

Original Article

Myology and osteology of the Whooper Swan *Cygnus cygnus*
(Aves: Anatidae)

Part 1. Muscles attached to the sternum, coracoid, clavicle,
scapula and humerus

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Abstract : We carried out anatomical work on the muscles of the pectoral and humeral regions of the Whooper Swan *Cygnus cygnus* (Aves: Anatidae), for the purpose of clarifying the relationship between the osteological structures and attachment of muscles that is essential when we reconstruct an extinct bird from the fossilized bones. In this study, we noted on and figured out the origins and insertions of the muscles on the sternum, coracoid, clavicle and humerus. The material was an old male with 1410 mm total length and 7250 g total body weight.

Key Words : Aves, Anatidae, Whooper Swan, *Cygnus cygnus*, Myology, Osteology

Introduction

To reconstruct the muscles of an extinct animal from the fossilized bones, paleontologists need detailed information on the connections between the osteology and myology of the related species. Avian myology has been described beautifully by ornithologists (e.g. George and Berger, 1966). However, for the paleontological purpose, it is still hard to identify the exact structure of the bone as the attachment of a muscle / tendon or a ligament in published literature.

Recently Gunma Museum of Natural History obtained a dead *Cygnus cygnus* from the Kiryugaoka Zoo, Gunma, to maintain the osteological and skin collection. The authors carried out anatomical work on this dead swan. The results will be published in a series of papers. As the first report, we describe the muscles which attach on the pectoral bones (sternum, clavicle, coracoid and scapula) and the humerus, the muscles used for the flight.

We follow Baumel (1979) for osteological, and Vanden Berge (1979) for myological terms. When George and Berger (1966) used different muscle names, they are given in square brackets. In this paper we categorized the

muscles as follows: muscles arising from the sternum, muscles around the shoulder, and muscles arising from the humerus. The last category includes *M. biceps brachii* and *M. triceps brachii*, although their origins are not on the humerus alone.

Material

A male *Cygnus cygnus*, GMNH-VA-04-02 (tentative number) of Gunma Museum of Natural History.

Its birth day and place unknown. Arrived the Kiryugaoka Zoo, Gunma Prefecture on June 3, 1983, and dead on August 12, 2004; at least aged 21 years in the zoo. The death was probably from senility. The distal wing tips were not clipped off, and the bones, tendons and feathers were all preserved.

Measurements:

Total length: 1410 mm.

Wing Length: Right 550 mm. Left 560 mm.

Head-neck (rostrum tip-neck/trunk boundary) length:
c. 780 mm.

Around chest: c. 680 mm.

Anus-tail feather tip: 205 mm.

Tarsus length: 110 mm.

Total body weight: 7250 g.

Body weight after skinning (in the condition all the skin with feathers and tarsal skin including webs removed, but the internal organs retained): 5720 g.

Weight of heart: 184 g.

Weight of liver: 210 g.

Weight of stomach-anus complex (stomach, gizzard with inside sand, small and large intestines, and ceca): 470 g.

Length of small intestine: 3150 mm.

Length of large intestine: 230 mm.

Length of two ceca: 252 and 260 mm.

The pectoral and humeral muscles

<Muscles arising from the sternum>

M. pectoralis (Fig. 1)

Arises widely from the shallow part of the clavicle, sternum (mainly from the carina but also from the sternal plane) and the lateral part of the rib cage. The attachment on the clavicle and sternum is direct and firm, whereas the attachment on rib cage is weak and not direct on the ribs but from the surface of underlying muscles.

This large muscle may be subdivided into three layers, which overlay cranially. Such subdivision has long been recognized by former authors, but we do not go further on this problem and just name them first (*I*), second (*II*) and third (*III*) layers from cranial to caudal. These three layers arise from different areas: *I* arising from the shallower part of the clavicle only, *II* from the deeper part of the clavicle and the carina of sternum, and *III* from the sternal plane and the rib cage. *III* partly lies between *II* in the caudal end of *II*. It was almost impossible to separate *I* and *II*, while the deeper part of *III* could easily be peeled off from the dorsal surface of *II*.

All components fuse together distally, and insert on the cranial surface of the *Crista pectoralis* on the proximal end of humerus (Fig. 3: 19).

The right one weighed 385 g. For both wings (770 g), the weight corresponds to about 11 % of total body weight.

For *M. pectoralis pars propatagialis* [*M. pectoralis pars propatagialis longus*], see under *M. tensor propatagialis*.

