

# Some Morphological Studies on the Wing and foot of the Southern Cassowary (*Casuarius casuarius*)

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With 8 figures

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## Abstract

The cassowaries are ratites (flightless birds without a keel on their sternum). The wings and feet of a doubled-wattled or Southern cassowary used in this study were radiographed. Pieces of the quills and claws were processed for histological examination, and the wings and feet were cleaned to study the bones.

The wings are small with only four long, slightly curved quills or remeges. Quills occurred in follicles, similar to the hair follicles of mammals. The shaft of a quill was formed by a central medulla consisting of a solid polygonal, non-nucleated cell mass surrounded by dense compact keratinized cells compressed to form a cortex.

The wing skeleton was formed by the humerus, a thick radius paired with a thinner curved ulna, ulnar and

radial carpals, carpometacarpal, and three digits. The second digit bore a long curved claw.

The skeleton of the foot was formed by the distal extremity of the tarsometatarsal, which had three articular surfaces (trochlea) representing the three digits (II, III, IV).

The first digit was missing. The second digit consisted of 3 phalanges, the distal phalanx of which was a long tapering cone sheathed completely by a keratinous long straight claw (dagger-shaped). The third digit was the largest, and consisted of 4 phalanges. The fourth digit was longer than the second one and shorter than the third one, and had five phalanges.

The gross anatomy described was supported by 8 images (x-rays, histology, and skeleton of the wings

and feet) and discussed in comparison with other bird species.

**Keywords:** Cassowary, quills, claws, digits, histology, radiology

## Introduction

The cassowaries are ratites (flightless birds without a keel on their sternum bone) in the genus *Casuaris*, native to the tropical forests of New Guinea, nearby islands, and northeastern Australia (Clements, 2007). There are three extant species recognized today: the Southern Cassowary or double-wattled; the Dwarf Cassowary or Bennett's; and the Northern Cassowary, or single-wattled). The most common of these, the Southern Cassowary, was the third tallest and second heaviest living bird, smaller only than the ostrich and emu.

All cassowaries have feathers that consist of a shaft and loose barbs. The feathers differ from other birds in that they have a quill that splits in two <sup>(1)</sup>. Actually, it was the afterfeather, which develops to the size of the feather itself. Cassowaries do not have retrices (tail feathers) or a preen gland. Cassowaries have small wings with 5-6 large remeges (Fig 1), reduced to stiff, keratinous quills, like porcupine quills, with no barbs (Davies, 2002). A claw was found on each second finger (Harmer and Shipley, 1899).

Cassowaries are also characterized by heavy, well-muscled legs, each had 3 toes, with the inside toe bearing a larger dagger-shaped claw (up to 120 mm long) <sup>2,4</sup>.

The majority of the articles and books on cassowaries mentioned nearly the same information about the number of quills and the curved claw on the second digit of the small wing. The histological structure of these quills and claws as well as radiographic anatomy of both the wings and feet could not be found in the available literature, hence the goal of the work was to shed more light on these unique structures of the cassowary.

## Material and methods

A cadaver of a cassowary bird, which had recently died in one of the wildlife sanctuaries near Townsville was presented in 2013 to the department of Anatomy and Pathology for postmortem examination. The wings and feet of the bird were kept for the anatomical study. One foot and a wing were X-rayed before studying their morphology. Small pieces from the quills and the claws of the other wing were processed with the routine histological methods, cut with the microtome into sections 5 µm thick and stained with H&E stain. The x-ray images were processed with the parameters: 53 kV and at 5 mAs.

## Results

### *I. Morphology of the wings*

In proportion to their size, cassowaries have very small wings (about 20 cm long). The cassowary of this study had only four long, slightly curved quills measuring 34, 31, 32, and 22 cm in the right wing and 25.5, 22, 20.5, 14 cm in the left wing. The claw of the left wing was smaller (2 cm long) than that of the right wing, which was strongly curved and measured 8.5 cm long (Fig 2). The quills were hollow with a diameter about 5 mm at the level of the middle of quill's length. They were embedded in the skin of the wing as shown in the x-ray image, with the claw attached to the 2<sup>nd</sup> digit of the wing (Fig 3).

