicinity of the tuber coxæ. This margin in the buffalo terminates as a highly rounded

point with its apex at the tuber coxæ. This same tip is a nearly right angle as seen in *Bos indicus* or is present as a roughened margin having many steplike projections as observed in *Bos taurus*.

ARTICULATED HINDLIMB

The articulated hindlimb (figs. 19 and 20) has been shown in anterior, medial, posterior and lateral views to facilitate the comparisons of the various elements which make up this

member of the post-cranial skeleton. The metatarsals are treated in the section dealing with the metacarpals and the diagnostic key characters are shown on figure 15.

FEMUR

The femur (fig. 21) in *Bison* has no noticeable ridge on the surface of the shaft between the head and the trochanter minor (A-1). In both *Bos indicus* and *Bos taurus* there is a definite raised area separating the trochanteric fossa from the neck of the femur (B-1 and C-1). The trochanter major in *Bos taurus* has more of a lateral projection when viewed from a posterior angle (C-1). The head of the femur in the bison has a slight tendency to form a lip at its junction with the neck (A-2) rather than a blending of these 2 areas as observed for *Bos* (B-2 and C-2). The complex of proximal anterior muscle scars is

quite distinct and separate in the buffalo (A-2) as compared with a fusing of these scar patches in *Bos* (B-2 and C-2). The distal end of the femur is separable by noting the relative positions of the condyles in relation to each other when viewed medially with the shaft held in a vertical position. Seen in profile the medial condyle and the medial patellar ridge extend in a distal direction to the same degree in *Bos* (B-4 and C-4). In *Bison* the epicondyle and the medial patellar ridge extend considerably farther in distal direction than does the medial condyle (A-4).

TIBIA

The tibia (fig. 22) differs in the buffalo by having a lateral condyle that extends farther around on the posterior side of the shaft and ending in a drawn-down point at the posterolateral corner (A-1), whereas in *Bos* this area is finished as a rounded projection (B-1 and C-1). The lateral condyle, when viewed from a lateral direction with the shaft of the tibia held in a vertical position, has a continuous curved margin in *Bison* (A-2) as compared with an angular edge in *Bos indicus* (B-2) or a nearly straight surface in *Bos taurus* (C-2). The muscle scars which are prominent on the dorsal side of the tibia below the articular sur-

faces are quite stable characters in all of the examined forms. In both *Bos indicus* and *Bos taurus* the first 3 scars, numbering from the lateral border, terminate near a common point below the proximal articular surface (B-1 and C-1). In the buffalo the third scar is considerably shorter when compared with the other 3 scars (A-1). The distal end of the bison tibia is separable from those of *Bos indicus* and *Bos taurus* by noting the absence of the groove for the flexor digitalis longus (A-3 and A-4). This groove is well developed in both *Bos indicus* (B-3 and B-4) and *Bos taurus* (C-3 and C-4).

FUSED CENTRAL AND FOURTH TARSAL AND TIBIAL TARSAL

The fused central and fourth tarsal (fig. 23) is a difficult bone to separate. Only one character was observed in all of the examined specimens which was constant enough to be used as a key. This character was noted in *Bison bison* as the continuous surface connecting the distal articular surface for the first tarsal and that of the fused second and third tarsals (A-2). In both species of *Bos* the articular surface for the first tarsal has a tendency for being a separate surface and in most cases was separated from the surface for the fused second and third tarsals by a well-defined gap (B-2 and C-2).

The tibial tarsal (fig. 23) in *Bos taurus* is separable from those of *Bos indicus* and *Bison bison* by noting the position of the medial tubercle in relation to a line drawn across the proximal margins of the distal trochlea. In *Bos taurus* the medial tubercle falls well below this line (C-3), whereas in *Bos indicus* or *Bison bison* the tubercle is in line with or is above this same line (A-3 and B-3). The old adult bisons that were examined had an excavated area on the distal posterior articular surface that was not observed in the skeletons of *Bos* which were compared (A-4).

FIBULAR TARSAL

The fibular tarsal (fig. 24) tends to be characteristic for *Bos taurus* and *Bison bison* but this same element in *Bos indicus* is difficult to separate from that of the buffalo. The sustentaculum, when viewed from a posterior plane, has a definite downward deflection in *Bison* and *Bos indicus* (A-5 and B-5). However, in *Bos taurus* the sulcus for the deep flexor tendon causes this surface to be dished and to protrude at a lateral right angle (C-5). When seen from a medial view the margin of the sustentaculum exhibits a continuous curved

outline in both *Bison* and *Bos indicus* (A-6 and B-6). This margin in *Bos taurus* forms a right angle with its edges (C-6). The anterior edge of the body of the fibular tarsal is quite dished in many of the examined Brahman specimens (B-2), a condition not observed in the other 2 animals (A-2 and C-2). Although not a constant character, it is worth noting that generally speaking the facet for the tibia is round in the buffalo (B-3) while it is oval in the majority of skeletons of *Bos taurus*.

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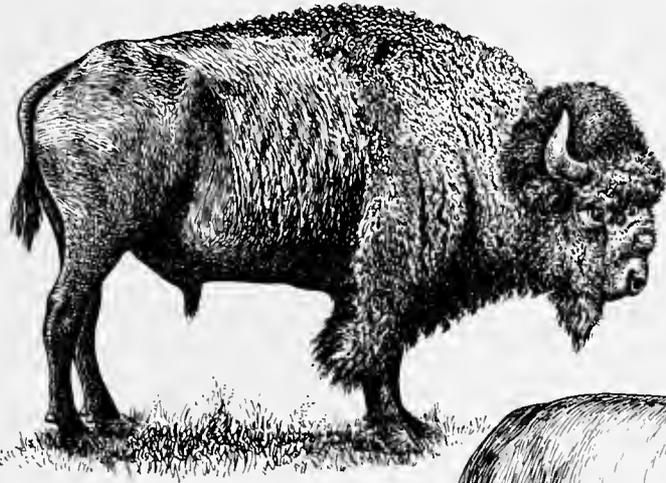
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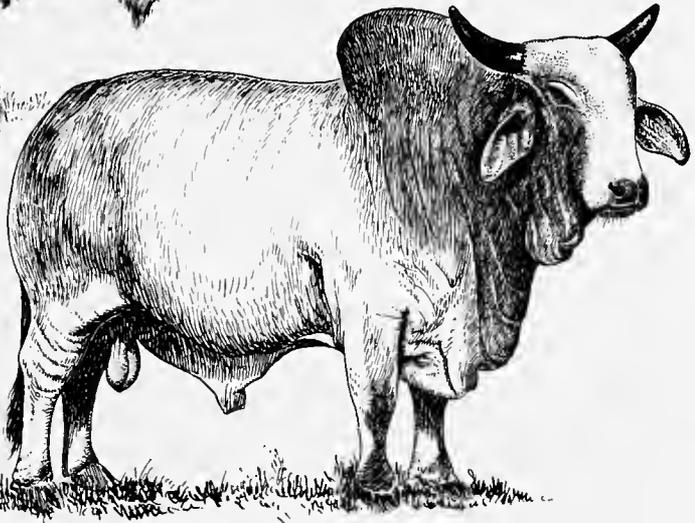
FIGURES 3-24

FIGURE 3

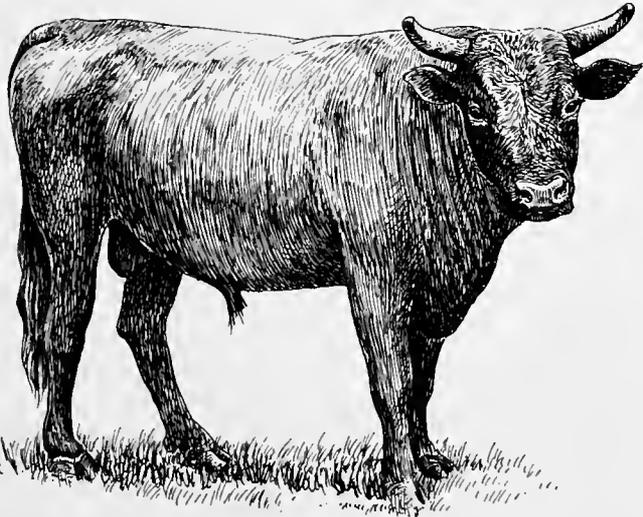
Body forms of living *Bison bison*, *Bos indicus* and *Bos taurus* illustrating relative proportions.