M. supracoracoideus

Arises from the deep corner of the ventral surface of the sternum (corner of carina and sternal plane) - *Rostrum sterni* of the sternum - and the complex membranous

ligaments (*Membrana sternocoracoclavicularis*) strongly connecting the sternum, coracoid and clavicle (see Fig. 1). In the ventral view, the profile is blade-like and simple. But the dorso-cranial part of the origin branches, as the *Membrana sternocoracoclavicularis* is intricate.

The strong tendon of insertion passes the canal formed by the clavicle, coracoid and scapula (see the dorso-lateral view of these bones in Fig. 2) and inserts on the *Tuberculum dorsale* on the caudal surface of the proximal end of the humerus (Fig. 3: 10).

The *Membrana sternocoracoclavicularis* is partly attached on the trachea. However, it is uncertain whether such situation provides any accessory function of "air pumping" during the flight.

The right one weighed 40 g.

M. coracobrachialis caudalis

[*M. coracobrachialis posterior*]

One of the two deep tongue-like muscles arising from the sternum. Lateral next to the *M. supracoracoideus* (see Fig. 1).

Arises widely from the cranio-lateral corner of the sternal plane and from the ventro-lateral surface of the basal part of the coracoid.

Inserts on the shallow notch on the dorsal slope of the *Tuberculum ventrale* (Fig. 3: 11) in the caudal surface of proximal end of the humerus.

M. sternocoracoideus

This is the only muscle which is in the internal surface of the thoracic cavity. May have the function to make the connection between the coracoid and sternum flexible.

Arises from the dorsal surface of the cranio-lateral corner of the sternum (*Proc. craniolateralis*) and the medial part of the cranial border of the rib cage (first rib).

Inserts on the large depression on the dorsal surface of the basal part of the coracoid.

<Muscles around the shoulder>

M. latissimus dorsi pars cranialis

[*M. latissimus dorsi pars anterior*]

The most superficial muscle in the back. This is a white muscle and is conspicuous in the back of the skinned bird (Fig. 2).

Arises from the neural spines of three thoracic vertebrae. But, this is the most superficial muscle and the aponeurotic attachment seems not on the bones directly, but seems to attach secondary on the neural spines,

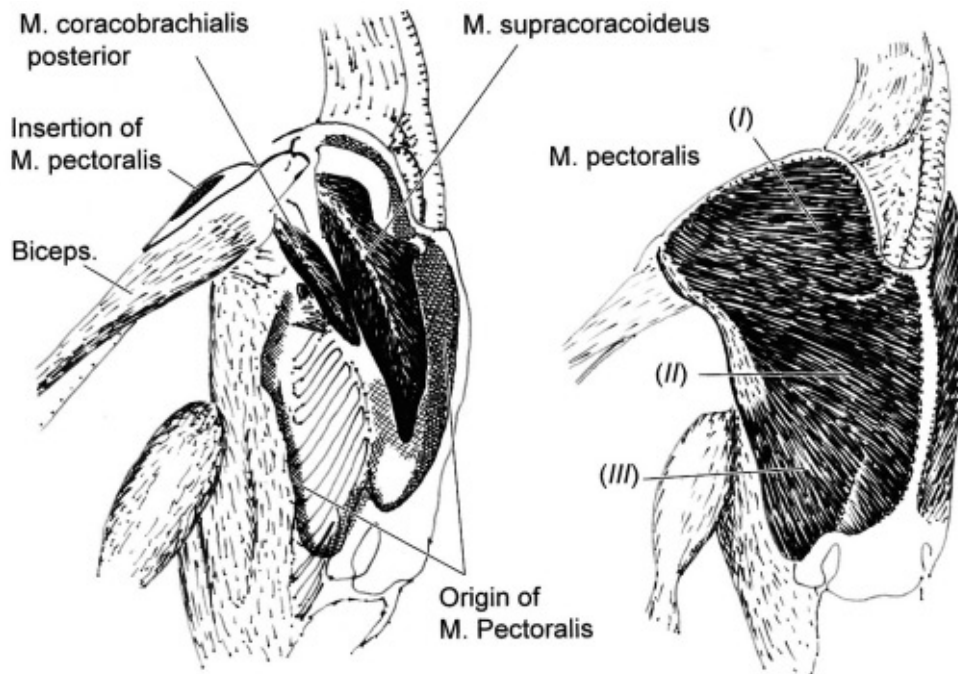


Fig.1: Pectoral muscles of *Cygnus cygnus*. See text for the I-III of *M. pectoralis*.

putting the aponeuroses of underlying deeper muscles in between. We need microscopic work to see whether the attachment of superficial muscle reach the bones or not, but that was not done in this study.

Fuse with *M. latissimus dorsi pars caudalis* in the portion of the armpit. See the next paragraph for the insertion.