The bones of the wing distal to the humerus (which bore a long curved "humeral" process, about 12 mm long) were the widely spaced radius and ulna. The ulna was stouter and longer than the radius and while the ulna was straight, the radius was bowed along its length. The elbow joint (Figs 3,4/1) was formed by the condyles of the humerus and the proximal ends of the radius and ulna. At the carpal joint (Figs 3,4/2) the ulna and radius articulated with the ulnar (smaller) and radial (larger) carpal bones. The carpometacarpal or manus was a single bone formed by

the union of the distal row of the carpals and the three digits. The alular or first digit, the major (second) digit with its two phalanges and a large curved claw and the minor digit (third) could be also identified on the x-ray image (Figs 3,4/A).

The carpals, metacarpals and the three digits were reduced to form a stiff skeletal unit for the anchorage of the primary flight feathers as well as the peculiar quills of the cassowary (of which there were four in this specimen).

A transverse histological section of the quill revealed that it grew from a follicle, similar to the hair follicle of mammals. The quill shaft was formed by a central medulla consisting of a solid polygonal, non-nucleated cell mass surrounded by dense compact keratinized cells forming a cortex.

The quill sheath was formed of three concentric layers (1) the internal sheath; consists of 10-15 layers of pale-stained flatten epithelial cells, which are recognized by its contents of keratohyaline granules, (2) the external sheath derived from the epidermal layer, consisted of epidermal epithelium and was separated from (3) the connective tissue outer sheath by a glassy homogeneous membrane (Fig 5).

The histological structure of the claw revealed that it consists of epidermal and dermal layers. The epidermis was formed of a stratum basale with cuboidal epithelium, a stratum spinosum with many layers of polygonal cells, a stratum granulosum of two layers of flattened cells and a stratum corneum. The dermis was formed of dense fibrous connective tissue and formed long dermal papillae interdigitating with the epidermis. It had many lymphoid cells but was devoid of the glands and feathers follicles (Fig 6).

## ***II. Morphology of the feet***

The tarsometatarsus was a long bone, about 32.5 cm long. Its proximal extremity (base) articulated with the tibia, which was also long, reaching 44 cm in length. It represents the fused distal row of tarsal bones as well as the digits II, III, IV. The body of the tibia was nearly triangular in cross section, with a deep wide dorsal groove flanked by two thick borders, each of which ended distally with a trochlea representing the second and fourth digits. Proximally, the tarsometatarsus presented a prominent ridge, which ended at the level of the distal third of the bone.

The distal extremity (head) of the tarsometatarsal had three articular surfaces (trochlea) representing the three digits (II, III, IV). The trochlea

of the D<sub>3</sub> was the largest, while the trochlea of D<sub>2</sub> was larger than that of D<sub>4</sub> and was separated from the D<sub>3</sub> by a deeper inter-trochlear insicura than that between D<sub>4</sub> and D<sub>3</sub>.

The first digit was missing. The second digit consisted of 3 phalanges; the proximal phalanx was 4.5 cm long and had a proximal base, a body and a distal head. The second phalanx was about 2 cm long and had only the proximal base and distal head without any readily-distinguished body. The distal phalanx was a long tapering cone of about 7 cm in length and had a proximal base and tapering distal end which was sheathed completely inside keratinous long straight claw (Figs 7,8). The second digit had two inter-phalangeal joints.

The third digit was the largest, and consisted of 4 phalanges. Each phalanx had a proximal base, a body, and a distal head, except the fourth distal phalanx, which had a tapering distal head, and was sheathed completely inside keratinous pointed claw. The length of the phalanges was 6.8, 5, 3, 4.3 cm respectively. The third digit had 3 inter-phalangeal joints.

The fourth digit was longer than the second one and shorter than the third one. It had five phalanges; each phalanx had a proximal base,

a body (except the fourth in which the body was undistinguished) and a distal head. The fifth phalanx had a tapering head and was sheathed completely inside the keratinous pointed claw. The length of the phalanges (I-V) was 5, 2.7, 1.9, 1.4 and 4 cm respectively. The fourth digit had 4 inter-phalangeal joints.