Bison bison



Bos indicus

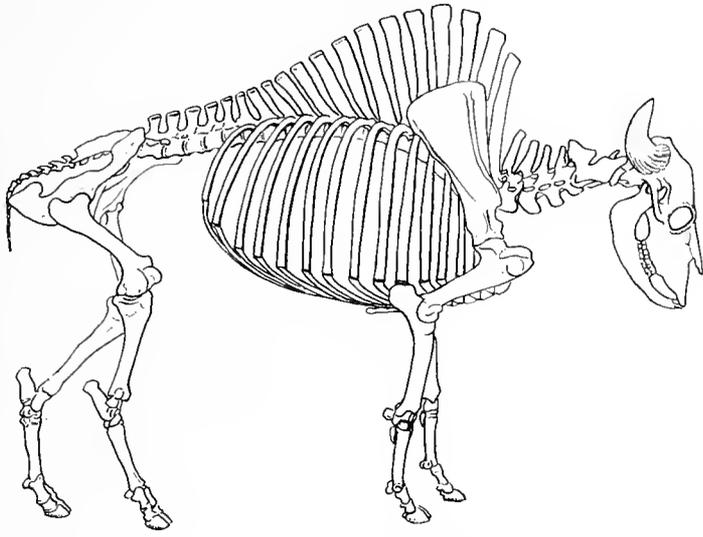


Bos taurus

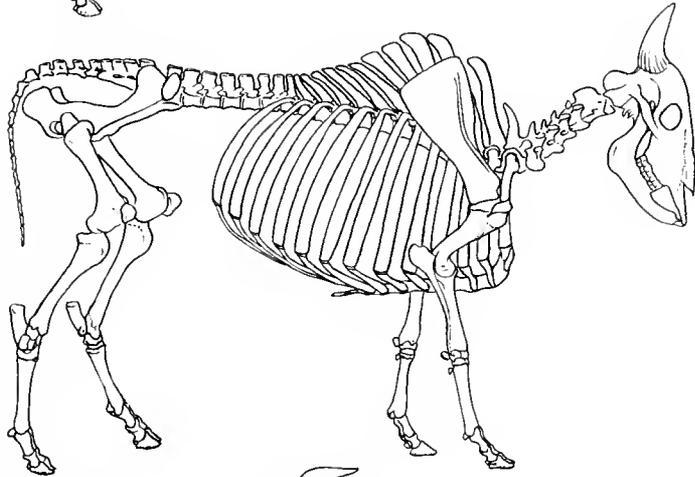
A. Janson

FIGURE 4

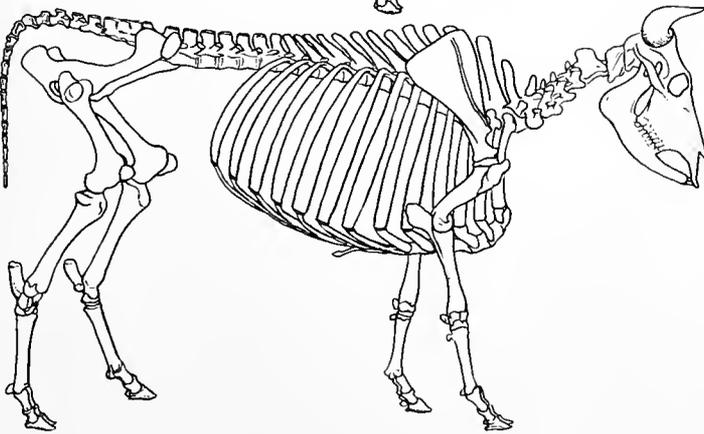
Articulated skeletons of *Bison bison*, *Bos indicus* and *Bos taurus* illustrating general body proportions and length of neural spines.



Bison bison



Bos indicus



Bos taurus

0 16.5 33 49.5 66 cm

A.R. Janson

FIGURE 5

Bison bison. Axis: A-1, lateral surface. Atlas: A-2, anterior surface; A-3, dorsal surface. Differentiating characters indicated by heavy dashed lines.

Bos indicus. B-1 to B-3, same views as for *Bison*.

Bos taurus. C-1 to C-3, same views as for *Bison*.

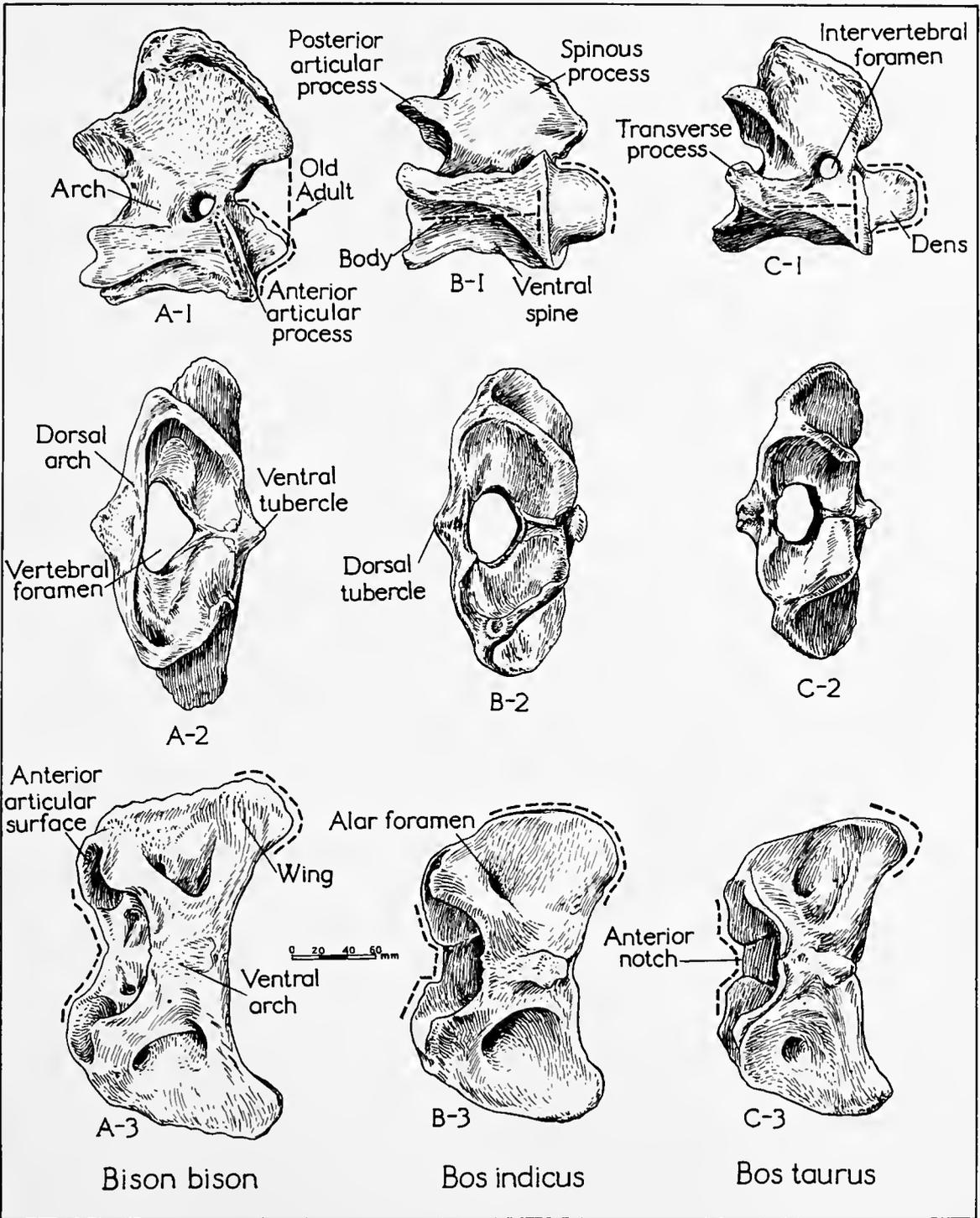
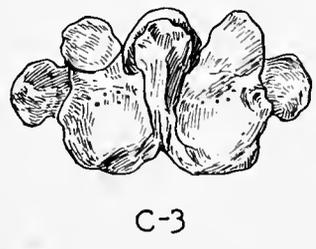
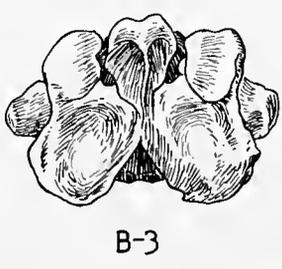
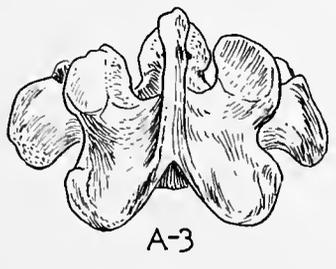
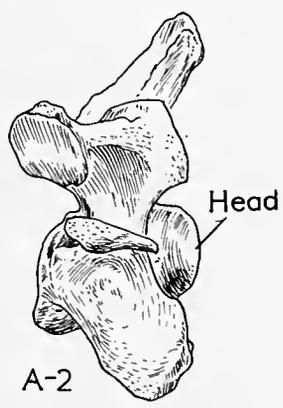
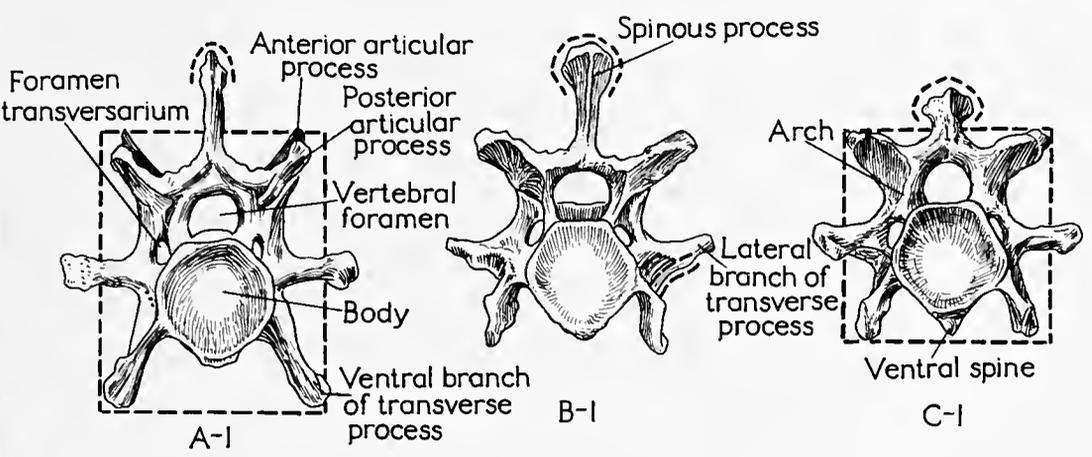


FIGURE 6

Bison bison. Fifth cervical vertebra: A-1, anterior surface; A-2, right lateral surface; A-3, dorsal surface. Differentiating characters indicated by heavy dashed line.

Bos indicus. B-1 to B-3, same views as for *Bison*.

Bos taurus. C-1 to C-3, same views as for *Bison*.



Bison bison

Bos indicus

Bos taurus

FIGURE 7

Bison bison. Second thoracic vertebra: A-1, lateral surface. Eighth thoracic vertebra: A-2, lateral surface; A-3, anterior surface. Differentiating characters indicated by heavy dashed lines.

Bos indicus. B-1 to B-3, same views as for *Bison*.

Bos taurus. C-1 to C-3, same views as for *Bison*.