M. latissimus dorsi pars caudalis
[*M. latissimus dorsi pars posterior*]

Arises from the neural spines of posterior thoracic vertebrae. The posterior tip of the origin reaches to the dorso-cranial region of the ilium. But the attachment is weak, and in a similar condition to the *M. latissimus dorsi pars cranialis*.

The *M. latissimus dorsi* (*M. latissimus dorsi pars cranialis et pars caudalis*) enters the proximal arm muscle system by passing through the slit between the *M. scapulotriceps* and *M. humerotriceps*. Inserts on the linear tuberosity on the caudal surface of the *Crista pectoralis* of the humerus (Fig. 3: 15). It is next to the marginal and much longer attachment of *M. deltoideus major*.

M. rhomboideus superficialis

Wide and sheet-like muscle connecting the vertebrae column and clavicle – scapula.

Arises from the line of the neural spines of the posterior cervical and thoracic vertebrae (see Fig. 2: left). The number of these vertebrae is probably eight. The attachment is in a similar condition to the *M. latissimus dorsi*. Because of the underlying muscles (muscles of back proper), the surface of these vertebrae are not seen directly even after the *M. rhomboideus superficialis* is removed.

Inserts on the medial margin of dorsal clavicle and the medial margin of the scapula (Fig. 2: 5). The insertion occupies more than two-thirds of length of the *Margo dorsalis* of the scapula.

M. rhomboideus profundus

A small muscle caudal to and deep to *M. rhomboideus superficialis*. As the origin from the vertebrae column is covered by and almost fused to the posterior portion of *M. rhomboideus superficialis*, we could not see the origin.

Inserts on the medial margin of the posterior extremity of the scapula (Fig. 2: 6).

M. subscapularis

Arises widely from the cranial three-fifth of medial surface of the scapula (Fig. 2: 15). This seems to be the *M. subscapularis pars interna*. We were unable to recognize *M. s. pars externa*.

Inserts by a strong tendon on the proximal slope of the

Tuberculum ventrale on the proximal end of the humerus (Fig. 3: 1).

Mm. serrati

Multiple muscles connecting between the vertebral column and the medial surface of the scapula (Fig. 2: 16). They must be the parts of *Mm. serrati*. However, we could not identify them in this study.

M. tensor propatagialis

[*Mm. tensor patagii longus et brevis*]

Singly bellies, and the total profile is like a petal, when its long distal tendon is cut off. This muscle looks like a shoulder-pad in the skinned bird. Covers loosely on the surface of *M. deltoideus major*.

Arises from the dorsal surface at the base the long apex of the clavicle (Fig. 2: 1). This is the most anterior muscle attaching on the dorso-lateral surface of the clavicle-coracoid- scapula complex, except the insertion of *M. rhomboideus superficialis*.

A small muscle, *M. pectoralis pars propatagialis*, arises from the proximal area of the cranial surface of the