The Cassowary leg was characterized also by the presence of 6 digital pads; a tarsometatarsal phalangeal at the same-named joints, one digital pad on the digit II and 2 digital pads on each of the digit III, IV (Figs 7,8). The skin of the pads was studded with rounded to polygonal papillae of different sizes and direction. The dorsal surface of the foot was covered by scales, which were about 12 in number covering the Digit II, 16 on digit III and 8 on digit II. The scales increased in length as they descended from the tarso-metatarsal region downwards. They were flat, rounded or conical in shape (Fig 8).

## Discussion

### *I. Wings*

In a very early monograph on cassowaries, Rothschild (1899) wrote that the wings are quite rudimentary, with about five round black shafts, without any indication of webs in the place of remiges; no rectrices were apparent. The body

was covered with stiff, hair-like feathers, in which the after-shaft was as long as the principal shaft.

The number of quills (remiges) found in this study was four, ranging between 31-34 cm long. Perron (1992) mentioned that the cassowary wing was vestigial, with the remiges (flight feathers) reduced to five or six spine-like quills (6.0 to 20.0 cm long in the adult). He mentioned also a claw on the major digit of the wing, which supports the findings of this study. The same number of quills on both sides of the body was also given by <sup>(2), (3)</sup>. They added that the quills protect the bird's body against thorny underbrush. The plumage of adult cassowaries was black and consists of hard, thin, bristle-like feathers. The tips of each wing have three to five long needle-like quills similar in size and form to the main feather as in the emu <sup>(4)</sup>. Other authors claimed that the cassowary's wings are almost non-existent, but from them grow several quills that lack barbs. These bare quills stretch out beyond the other feathers on each side and serve to help push obstructions aside <sup>(5), (6)</sup>. The official site of the Queensland Government <sup>(6)</sup> mentioned that the cassowary had hair-like feather with no barbules.

Stettenheim (2000) claimed that spurs arise on the radial side of the

carpus or metacarpus in cassowaries, screamers, Spur-winged Geese, certain jacanas and lapwings, and sheathbills. They vary in length, sharpness, and number. Such spurs were not noticed in the cassowary of this study.

Parker (1888) mentioned that in the adult Indian Cassowary (*C. galeatus*) there was only one carpal bone free; the "manus" was a solid single piece, with only one finger (the second or "index") developed, and this had only two phalanges instead of three; and the distal phalanx was an inch long and carried a large claw. The same author mentioned also that in the ripe embryo of (*C. bennetti*) there are four cartilaginous carpal nuclei and three metacarpal rays: the first was very small and feeble; the second very strong and with the normal number of phalanges (3 beside the metacarpal), and the distal or ungula joint was very long and carried a long claw; the third metacarpal was about one sixth the size of the second, and had no phalanges on it.

The results of this study disagree with Parker (1888) in that we observed two separate carpal bones (radial and ulnar), and agreed with him in the presence of a consolidated single manus (resulting from fusion of the Digits I, II, III) and in the presence of one large finger (the

second) with two phalanges and bears a large claw.

Bacha Jr. and Bacha (2012) mentioned that in structures composed of hard keratin (rather than soft keratin), such as hooves and claws, both the stratum granulosum and stratum lucidum are absent. In the claws of cassowary of this study, the stratum lucidum was not detected.

## **II. Feet**

Cassowaries have a long tibia, which was the largest bone in the pelvic limb. The length of the tibia is related to a bird's habits, being longest in wading birds, coming next in runners, and of considerable development in swimming birds<sup>(8)</sup>.