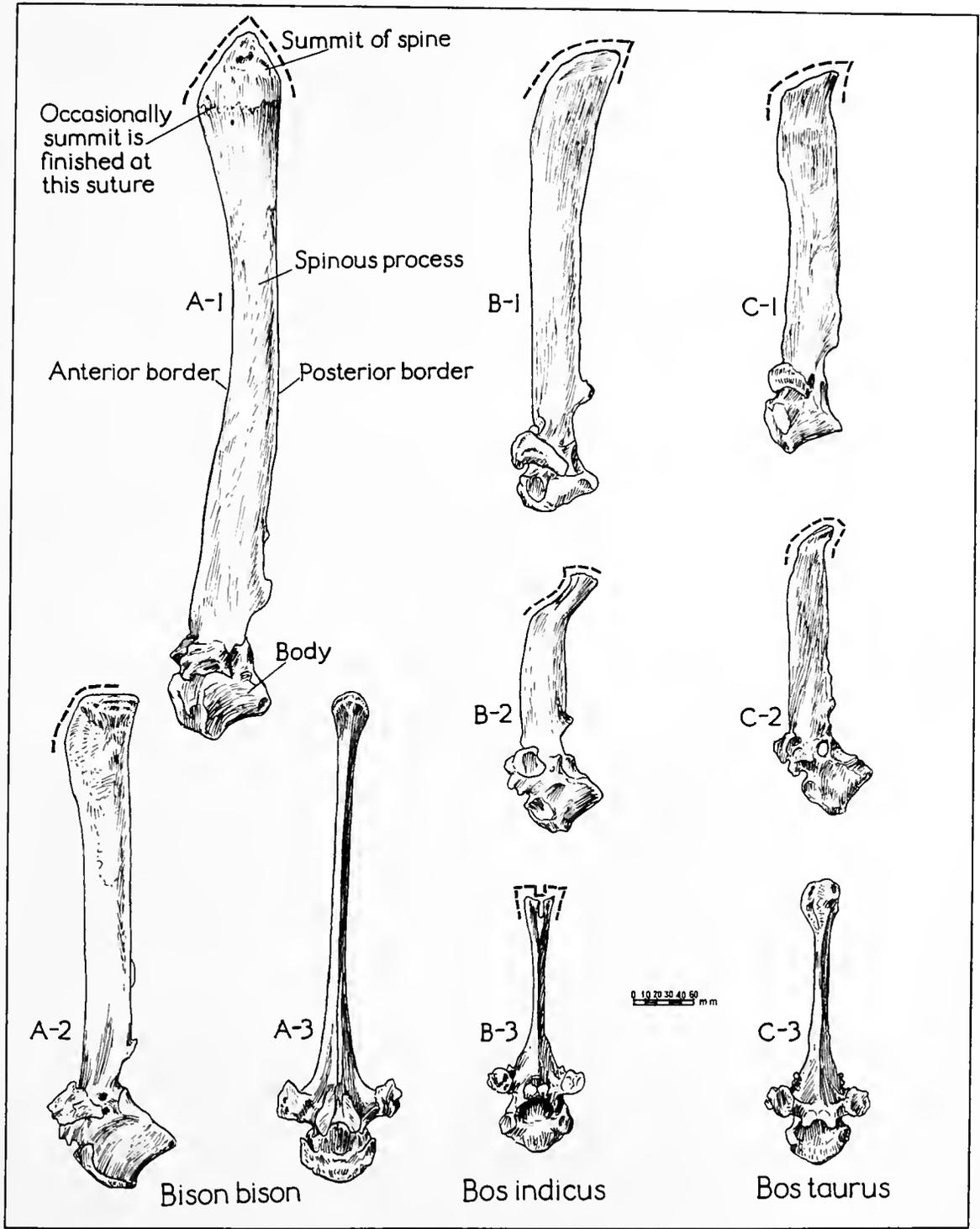


FIGURE 8

Bison bison. Lumbar vertebræ: A-1, left lateral surface; A-2, dorsal surface.
Differentiating characters indicated by heavy dashed line.

Bos indicus. B-1 and B-2, same views as for *Bison*.

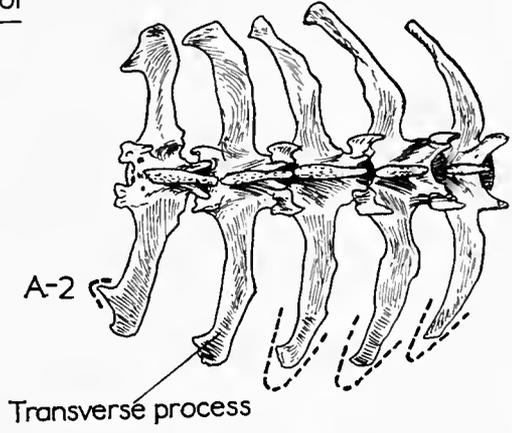
Bos taurus. C-1 and C-2, same views as for *Bison*.

Anterior
←



A-1

Bison bison



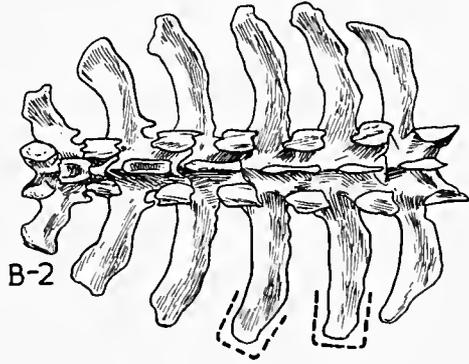
A-2

Transverse process



B-1

Bos indicus

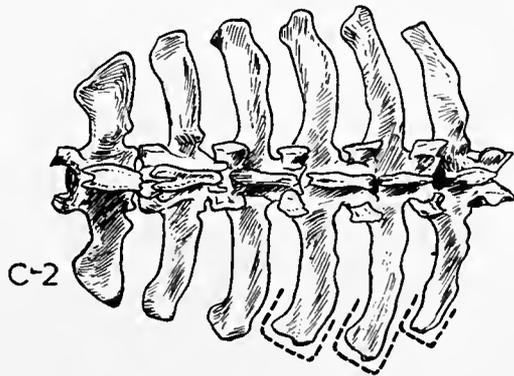


B-2



C-1

Bos taurus



C-2

0 20 40 mm

FIGURE 9

Bison bison. Sacrum: A-1, dorsal surface; A-2, ventral surface; A-3, anterior, articular surface. Differentiating characters indicated by heavy dashed lines.

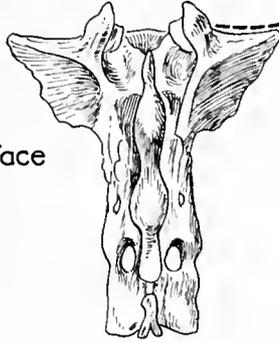
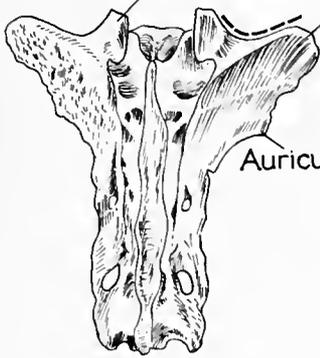
Bos indicus. B-1 to B-3, same views as for *Bison*.

Bos taurus. C-1 to C-3, same views as for *Bison*.

Articular process

Wing

Auricular surface

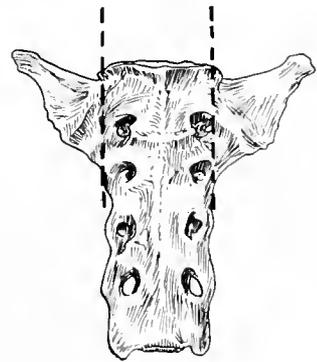
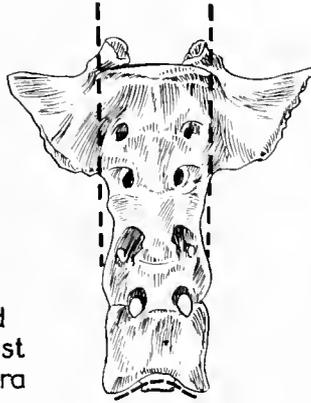
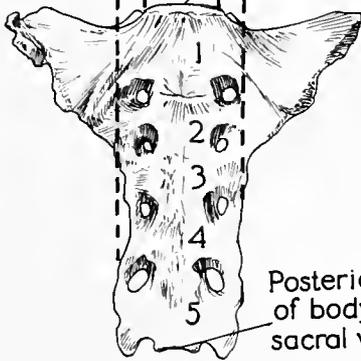
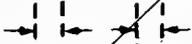


A-1

B-1

C-1

Anterior end of body of first sacral vertebra



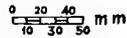
A-2

B-2

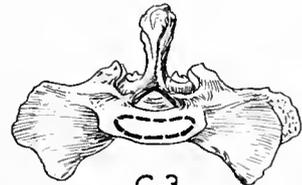
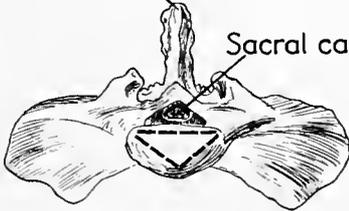
C-2

Posterior end of body of last sacral vertebra

Median crest



Sacral canal



A-3

B-3

C-3

Bison bison

Bos indicus

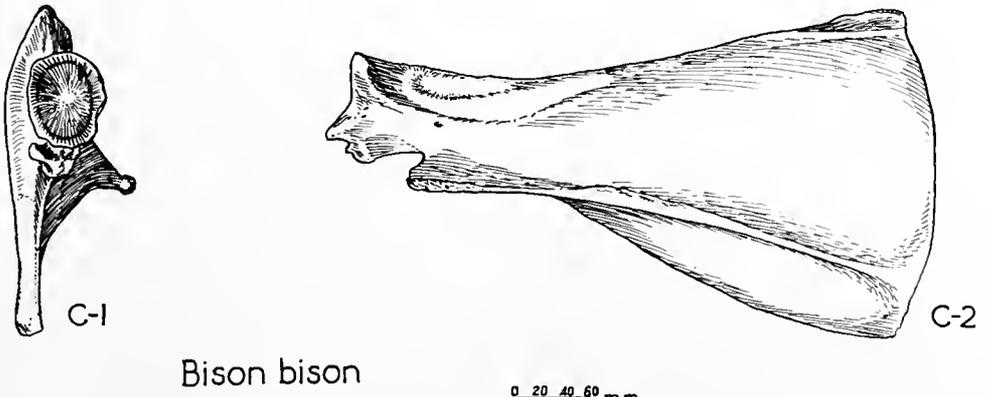
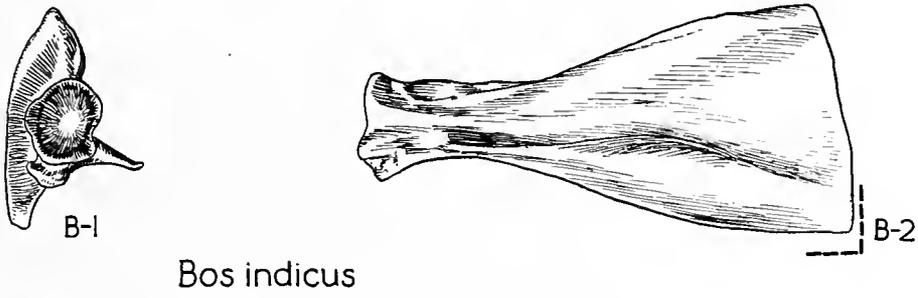
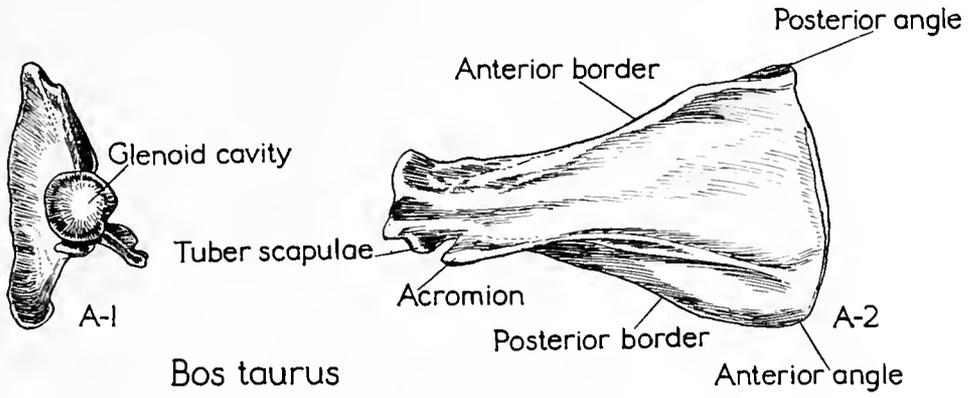
Bos taurus