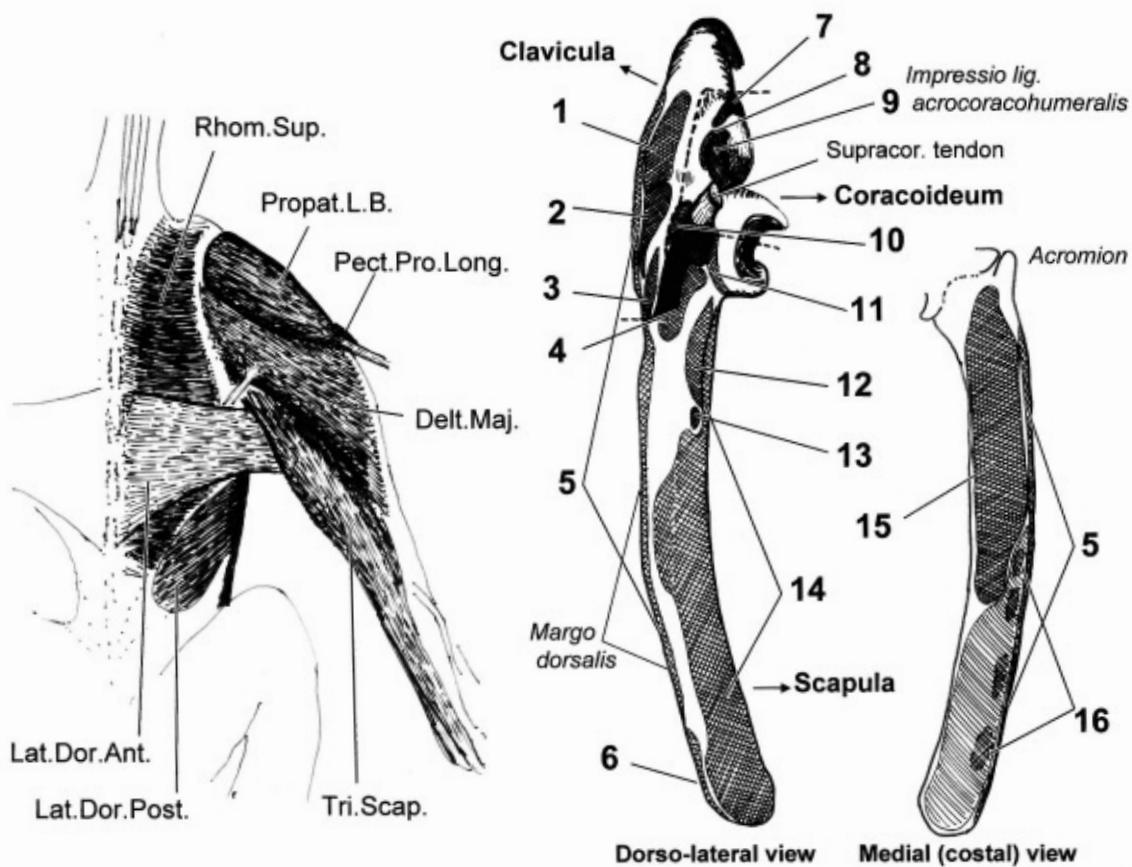


Fig.2: The superficial muscles around the shoulder of *Cygnus cygnus* (left), and the areas where muscles attached on the clavicle-coracoid-scapula complex (its dorso-lateral view, center; the medial view, right).

1: Origin of *M. tensor patagii longus et brevis*. 2: Origin of the posterior head of *M. deltoideus major*. 3: Origin of the dorsal head of *M. scapulothriceps*. 4: Origin of the anterior head of *M. deltoideus major*. 5: Insertion of *M. rhomboideus superficialis*. 6: Insertion of *M. rhomboideus profundus*. 7: Origin of *M. biceps brachii*, its main origin. 8: Origin of *M. coracobrachialis cranialis* [*M. coracobrachialis anterior*]. 9: Origin of *Lig. acrocoracohumeralis*. 10: Origin of *M. deltoideus minor*. 11: Origin of *Lig. coracohumeralis dorsale* and the ventral head of *M. scapulothriceps*. 12: Origin of *M. scapulohumeralis cranialis* [*M. proscapulohumeralis*]. 13: Attachment of the scapular anchor of *M. deltoideus major*. 14: Origin of *M. scapulohumeralis caudalis* [*M. dorsalis scapulae*]. 15: Origin of *M. subscapularis*. 16: Insertion of *Mm. serrati*. Abbreviations: Delt.Maj.- *M. deltoideus major*. Lat.Dor.Ant.- *M. latissimus dorsi pars anterior* = *M. latissimus dorsi pars cranialis*. Lat.Dor.Post.- *M. latissimus dorsi pars posterior* = *M. latissimus dorsi pars caudalis*. Pect.Pro.Long.- *M. pectoralis pars propatagialis longus*. Propat.L.B.- *M. tensor patagii longus et brevis* = *M. tensor propatagialis*. Rhom.Sup.- *M. rhomboideus superficialis*. Sca.Anc.- Scapular anchor of *M. deltoideus major*. Tri.Scap.- *M. scapulothriceps*.

Crista pectoralis on the proximal end of the humerus (Fig. 3: 18), and is merged into the belly of *M. tensor propatagialis* (see Fig. 2: left).

The inserting tendon, that is cut in Fig. 2, goes toward the wrist, like the bowstring of the arch humerus and ulna - radius form. A weak tendon branches off to connect the main tendon and the cranio-proximal portion of the ulna - radius.

M. deltoideus major

Two origins and the scapular anchor (Fig. 2, left). The superficial and major one is the “posterior head”, although it is actually anterior to the “anterior head”. It arises from the dorsal surface at the tip area of long apex of the clavicle (Fig. 2: 2), where it is just posterior to the origin of *M. tensor propatagialis*.

The scapular anchor, a diverging small tendon, attaches to the small area on the dorsal surface of the scapula in between the posterior end of the attachment of *M. proscapulohumeralis* in the anterior end and the anterior end of *M. dorsalis scapulae* in the posterior end (Fig. 2: 13).

The deeper head, the “anterior head”, arises from the middle of the anterior end in the lateral surface of the scapula (Fig. 2: 4).