The upper end of the tarsus and its relation to the tendons is a fair index to the position of its owner, being simplest in Ostriches and other birds undeniably low or generalized in character, and more complicated in higher forms, reaching its greatest complexity in the perchers<sup>(8)</sup>. The same author added that the three divisions of the lower end of the tarsus indicate that it was composed of three bones, which were clearly shown only in embryos, in young ostriches and in penguins. The metatarsus was shorter than in most other Ratites, very robust, and

covered in front with hexagonal scutes, and transverse ones near the toes. Toes numbered three, the two outer ones with obtuse, curved, and short claws; the inner toe with a long, straight, powerful, pointed claw, which was a dangerous weapon (Rothschild, 1899)

Cassowaries have three-clawed toes on each foot. The claw on the middle digit was specially large and sharp, like a dagger. It is used as a weapon by leaping at an enemy feet-first <sup>(4)</sup>. Other authors mentioned the inside toe which bears the dagger-shaped claw (up to 120 mm long) <sup>(2), (6)</sup>. Perron (1992) and McLelland (1990) agreed that all the distal phalanges are sheathed completely inside keratinous nails. The former author added especially that the very long, sharply-pointed inside ones may eventually reach 18 cm. The before mentioned description of the foot and claws agreed with the findings of this study.

McLelland (1990) mentioned that digits I-IV have two, three, four and five phalanges respectively (which agree with this study's results). This seems to be a general phalangeal formula for birds. He claimed that amputation or surgical pinioning of the wing to prevent escape of waterfowl and other ornamental birds was performed by cutting off the manus of one wing through the proximal

part of the carpometa-carpus, so that the bird would be off-balance when trying to fly. He added that surgical pinioning was illegal in birds kept for agricultural purposes.

Stettenheim (2000) mentioned that adult cassowaries have a large pointed claw on the tip of the main digit, which they use as a formidable weapon. He added that spurs arise on the back of the tarsometarsus in cassowaries, pheasants, guinea-fowl, and turkeys. No spurs were found on the cassowary tarso-metatarsus of the study.

Cho, et al (1984) described three toes for the emus, cassowaries and rheas (Digits II, III, IV), all of which have claws. However, he added, digit two of cassowaries was modified with a straight sharp claw that can grow to 10 cm in length. The same author mentioned that the modified wing feathers and the casque of cassowaries aid in maneuvering through dense vegetations.

Naish (2010) <sup>7</sup> mentioned that claws are curved to varying degrees because the dorsal portion grows faster than the ventral portion. In addition to variation in curvature, claws also vary in relative length and pointedness (Stettenheim 2000).

Dyce et al. (2010) said that the distal tarsal elements of birds merge

with the metatarsal bone (itself a fusion of metatarsals II, III, and IV) to form the *tarsometatarsus*. With no free tarsal bones present, the hock was an intertarsal joint with mainly flexion and extension movement. The tarsometatarsus gives rise to four digits, although the phalangeal formula varies between species.

Stettenheim (2000) mentioned that the podotheca (integumentary covering of the feet) was heavily cornified in land birds, softer and more flexible in water birds. Fowler (1991) reported that all ratites had a digital cushion similar to that of the horse. He also noted that the ostrich digital cushion was continuous along the plantar aspect of the weight-bearing digit, whereas the other ratites had a cushion only underneath the joint (in agreement with the findings of this study in Cassowary). Recently, El-Gendy et. Al., (2011) described four digital pads for the ostrich: two on the Digit III, one on the Digit IV and one at the metatarsophalangeal joint. They added also that the ventral surface of each footpad was covered by numerous papillae, which are varied in direction, length and thickness. The cassowary of this study possessed 6 digital pads; a tarso-metatarsal phalangeal at the same named joints, one digital pad on the digit II and 2 digital pads on

each of the digit III, IV. We agreed with the afore-mentioned authors in the presence of papillae, and their shape and size on the plantar surface of the pads.

Köng et al., (2003) added that the digital cushion found in the depth of the digital pads serves to absorb mechanical shocks and provide support to the limb. Stettenheim (2000) added that it would withstand compression, especially in terrestrial species.

The presence of scales covering the dorsal and plantar aspects of the tarso-metatarsals was also confirmed by Stettenheim (2000). He added that the scales (reticulate in type) tend to be larger, more rectangular, and more regularly arranged on the anterior and caudal surfaces than on the remaining surfaces of the tarso-metatarsal.