FIGURE 10

Bos taurus. Right scapula: A-1, articular surface; A-2, lateral surface. Differentiating characters indicated by heavy dashed lines.

Bos indicus. B-1 and B-2, same views as for *Bos taurus*.

Bison bison. C-1 and C-2, same views as for *Bos taurus*.



0 20 40 60 mm

FIGURE 11

Bison or *Bos*. Articulated left forelimb: A, anterior view; B, medial view.

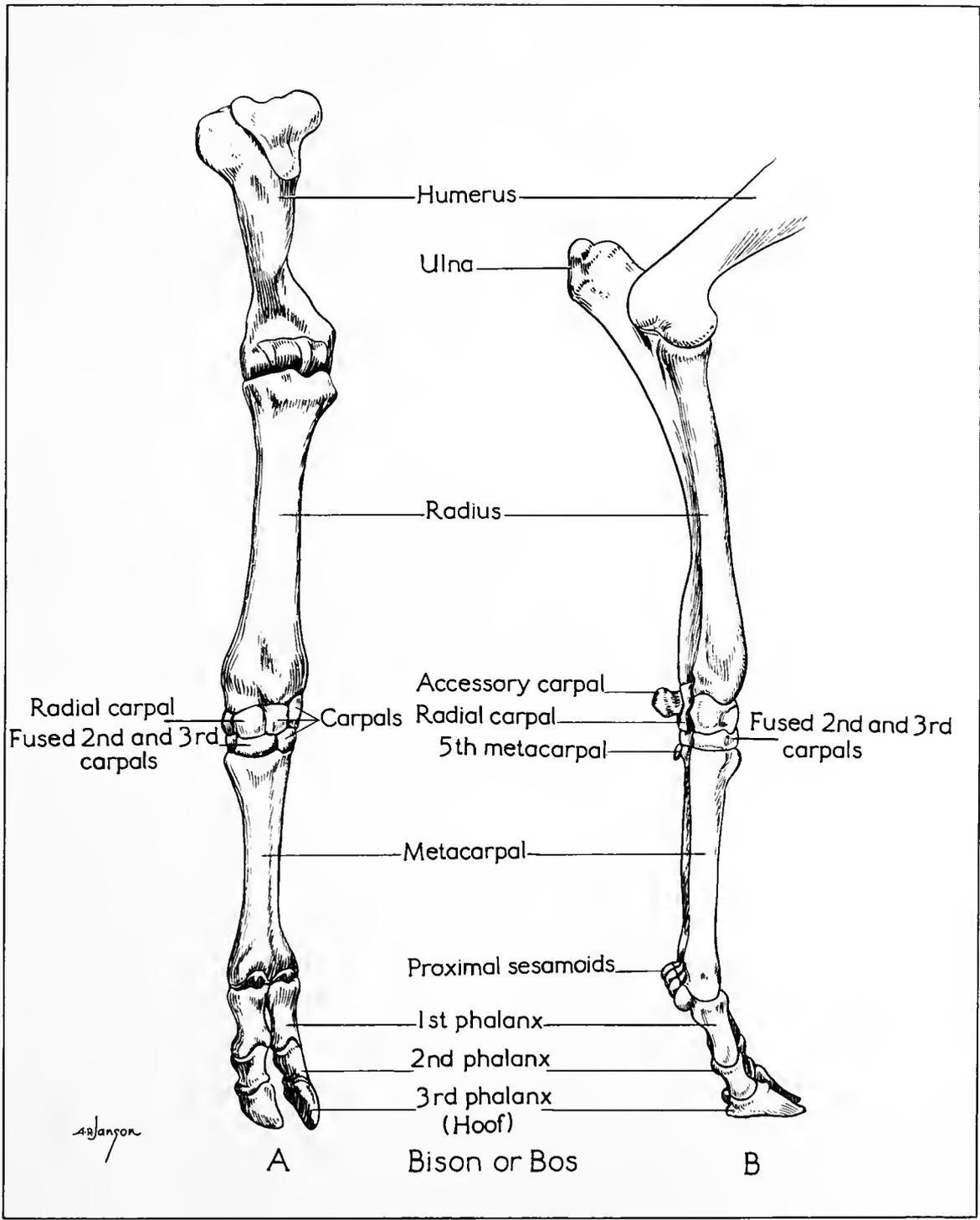
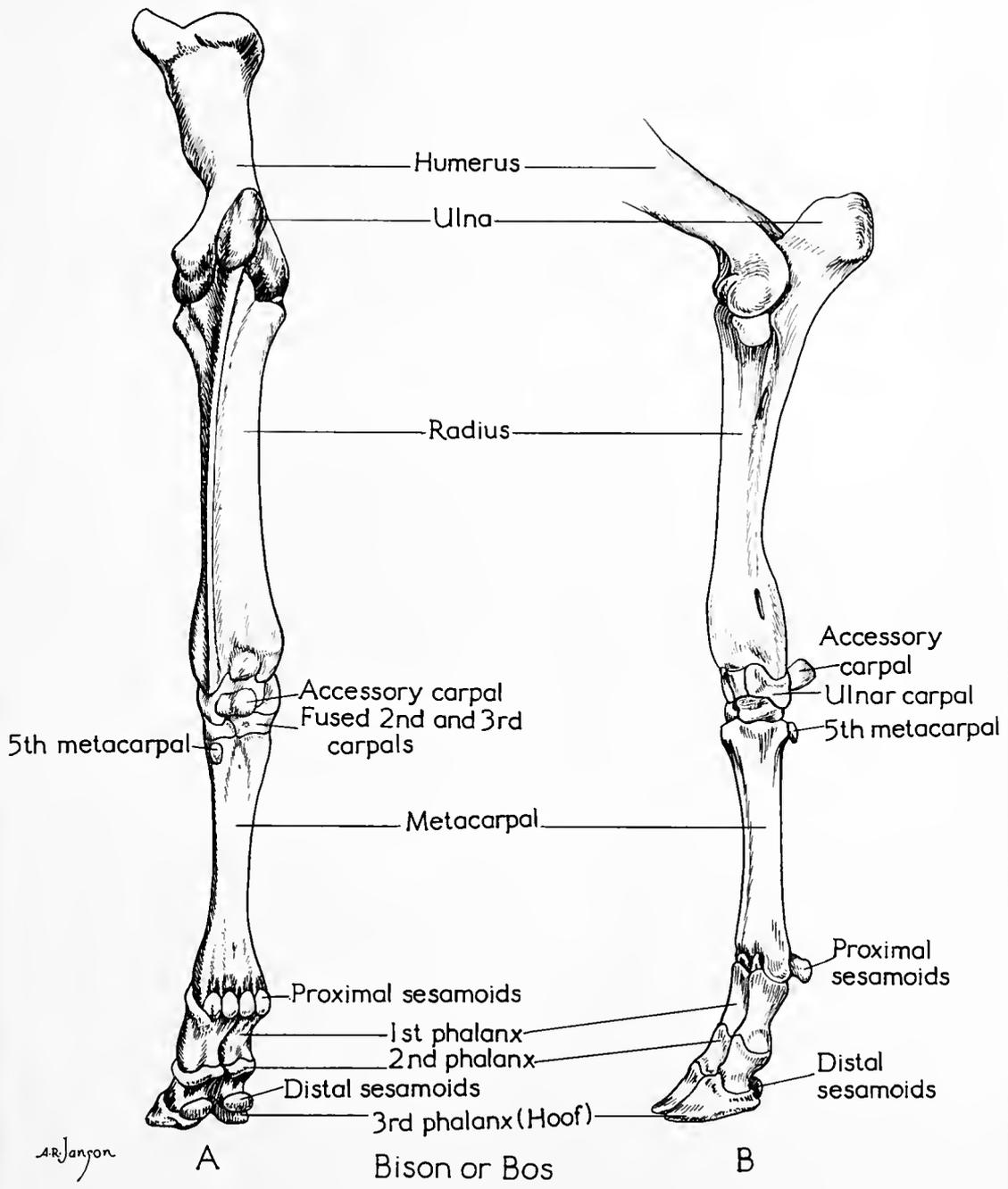


FIGURE 12

Bison or *Bos*. Articulated left forelimb: A, posterior view; B, lateral view.



AR Janson

FIGURE 13

Bison bison. Right humerus: A-1, proximal end, anterior surface; A-2, proximal end, three-quarter lateral view; A-3, distal end, lateral surface; A-4, distal end, medial surface. Differentiating characters indicated by heavy dashed lines.

Bos indicus. B-1 to B-4, same views as for *Bison*.

Bos taurus. C-1 to C-4, same views as for *Bison*.



