NORTHERN ILLINOIS UNIVERSITY

Muscle Maps for Selected Hind Limb Bones of a Saber-tooth Tiger

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By

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Abstract

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It was found from the completed muscle maps and documented research that there seemed to be closer similarities between the clouded leopard and *Smilodon*. The muscles, although not differing by much from the cats, had subtle differences present in both the clouded leopard and *Smilodon*. It was also found that clouded leopards contain features that only seem to be present in extinct saber-tooth cats, thus making them appear to be a more closely related species.

This study overall is important for learning how extinct species were able to live, as well as give an understanding on how the species were made up and able to move providing us with information on behavior and place in the ecosystem of the species. This, in turn, allows us to see how species were able to evolve over time.

University Honors Program

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This study overall is important for learning how extinct species were able to live, as well as give an understanding on how the species were made up and able to move providing us with information on behavior and place in the ecosystem of the species. This, in turn, allows us to see how species were able to evolve over time.

Introduction

There have been a number of studies done in the past which have attempted to make a connection between the anatomy of living and extinct species. These studies attempted to show muscle attachment sites of similar species and compare them to extinct species bones in order to learn more about the extinct species. Dr. Virginia Naples did a study which compared nimravid barbourofelins, an extinct species of felid, to rodents.

These species only have a distant phylogenetic relationship so their common features are due to convergent evolution (Naples, 2000). Convergent evolution is when unrelated species form similar traits due to environment or ecological niche. This study showed a similar jaw structure in nimravids and rodents. The property present in both species was an enlarged infrorbital foramen (hystricomorphy) that allowed for the rodents to have improved mechanical advantage of the jaw for gnawing and the nimravids to compensate for their saber-teeth (Naples, 2000). Another study by Dr. Virginia Naples reconstructed the facial features in the extinct nimravid barbourofelins using extant felids. Since they were derived from common ancestors the muscle attachment scars on the cranial bones of barbourofelins indicated similar muscles in the extant felids (Naples, 2000). This study estimated the size, shape and position of some features of the face such as the mouth and nose. The findings showed the mouths in nimravids were wider due to their saber-tooth characteristic. There lips had to stretch further and be larger leading to large origin scars for muscles that elevate and retract the lip (Naples, 2000). The nasal shape was close to that of extant felids. The muscle pyramidas elevates nasal tissue when the cat snarls or bites, which was probably a similar action in both extinct and extant felids (Naples, 2000). These are just some examples of ways extinct features can be inferred from extant species.

Muscle attachment sites can be identified by creating muscle maps, which are drawings of the points where the muscles attach to the bones. Muscle attachment sites often have roughened edges caused by muscles pulling on particular regions of bone. The bones of similar species should also have these roughened regions in the same areas. It should be possible then to use the muscle maps of a living species to extrapolate the muscle positions of an extinct species.

Materials and Methods

The living species used were a domestic cat (*Felis catus*) and a clouded leopard (*Neofelis neulosa*), an endangered species. These animals are from the same family but are different species and yet they have muscle attachment sites in the same area. The muscle maps from these living species will be used to attempt to reconstruct muscle maps for a similar extinct group, the saber-tooth tiger (*Smilodon*). The Smilodon is described as a dirk-toothed cat, which had more elongated, finely serrated canines coupled to short legs built for power rather than speed (Naples, 1999). This suggests *Smilodon* didn't chase prey over long distances like lions and cheetahs do. Instead, it probably used cunning and ambush rather than speed to capture prey (Janczewski, 1992). A study was preformed that showed phylogenetic similarities in *Smilodon* and extant felids. This study extracted ancient DNA from bones and cloned it by PCR amplification (Janczewski, 1992). The sequences were then compared to extant species for estimation of phylogenetic relationships. The results showed that *Smilodon* was clearly placed in Felidae, however the rate of evolutionary divergence was slow leading to an inability to resolve it further (Janczewski, 1992). Nonetheless, it showed that Smilodon, the clouded-leopard, and the domestic cat are related species.

Muscle maps are uncommon for any species, outside of humans. In order to have muscle maps to compare to the extinct species bones a careful dissection of the cat and leopard were preformed. From this dissection muscle maps were constructed to use for comparison with the *Smilodon* bones.

After the muscle maps for the cat and leopard were completed the saber-tooth tiger bones were observed and photographed. The pictures were taken of all the different angles and positions of the bones. The pictures taken showed the roughened region that was present on the bone. These regions were where the muscles most likely attached to the bone. The bones were then compared to the muscle maps of the cat and leopard and muscle maps of the extinct species extrapolated.

Results

Muscle maps attached show the muscle positions for the domestic cat, clouded leopard, and *Smilodon*, respectively. Figures I, IA, and IB show the muscles on the lateral pelvis. Figures II, IIA, and IIB show the muscles on the dorsal pelvis. Figures III, IIIA, and IIIB show the muscles on the ventral pelvis. Figures IV, IVA, and IVB show the muscles on the anterior femur. Figures V, VA, and VB show the muscles on the medial femur. Figures VI, VIA, and VIB show the muscles on the posterior femur. Figures VII, VIIA, and VIIB show the muscles on the lateral femur.