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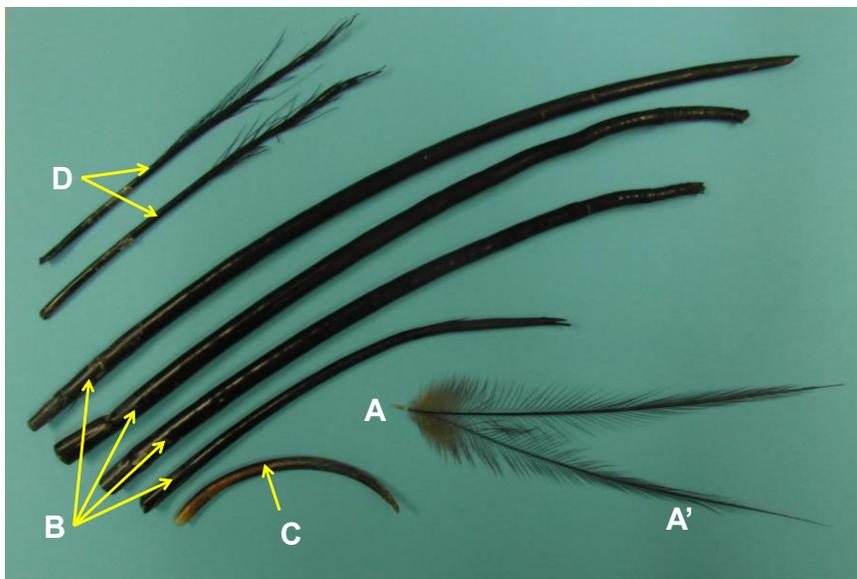
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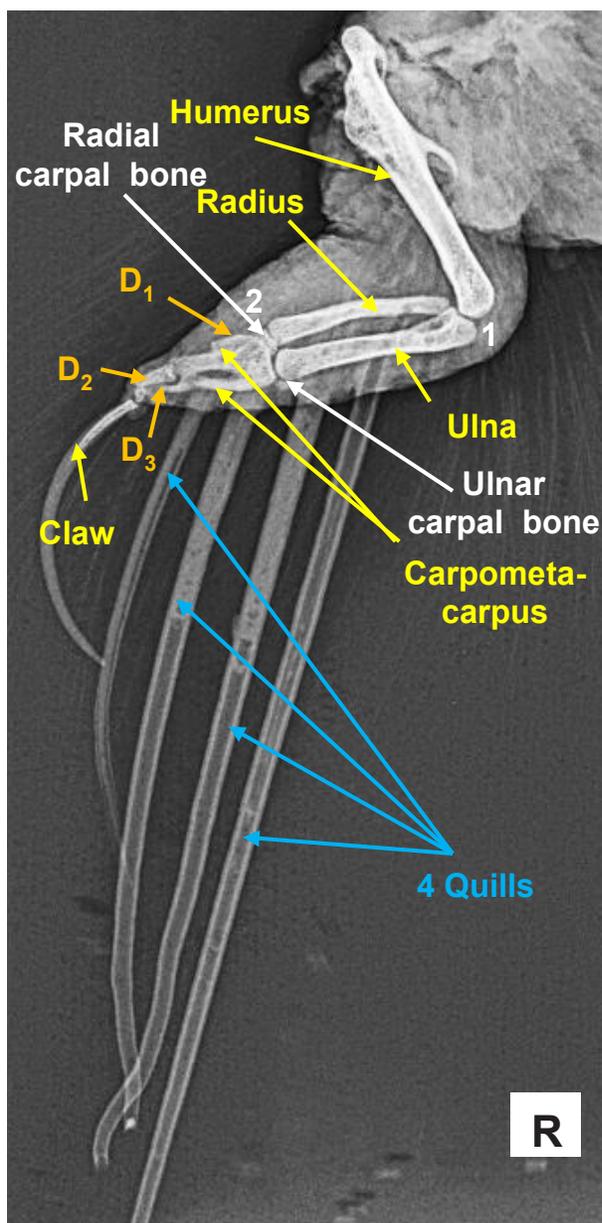
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**Fig (1):** Cassowary. Notice the position, shape and number of the quills and the dagger-like claw in the inner digit  
 (Source: <http://animal4u.wordpress.com/2013/01/27/miscellaneous-bird-cassowary/>, Retrieved 12/2/2014)