Medial tuberosity

Lateral tuberosity

Head

Shaft

B-1

C-1



Fossa

Lateral condyle



Lateral epicondyle



Medial epicondyle

Medial condyle



Shaft



Bison bison

0 30 40 50 mm

Bos indicus

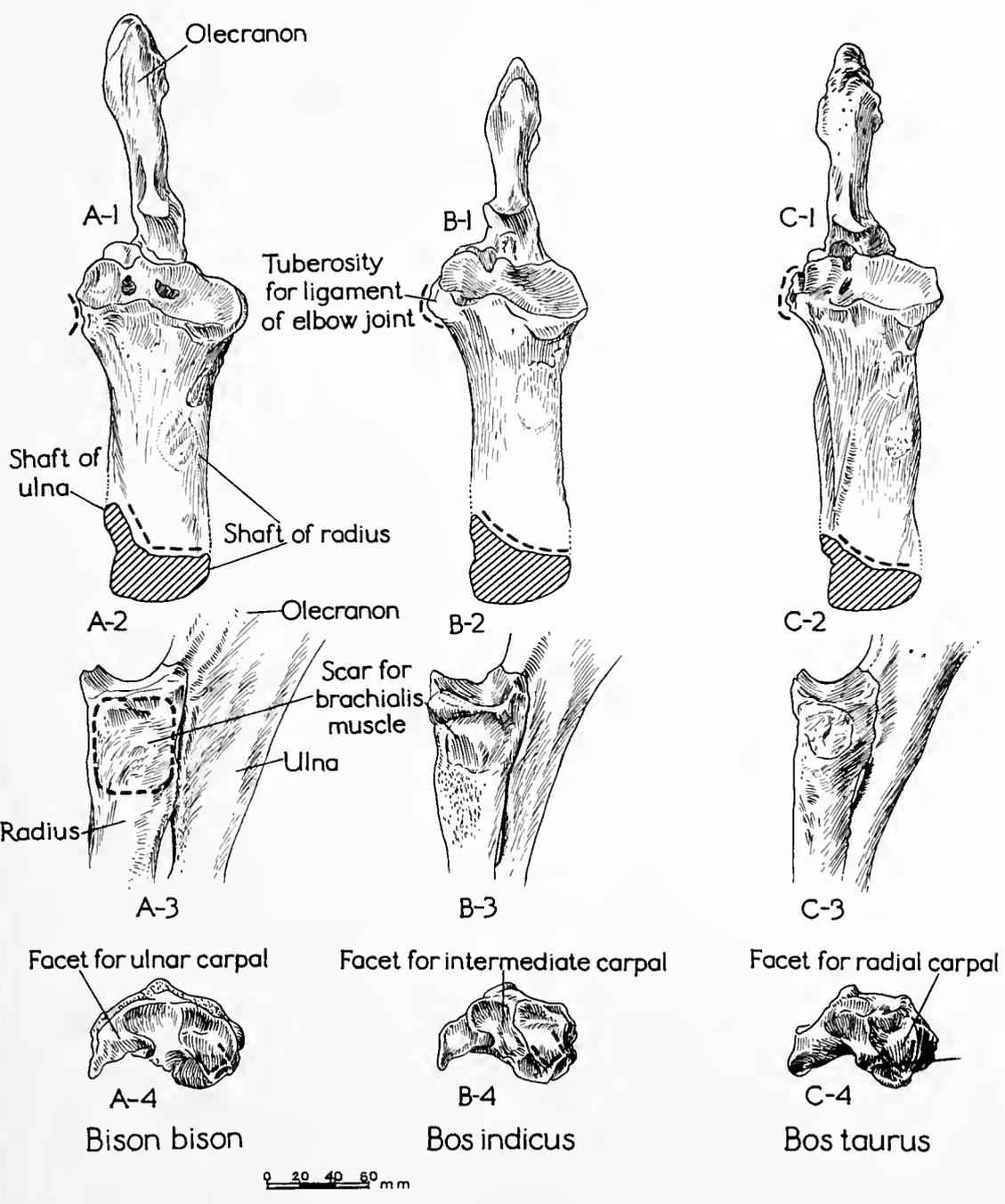
Bos taurus

FIGURE 14

Bison bison. Right radius and ulna: A-1, three-quarter view of proximal articular surface; A-2, transverse section showing relation of fused shafts of radius and ulna; A-3, medial surface of proximal end of radius; A-4, articular surface of distal end of radius. Differentiating characters indicated by heavy dashed lines.

Bos indicus. B-1 to B-4, same views as for *Bison*.

Bos taurus. C-1 to C-4, same views as for *Bison*.



Olecranon

A-1

B-1

C-1

Tuberosity
for ligament
of elbow joint

Shaft of
ulna

Shaft of radius

A-2

B-2

C-2

Olecranon

Scar for
brachialis
muscle

Ulna

Radius

A-3

B-3

C-3

Facet for ulnar carpal

Facet for intermediate carpal

Facet for radial carpal



A-4

B-4

C-4

Bison bison

Bos indicus

Bos taurus

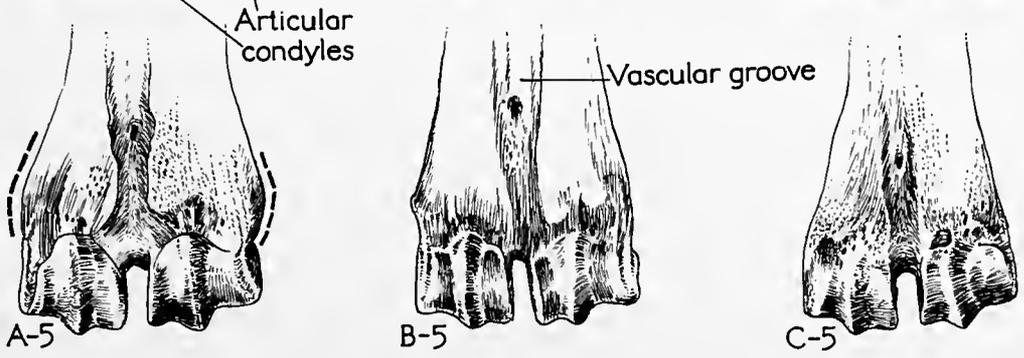
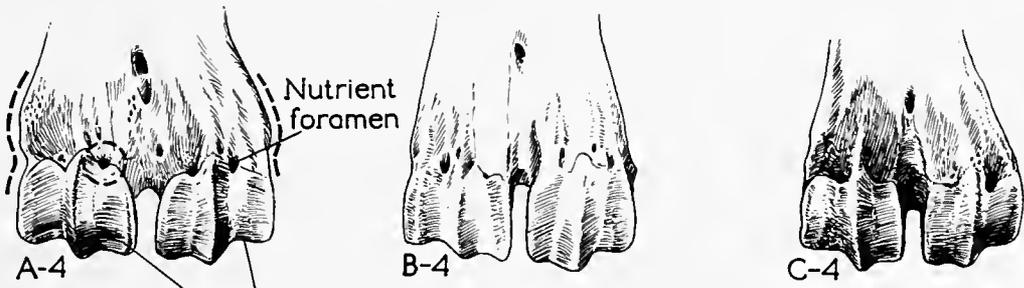
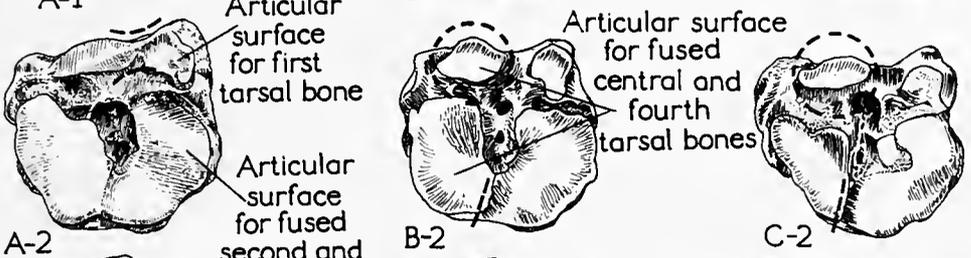
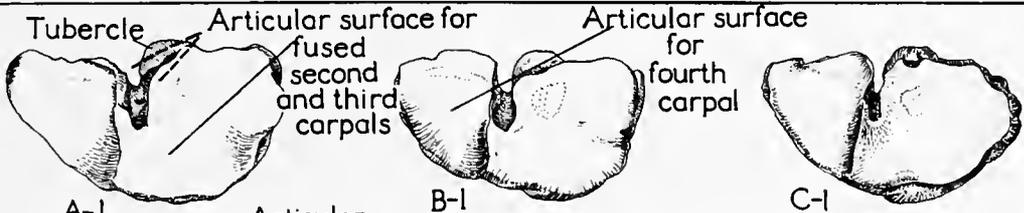
0 20 40 60 mm

FIGURE 15

Bison bison. Right metacarpal: A-1, proximal articular surface. Right metatarsal: A-2, proximal articular surface; A-3, anterior surface of proximal end; A-4, posterior surface of distal end; A-5, anterior surface of distal end. Differentiating characters indicated by heavy dashed lines.

Bos indicus. B-1 to B-5, same views as for *Bison*.

Bos taurus. C-1 to C-5, same views as for *Bison*.



Bison bison Bos indicus Bos taurus

0 10 20 30 mm

FIGURE 16

Bison bison. Second phalanx: A-1, dorsal surface; A-2, lateral surface. First phalanx: A-3, dorsal surface; A-4, ventral surface. Differentiating characters indicated by heavy dashed lines.

Bos indicus. B-1 to B-4, same views as for *Bison*.

Bos taurus. C-1 to C-4, same views as for *Bison*.