The insertion has two branches. The anterior major branch (“posterior head”) inserts widely on the anconal surface of the *Crista pectoralis* of the humerus (Fig. 3: 14), and its fibrous extension runs along the dorsal margin of the shaft (*Margo dorsalis*) of the humerus. Its linear tuberosity is long and is reaching to half the shaft.

The posterior branch (“anterior head”) inserts on the depression in between the head (*Caput humeri*) and *Tuberculum dorsale* in the anconal surface of the proximal end of the humerus (Fig. 3: 9).

M. deltoideus minor

A short and flat muscle that covers the dorso-proximal corner of the humerus, and wraps half of the very strong tendon of *M. supracoracoideus* inserting on the *Tuberculum dorsale*.

Arises from the hard ligament connecting the posterior tip of the head of the coracoid and the acromion of the scapula (Fig. 2: 10).

Inserts on the dorsal slope of the *Tuberculum dorsale* in the proximal end of the humerus (Fig. 3: 12). The cranial margin fuses with *Lig. coracohumerale dorsale*, connecting between the posterior margin of *Facies*

articularis humeralis of the scapula (Fig. 2: 11) and the anconal margin of the *Tuberculum dorsale* (Fig. 3: 11).

M. scapulohumeralis caudalis

[*M. dorsalis scapulae*]

Arises widely from the lateral surface of the blade of the scapula (Fig. 2: 14). Its cranial part, deep to the origin of *M. scapulohumeralis cranialis*, reaches to the caudal margin of the glenoid.

Inserts on the small notch on the caudal surface of the *Crus ventrale fossae* of the proximal end of the humerus (Fig. 3: 4).

M. scapulohumeralis cranialis

[*M. proscapulohumeralis*]

Pink colored thick and short muscle.

Arises from the postglenoid area of the lateral surface of the scapula (Fig. 2: 12). It is just cranial to the attaching point of the scapular anchor of *M. deltoideus major*.

Inserts on the basal area of the *Crus dorsale fossae* (Fig. 3: 5) in the caudal surface of the proximal end of the humerus.

M. coracobrachialis cranialis

[*M. coracobrachialis anterior*]

Arises from the dorsal slope of the head of the coracoid (Fig. 2: 8), just upon the *Impressio lig. acrocoracohumeralis* (fig. 2: 9) that is the origin of the *Lig. acrocoracohumerale*. *Lig. acrocoracohumerale* inserts on the *Sulcus lig. transversus* on the cranial surface of the proximal end of the humerus (Fig. 3: 17).

M. coracobrachialis cranialis inserts on the cranial surface of the proximal end of humerus (Fig. 3: 16). The attachment is wide. When the attachment is strong with a deep impression, this area is called *Impressio m. coracobrachialis cranialis*. However, the condition of the attachment in *Cygnus cygnus* may not be enough to be called so.

<Muscles arising from humerus>

M. biceps brachii

Arises by a strong sheet of tendon from the cranio-lateral surface of the head of the coracoid (Fig. 2: 7). The tendinous sheet covers the *Intumescencia* in the cranial (palmer) surface of the proximal end of the humerus. The “shoulder” of the tendon is hooked to the caudal (anconal) surface, and arises from the notch on the ventral slope of the *Tuberculum ventrale* (Fig. 3: 3) in the proximal end of

the humerus.

The biceps muscle has two bellies, which are distinct distally (see Fig. 4). The insertion is surrounded by the proximal ulno-radial muscles, and the attachment was not observed in this study.

M. triceps brachii

This triceps muscle is composed of two distinct muscles, *M. scapulothoracicus* and *M. humerotriceps*, the former one being dorsal to the latter (Fig. 3). *M. humerotriceps* has two distinct heads, the dorsal and

ventral heads, and is composed of two bellies especially distinct in the proximal half. The dorsal margin of *M. humerotriceps* is overlaid with the ventral margin of *M. scapulothoracicus*.

M. scapulothoracicus has two heads. The dorsal one arises from the posterior tip of the dorsal surface of the clavicle (Fig. 2:3). The deeper one arises from the posterior half (the part of the scapula) of the dorsal lip of coracoid-scapular glenoid (Fig. 2: 11), together with a strong ligament. This strong ligament is *Lig. coracohumerale dorsale*, that inserts to the caudal margin of *Tuberculum*