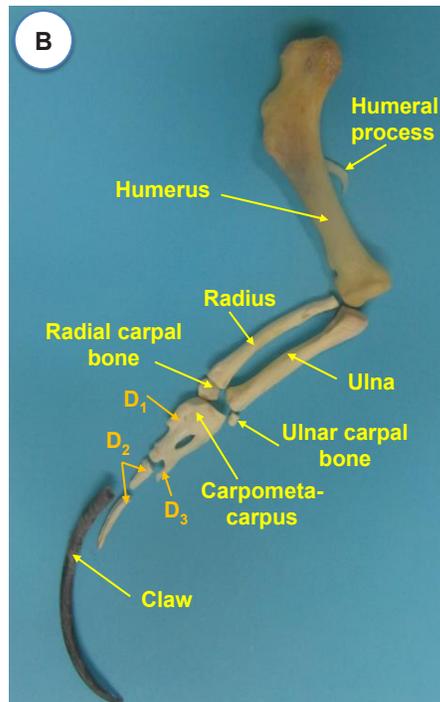
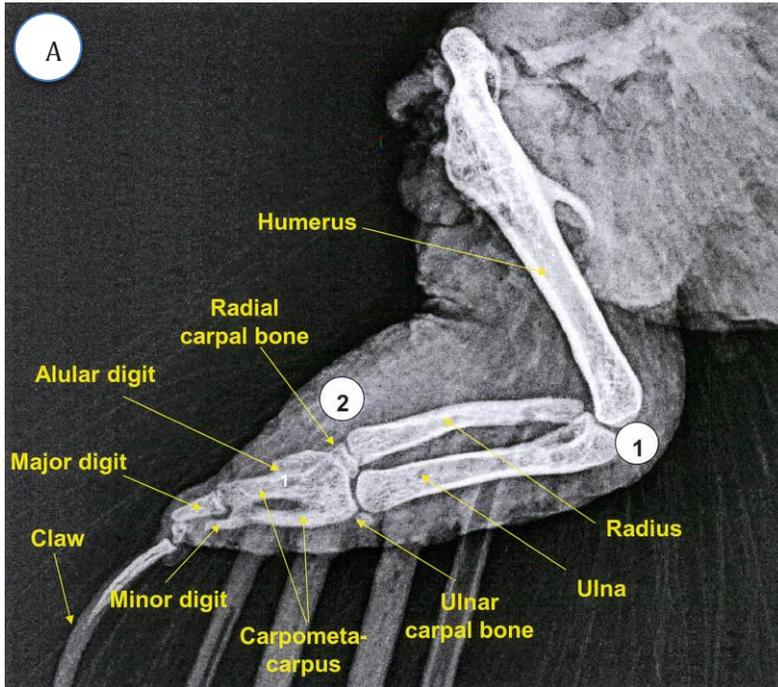


**Fig (2):** Types of feathers of the Southern cassowary: A normal body feather, A' after-shaft which have the same length of the feather, B Separated quills, C small claw, D consolidated feathers in the wings.



**Fig (3):** D/V X-ray image of the right wing of Southern cassowary showing its wing skeleton.

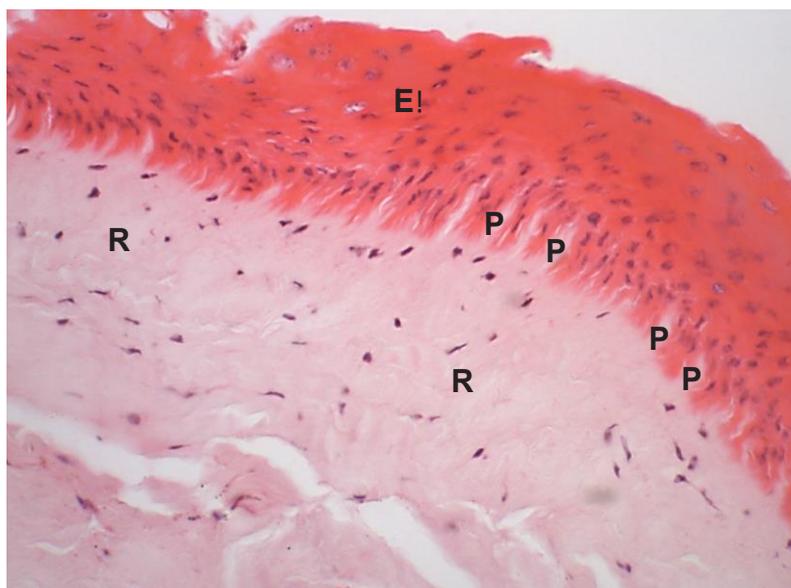
D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub>, the first, second and third digits respectively. 1 elbow joint, 2 carpal joint, Notice the implantation of the 4 quills in the skin of the wing and mounting of the long curved claw on the second digit of the wing.