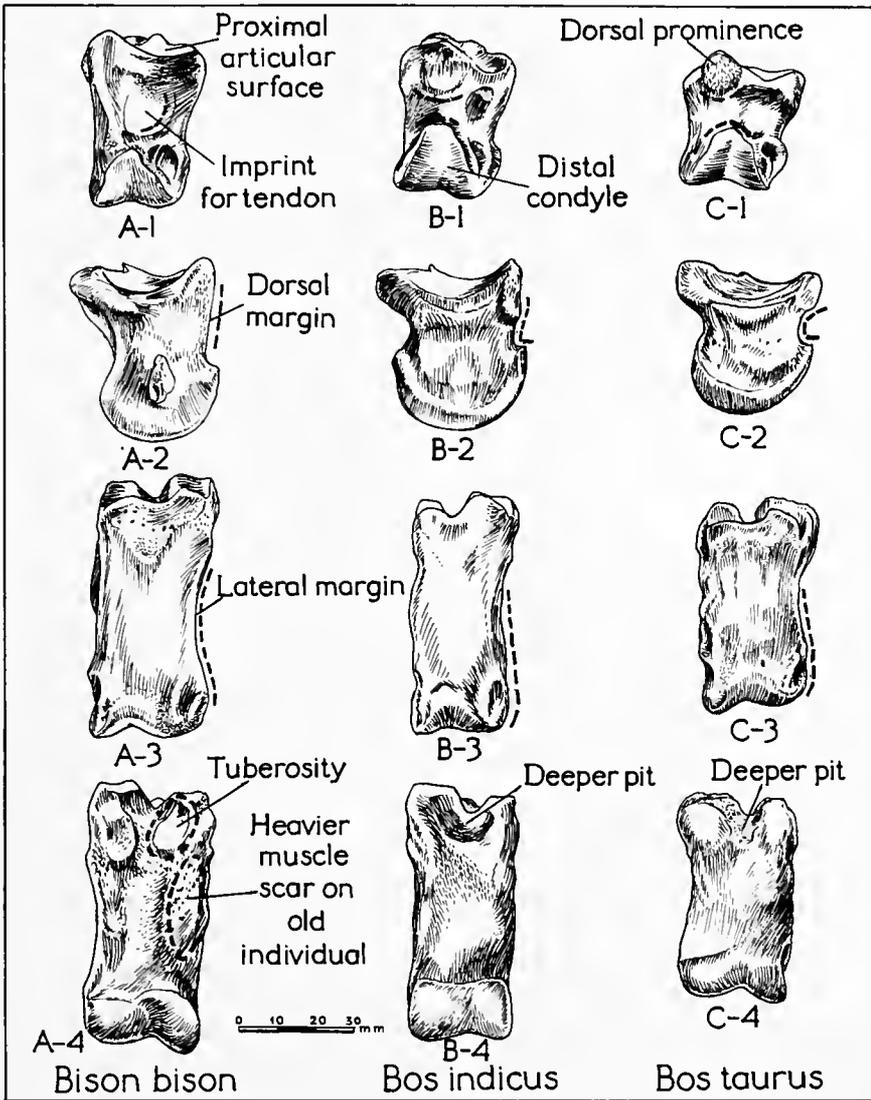
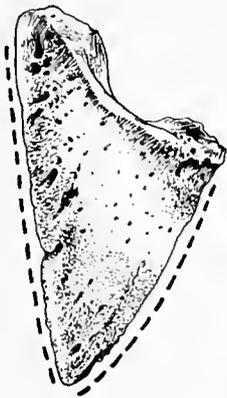


FIGURE 17

- Bison bison*. Hoof bone or third phalanx: A-1, lateral surface; A-2, dorsal surface; A-3, articular surface; A-4, plantar surface; A-5, medial surface. Differentiating characters indicated by heavy dashed lines.
- Bos indicus*. B-1 to B-5, same views as for *Bison*.
- Bos taurus*. C-1 to C-5, same views as for *Bison*.



A-1

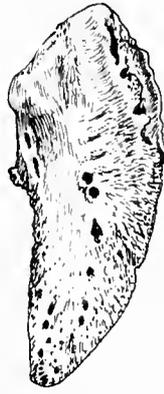


A-2

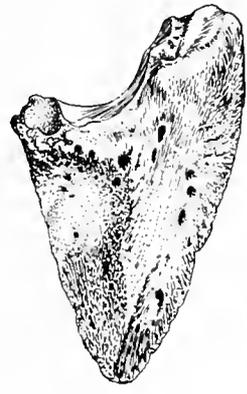


A-3

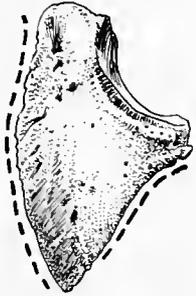
Bison bison



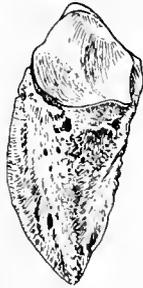
A-4



A-5



B-1



B-2

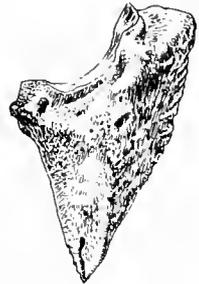


B-3

Bos indicus



B-4



B-5



C-1



C-2

Outer
Plantar
Margin



C-3

Bos taurus



C-4



C-5

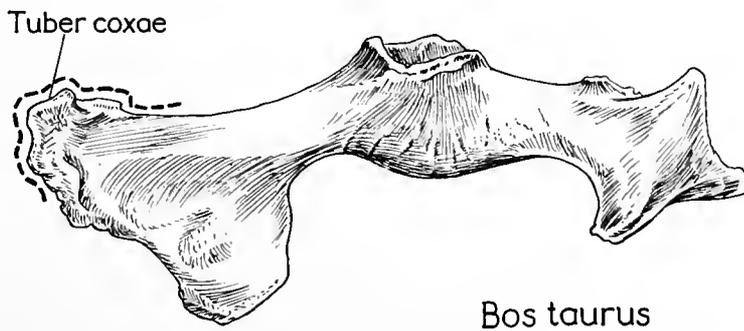
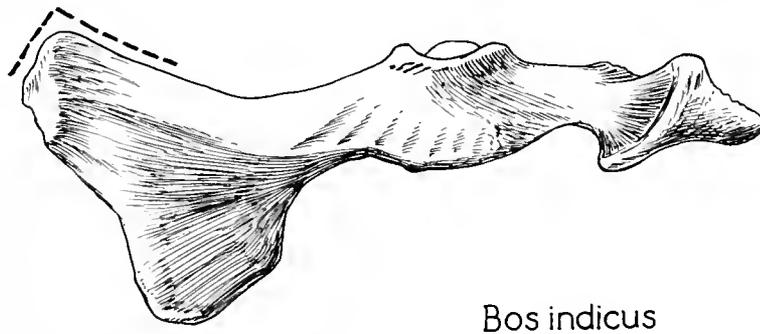
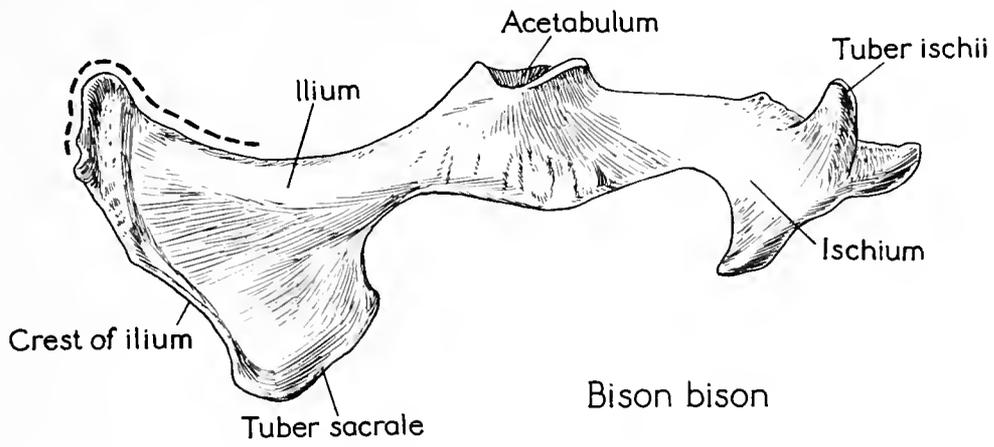
0 10 20 30 40 mm

FIGURE 18

Bison bison. Left os coxæ, lateral surface. Differentiating characters indicated by heavy dashed lines.

Bos indicus. Same view as for *Bison*.

Bos taurus. Same view as for *Bison*.



0 20 40 mm
10 30

FIGURE 19

Bison or *Bos*. Articulated left hindlimb: A, anterior view; B, medial view.