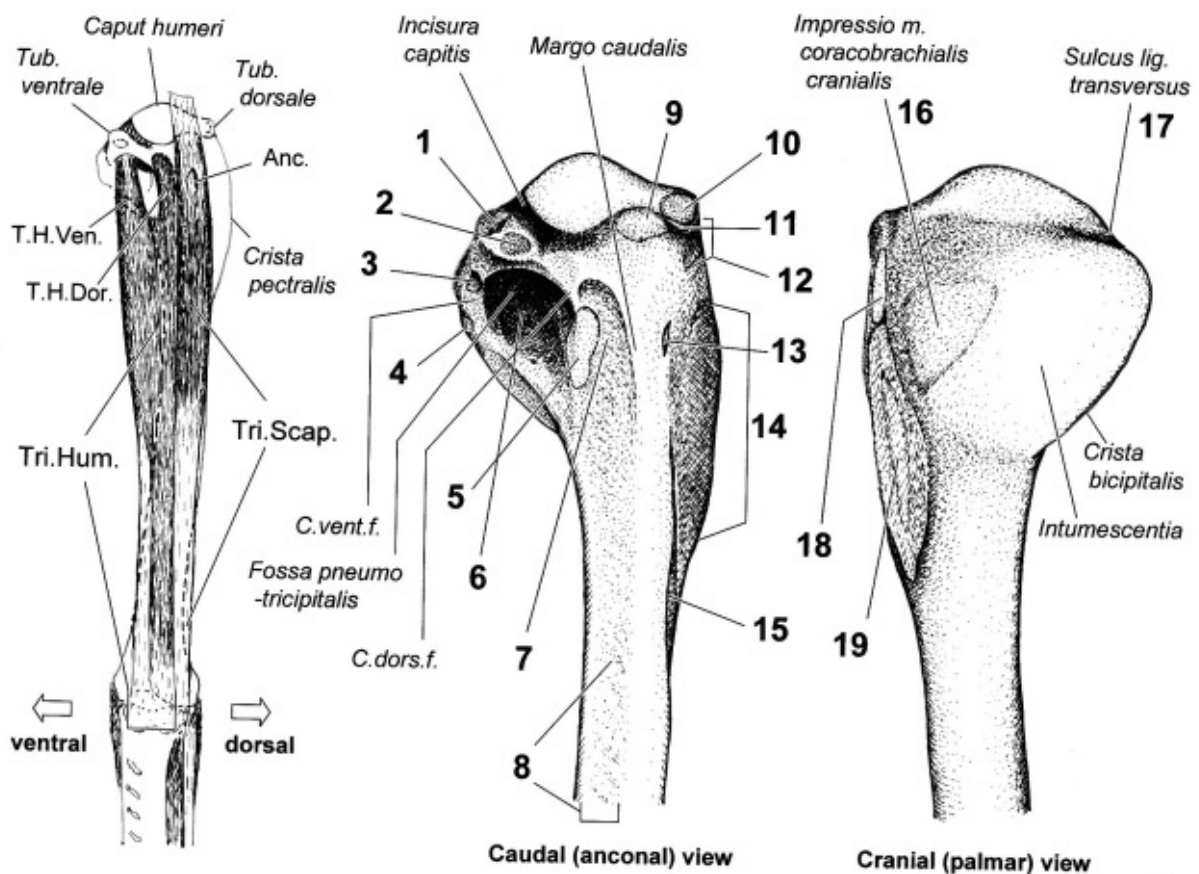


Fig.3: The caudal (anconal) view of the upper arm skeleton of the right wing with *M. triceps brachii* (left end), and the cranial and caudal views of the proximal humerus.

1: Insertion of *M. subscapularis*. 2: Insertion of *M. coracobrachialis caudalis* [*M. coracobrachialis posterior*]. 3: An accessory origin of *M. biceps brachii*. 4: Insertion of *M. scapulothoracicus caudalis* [*M. dorsalis scapulae*]. 5: Insertion of *M. scapulothoracicus cranialis* [*M. proscapulothoracicus*]. 6: Origin of the ventral head of *M. humerotriceps*. 7: Origin of the dorsal head of *M. humerotriceps*. 8: Origin of the ventral belly of *M. humerotriceps*, continuous from 7. 9: Insertion of the posterior branch of *M. deltoideus major*. 10: Insertion of *M. supracoracoideus*. 11: Insertion of *Lig. coracohumerale dorsale*. 12: Insertion of *M. deltoideus minor*. 13: Attachment of the humeral anchor of *M. scapulothoracicus*. 14: Insertion of the main part of *M. deltoideus major*. 15: Insertion of *M. latissimus dorsi*. 16: Insertion of *M. coracobrachialis cranialis* [*M. coracobrachialis anterior*]. 17: Insertion of *Lig. acrocoracohumerale*. 18: Origin of *M. pectoralis pars propatagialis longus*. 19: Insertion of *M. pectoralis*.