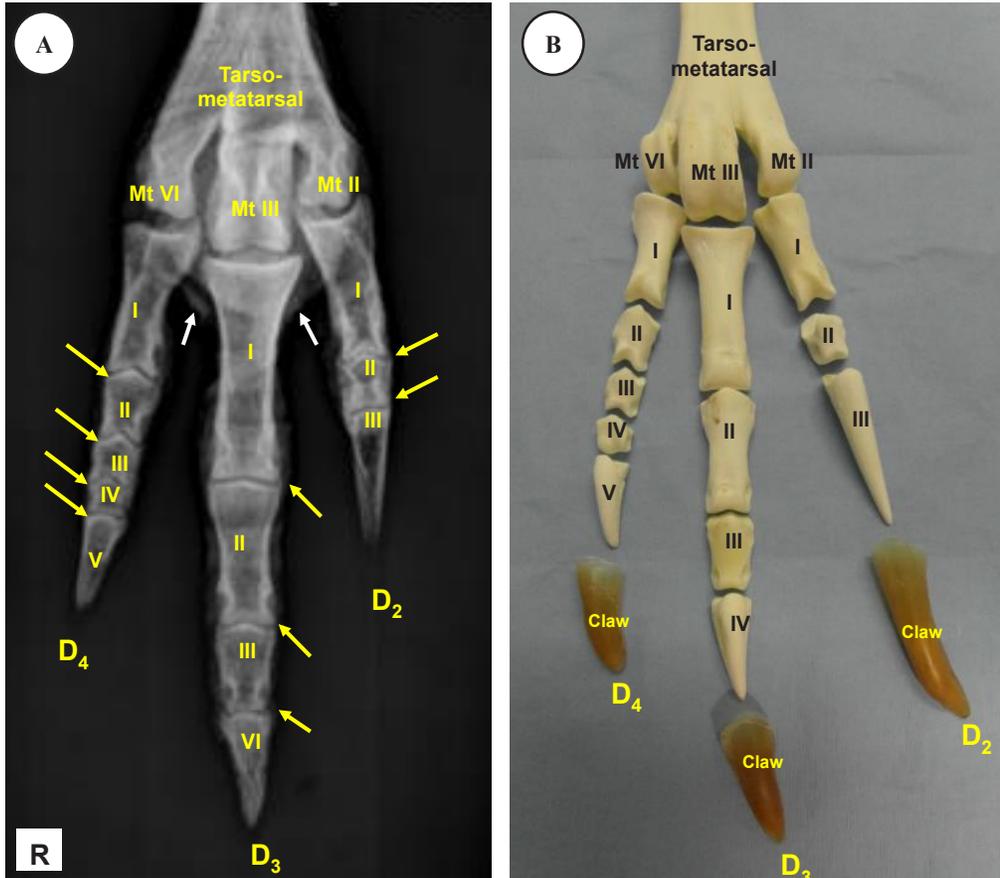
**Fig (4):** X-ray image of the right wing of the Southern cassowary. **A** magnification from Fig 3, **B** wing skeleton. Notice the anchorage of the 4 quills in wing.