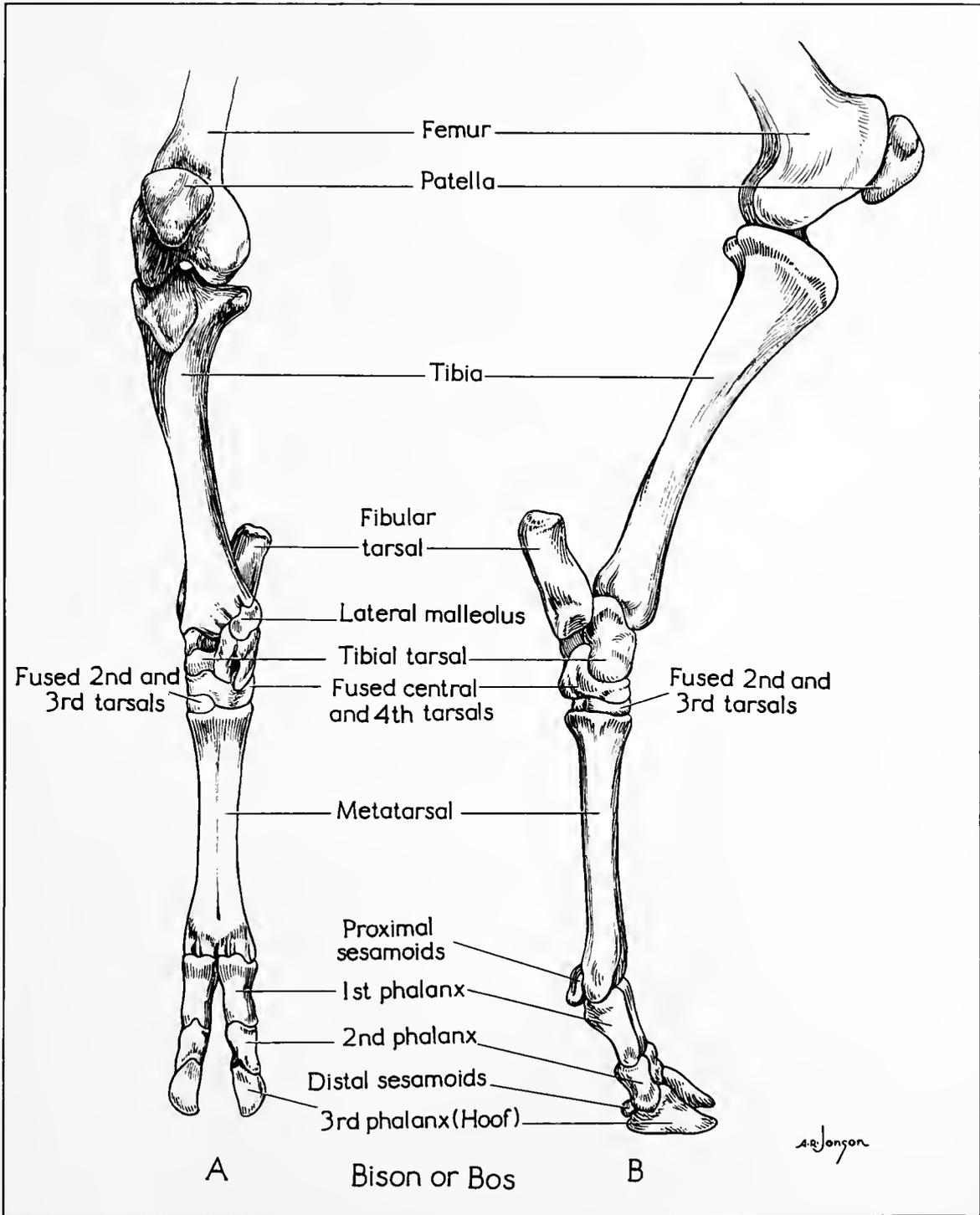
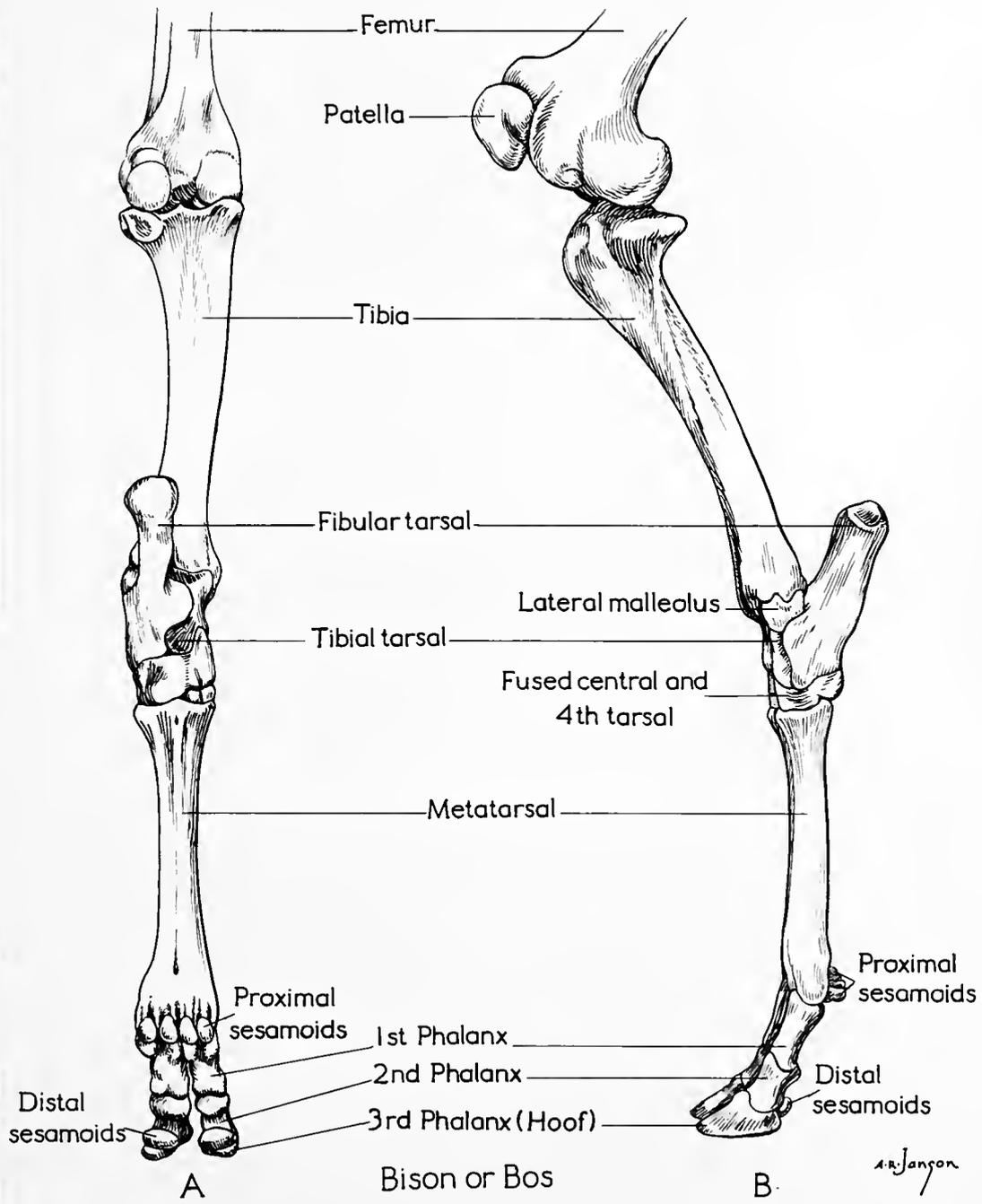


FIGURE 20

Bison or *Bos*. Articulated left hindlimb: A, posterior view; B, lateral view.



A

Bison or Bos

B

A.R. Janson

FIGURE 21

Bison bison. Right femur: A-1, proximal end, posterior surface; A-2, proximal end, anterior surface; A-3, distal end, lateral surface; A-4, distal end, medial surface. Differentiating characters indicated by heavy dashed lines.

Bos indicus. B-1 to B-4, same views as for *Bison*.

Bos taurus. C-1 to C-4, same views as for *Bison*.

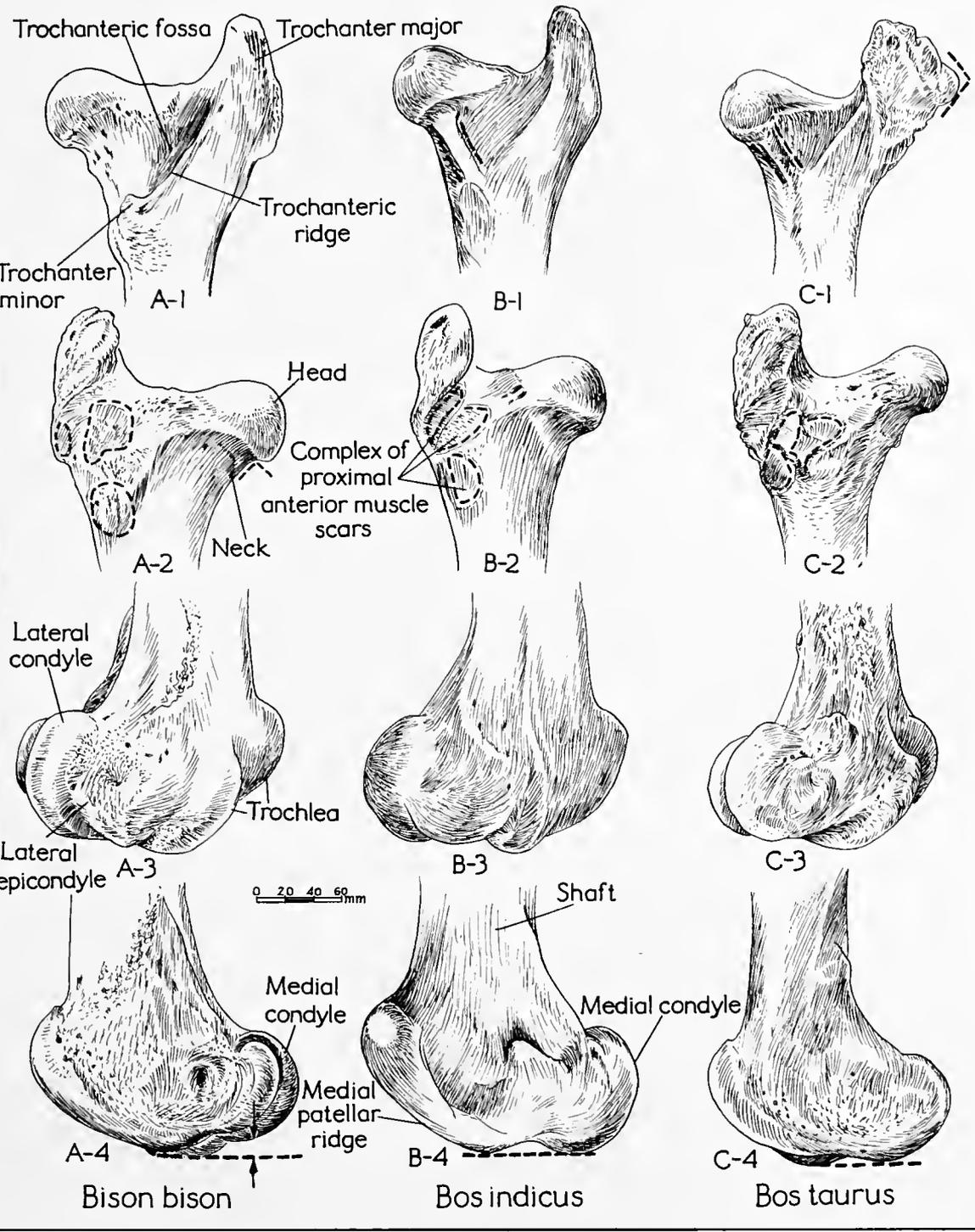
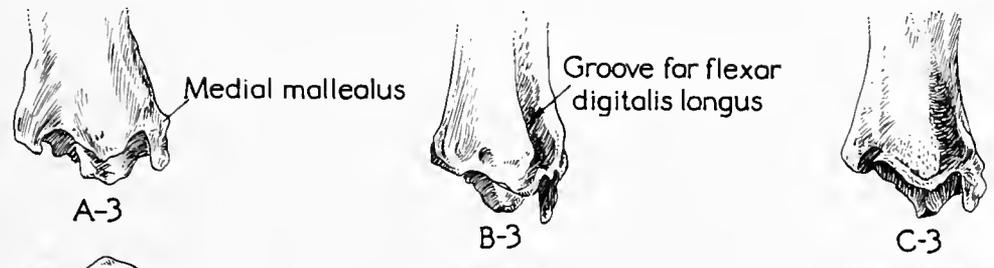
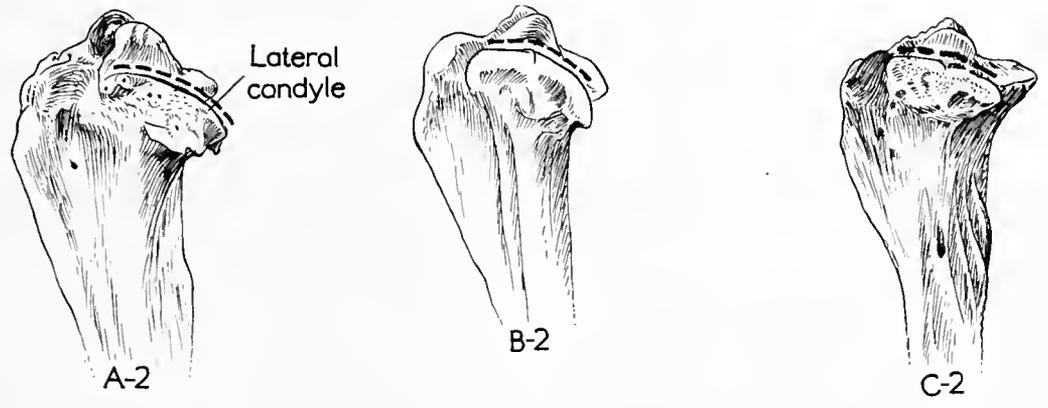
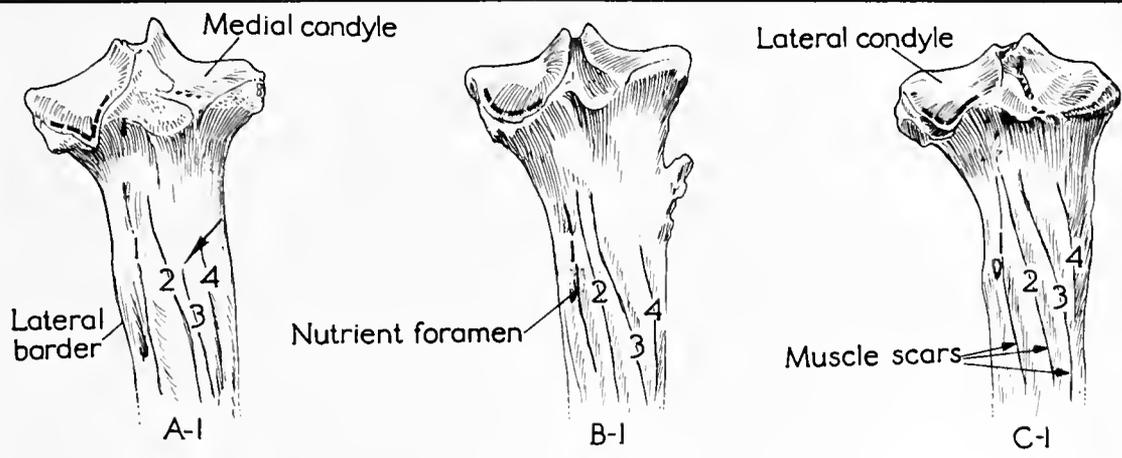