Abbreviations: Anc.- Humeral anchor of *M. scapulothoracicus*, actually invisible because this is in back of the main belly of *M. scapulothoracicus*. C.dors.f.-*Crus dorsale fossae*. C.vent.f.-*Crus ventrale fossae*. T.H.Dor.- The dorsal head of *M. humerotriceps*. T.H.Ven.- The ventral head of *M. humerotriceps*. Tri.Hum.- *M. humerotriceps*. Tri.Scap.- *M. scapulothoracicus*. Tub.-*Tuberculum*.

dorsale on the caudal surface of the proximal end of the humerus (Fig. 3:11). One more, a small branching flat tendon, Humeral anchor, arises from the proximal part of the base of *Crista pectoralis* on the caudal surface of the humerus (Fig. 3: 13).

The distal half of *M. scapulotriceps* is tendinous. It inserts to the dorso-caudal lip of the proximal end of the ulna. In the caudal surface of the distal end of the humerus, this tendon is held in the *Sulcus m. scapulotriceps* (Fig. 4 :3).

M. humerotriceps is Y-shaped. The head of the dorsal belly attaches on the entire length of the ventro-caudal surface of the shaft of the humerus (Fig. 3 : 7-8 ; Fig. 4 : 2). The head leaves an especially deep impression (Fig. 3 : 7).

The ventral head of *M. humerotriceps* arises from the roof and internal groove inside the *Fossa pneumotricipitalis* (Fig. 3 : 6). The ventral belly of *M. humerotriceps* and its tendon distally runs along the ventral side of the caudal humerus, like a bowstring, toward the olecranon of the ulna. The tendinous distal end of the ventral belly of *M. humerotriceps* is held in a groove (Fig. 4 : 1) being the ventral one-third of the *Sulcus m. humerotricipitis*, over the *Fossa olecrani* in the caudal surface of the distal end of the humerus.