**Fig (5):** Light micrograph of cross section of cassowary quill showing the cortex of the quill (Cx), the medulla (M), internal sheath (I) external sheath (E) the glassy membrane (G) separate the external sheath (E) from the outer connective tissue sheath (S). (H & E stain; x20)

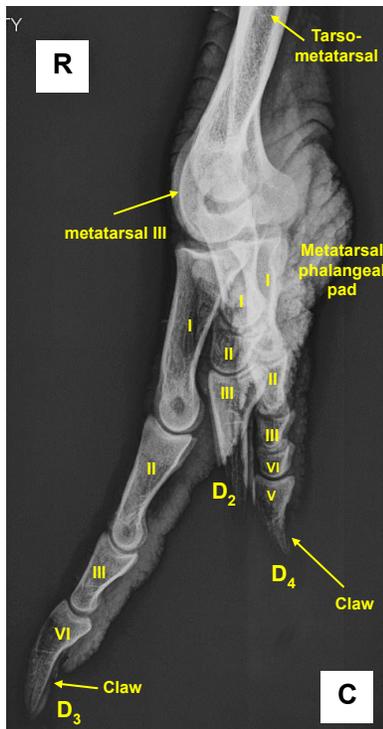
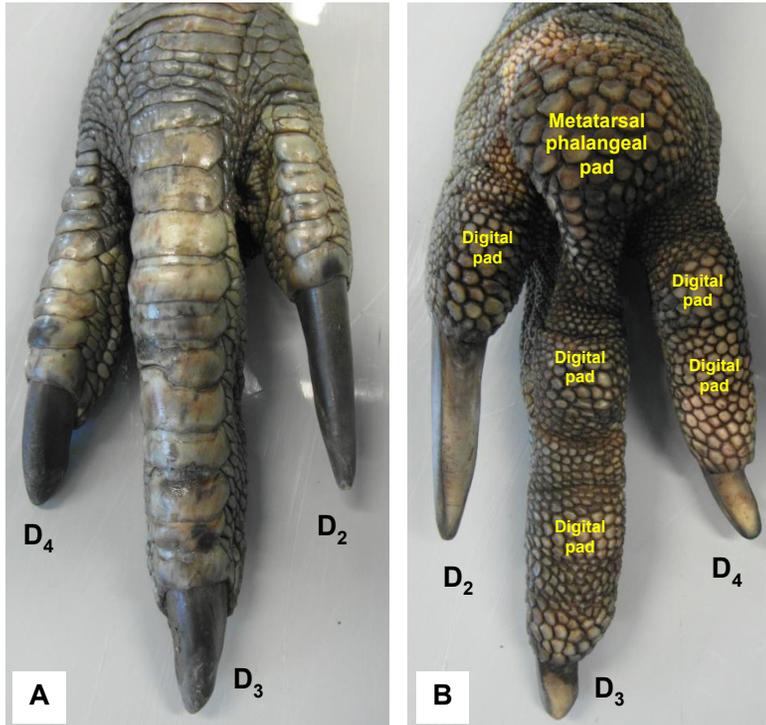


**Fig (6):** Light micrograph of the cassowary claw at its base showing the epidermis (E), dermal papillae (P) and reticular layer(R) which devoid of glands and feathers (H&E stain; x 40)



**Fig (7):** (A) D/ V X-ray image of the right foot of Southern cassowary showing its three digits (D<sub>2</sub>, D<sub>3</sub>, D<sub>4</sub>) and the phalanges of each digit (I-III, I-VI, I-IV respectively). The claws are present at the tip of the distal phalanx of each digit. (B) Bones of the right foot of the same bird.

*Notice:* the two interphalangeal joints in D<sub>2</sub>, the three interphalangeal joints in D<sub>3</sub> and the four inter-phalangeal joints in D<sub>4</sub> (indicated by yellow arrows). White arrows indicate the position of the digital pads.



**Fig (8):** Right foot of cassowary

- A) Dorsal view showing the scales covering the digits (II, III, IV)
- B) Plantar view of the right foot showing the metatarsal phalangeal pad and the digital pads on each digit.
- C) Latero/medial, X-ray image of the right foot of the Southern cassowary showing: the three digits (D<sub>2</sub>, D<sub>3</sub>, D<sub>4</sub>) and the phalnges of each. Notice the position of the tarso-metatarsal phalangeal pad underneath the joint.