FIGURE 22

Bison bison. Left tibia: A-1, proximal end, posterior surface; A-2, proximal end, lateral surface; A-3, distal end, posterior surface; A-4, distal end, articular surface. Differentiating characters indicated by heavy dashed lines.

Bos indicus. B-1 to B-4, same views as for *Bison*.

Bos taurus. C-1 to C-4, same views as for *Bison*.



0 20 40 60 mm

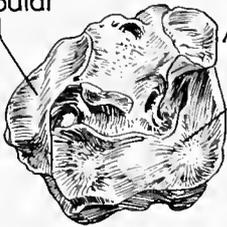
FIGURE 23

Bison bison. Right fused central and fourth tarsal: A-1, proximal articular surface; A-2, distal articular surface. Left tibial tarsal: A-3, anterior surface; A-4, posterior surface. Differentiating characters indicated by heavy dashed lines.

Bos indicus. B-1 to B-4, same views as for *Bison*.

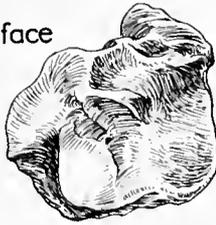
Bos taurus. C-1 to C-4, same views as for *Bison*.

Articular surface
for fibular
tarsal

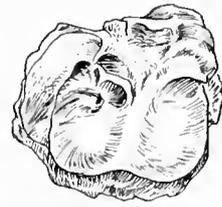


A-1

Articular surface
for tibial
tarsal

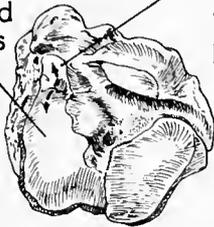


B-1



C-1

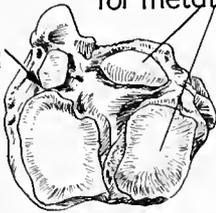
Articular surface
for fused 2nd
and 3rd
tarsals



A-2

Articular surface
for 1st tarsal

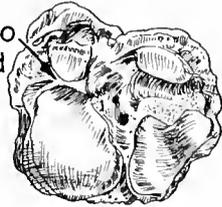
Tendency to
be separated



B-2

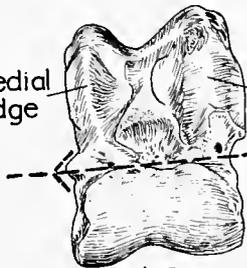
Articular surfaces
for metatarsal

Tendency to
be separated



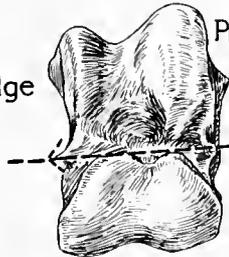
C-2

Medial
ridge



A-3

Lateral ridge

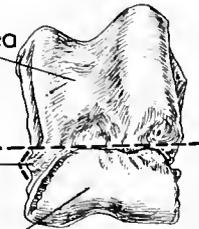


B-3

Proximal trochlea

Medial
tubercle

Distal trochlea



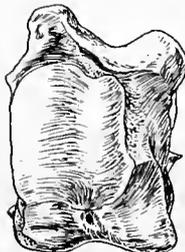
C-3

Old
adult



Bison bison

Posterior
articular
surface



Bos indicus



Bos taurus

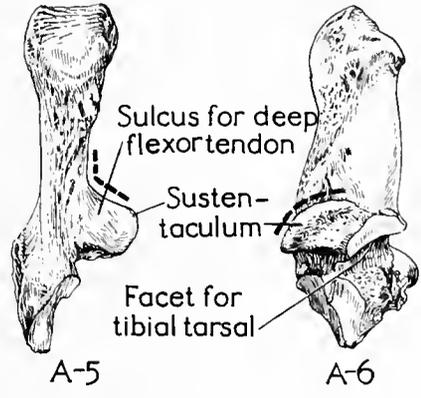
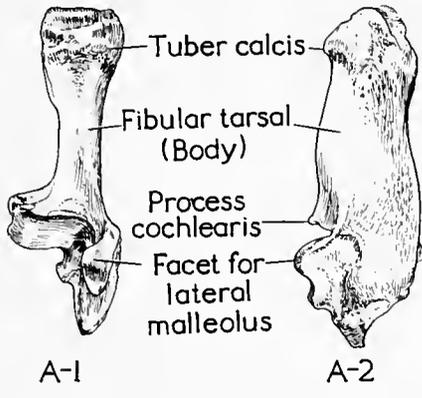
0 10 20 30 mm

FIGURE 24

Bison bison. Left fibular tarsal bone: A-1, anterior view; A-2, lateral view; A-3, superior view; A-4, inferior view; A-5, posterior view; A-6, medial view. Differentiating characters indicated by heavy dashed lines.

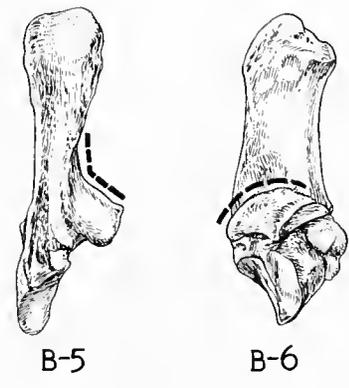
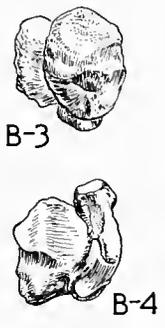
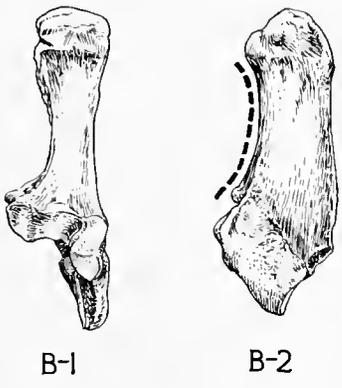
Bos indicus. B-1 to B-6, same views as for *Bison*.

Bos taurus. C-1 to C-6, same views as for *Bison*.



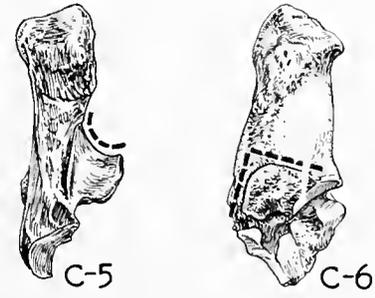
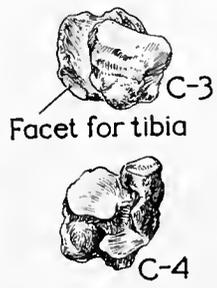
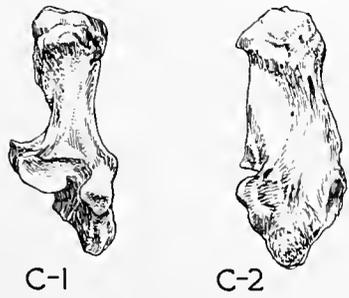
A-1 A-2 A-3 A-4 A-5 A-6

Bison bison



B-1 B-2 B-3 B-4 B-5 B-6

Bos indicus



C-1 C-2 C-3 C-4 C-5 C-6

Bos taurus



(Continued from inside front cover.)

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