<Muscles arising from the distal end of the humerus>

M. brachialis is a thick and short muscle arising from the *Fossa m. brachialis* in the cranial surface of the distal

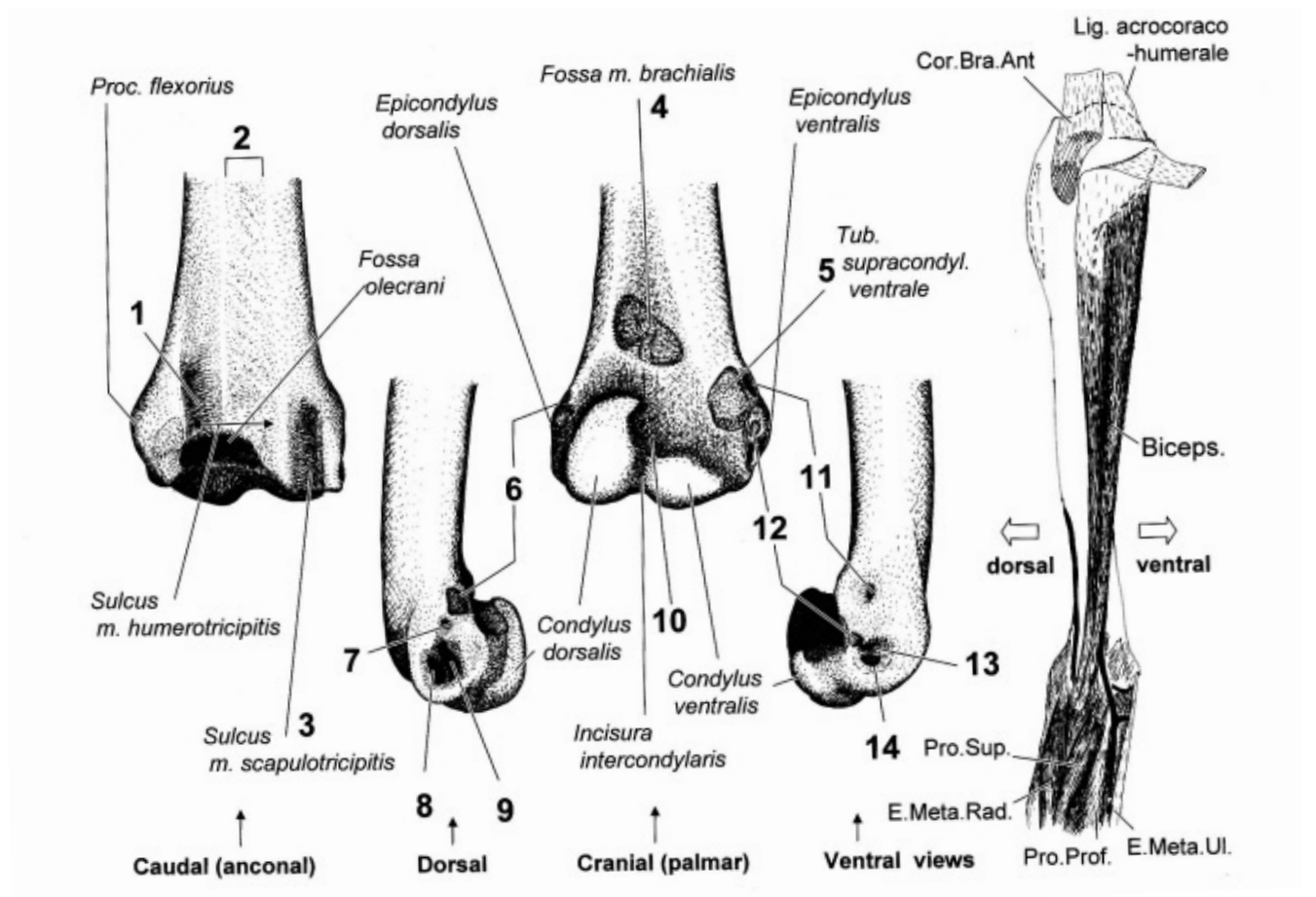


Fig.4: The cranial (palmar) view of the upper arm skeleton with *M. biceps brachii* (right end), and four views of the distal end of the humerus.

1: Groove for the ventral belly of *M. humerotriceps*. 2: Attachment surface of the dorsal belly of *M. humerotriceps*. 3: Groove for the *M. scapulotriceps*. 4: Origin of *M. brachialis*. 5: Origin of the ligament connects to ulna. 6: Origin of *M. extensor metacarpi radialis*. 7: Origin of *M. extensor digitorum communi*. 8: Origin of *M. flexor carpi ulnaris*. 9: Origin of *M. supinator*. 10: Origin of the ligament that inserts into the ulna- radius junction. 11: Origin of the proximal head of *M. pronator superficialis*. 12: Origin of the distal head of *M. pronator superficialis*. 13: Origin of *M. pronator profundus*. 14: Origin of *M. extensor metacarpi ulnaris*.

Abbreviations: Cor.Bra.Ant- *M. coracobrachialis anterior* = *M. coracobrachialis cranialis*. E.Meta.Rad.- *M. extensor metacarpi radialis*. E.Meta.Ul.- *M. extensor metacarpi ulnaris*. Pro.Prof.- *M. pronator profundus*. Pro.Sup.- *M. pronator superficialis*.

end of the humerus (Fig. 4 : 4).

On the dorsal surface, four muscles originate from sharp depressions: *M. extensor metacarpi radialis* (Fig. 4 : 6), *M. extensor digitorum communis* (Fig. 4 : 7), *M. flexor carpi ulnaris* (Fig. 4 : 8) and *M. supinator* (Fig. 4 : 9).

On the ventral surface, originating three muscles leave sharp depressions: two for the Y-shaped head of *M. pronator superficialis* (Fig. 4 : 11, 12), and one for *M. pronator profundus* (Fig. 4 : 13) and *M. extensor metacarpi ulnaris* (Fig. 4 : 14), respectively.

Acknowledgements

We express our sincere gratitude to Dr. Hiroyuki Morioka of the National Science Museum, Tokyo who

reviewed our manuscript and kindly helped to complete it. We also thank the staffs of Gunma Museum of Natural History for their assistants during our anatomical work.

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オオハクチョウの筋学と骨学 その1 : 胸骨・烏口骨・叉骨・肩甲骨・上腕骨に付着する筋

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要旨：鳥類の筋学は長い歴史があり筋の位置や概略的な付着点はよく記載されているが、骨化石を材料とする古生物学的研究に利用しようとする時、骨表面の小構造と筋付着点との関係が必ずしも明確ではなかった。そこでオオハクチョウの胸帯と上腕骨周辺の解剖を行い、筋類の骨格要素への付着部を明らかにして記載・図示した。本研究で観察した、胸骨・烏口骨・叉骨・肩甲骨・上腕骨に付着する筋類は、飛翔や翼の開閉に関連したものである。使用したオオハクチョウは、群馬県桐生市立桐生が岡動物園にて1983年6月から2004年8月にかけて21年以上飼育され、おそらく老衰によって死亡した老年個体である。解剖にあたっては外部計測のほか内臓や一部の筋の重量も計測した。

キーワード：鳥類, カモ科, オオハクチョウ, *Cygnus cygnus*, 筋学, 骨学