The color next to name of the muscles corresponds to the color on the muscle map. Descriptions (origin, insertion, and use) of these muscles are listed as follows:

Tensor Facia Latae:

The tensor facia latae in the cat has its origin (Figure I) on the ventral border and cranial border of the ilium and from fascia covering the gluteus medius. It inserts into the fascia lata. The tensor facia latae in the leopard has its origin (Figure IA) on the ventral border of the ilium, however it does not go up into the cranial border as the cats origin does. Its insertion and is the same as the cat. The tensor fascia latae in *Smilodon* has its origin (Figure IB) on the cranial and ventral border of the ilium; however it is on the cranial border to a lesser degree than then in the cat. Its insertion is the same as the cat and leopard. The tensor fascia latae tenses the side of the thigh and aids in extending the leg.

Biceps Femoris:

The biceps femoris in the cat has its origin (Figures I and II) from the tuberosity of the ischium by tendinous and fleshy fiber attachments. It inserts into the proximal third of the lateral side of the tibia and into the lateral side of the patella. The leopard and *Smilodon* have the same origin (Figures II, IIA, III and IIIA), insertion for all of the hamstring muscles which include biceps femoris, semitendinosus, and semimembranosus. This is probably due to the small size of the muscles and small region these muscles occupy. The biceps femoris is an extensor of the thigh as well as an abductor to a small degree.

Gluteus Medius:

The gluteus medius in the cat has its origin (Figures I and II) on the dorsal half of the crest of the ilium and the dorsal half of the lateral surface of the ilium. It also has attachments to the transverse process of the last sacral and first caudal vertebrae. It inserts (Figure VII) into the proximal end of the greater trochanter. The gluteus medius in the leopard has its origin (Figures IA and IIA) in the same place however there is a greater attachment area covered by the muscle. It extends more cranially then in the cat. The insertion (Figure VIIA) also covers more area than the insertion for the cat. The gluteus medius origin (Figures IB and IIB) in *Smilodon* also extends more cranially than in the cat, however it becomes thinner the closer it gets to the crest of the ilium. The insertion

(Figure VIIB) is more like the leopards in that it covers more area. The gluteus medius abducts and extends the thigh.

Semitendinosus:

The semitendinosus in the cat has its origin (Figures I and II) on the tuberosity of the ischium beneath the origin of the biceps femoris. It passes to the medial side of the crest of the tibia to insert into the crest of the tibia. The origin (Figures IA, IIA, IB, and IIB) and insertion are the same in the leopard and *Smilodon* since it is one of the hamstring muscles. The semitendinosus extends the hip and flexes the thigh.

Quadratus Femoris:

The quadratus femoris in the cat has its origin (Figure I) on the lateral surface of the ischium near the tuberosity. It inserts (Figure VI) into the ventral border of the greater trochanter. The quadratus femoris origin (Figure IA) in the leopard is also on the ischium, but is closer to the tuberosity then it is in the cat. The insertion (Figure VIA) is the same as in the cat. The quadratus femoris origin (Figure IB) in *Smilodon* is on the ischium, but seems more rounded that the origin of the cat and leopard. The insertion (Figure VIB) is the same as in the cat and leopard. It is an extensor and outward rotator of the thigh.

Obturator Internus:

The obturator internus in the cat has its origin (Figure II) from the medial surface of the ramus of the ishium. It inserts (Figure VI) into the bottom of the trochanteric fossa of the femur. The origin (Figure IIA) of the obturator internus in the leopard takes up more area than the cats and covers more area around the obturator foramen. The insertion (Figure VIA) is the same as in the cat. The origin (Figure IIB) of the obturator internus in the *Smilodon* is not clear due to lack of a roughened region. The position is therefore estimated. The insertion (Figure VIB) and is the same as in the cat and leopard. The obturator internus is an abductor of the thigh and outward rotator of the hip joint

Gemellus Superior:

The gemellus superior in the cat has its origin (Figures I and II) on the dorsal border of the ilium and ischium. Its fibers converge into a strong tendon which inserts (Figure VII) into an area near the tip of the greater trochanter. The gemellus superior origin (Figures IA, IB, IIA, and IIB) in the leopard and *Smilodon* seems to be more elongated than in the cat. The insertion (Figures VIIA and VIIB) is the same in the cat and leopard; however it is more elongated in *Smilodon*. The gemellus superior serves to rotate and abduct the femur.

Gemellus Inferior:

The gemellus inferior in the cat has its origin (Figures I and II) on the dorsal one-half of the whole lateral surface of the ischium. It inserts into the inner surface of the tendon of the obturator internus. It is sometimes considered a separate head for the obturator internus. The origins (Figures IA, IB IIA, and IIB) and insertions are the same for the leopard and *Smilodon*. The gemellus inferior serves as an abductor of the thigh.

Capsularis:

The capsularis in the cat has its origin (Figure I) on the ilium on the cranial side of the acetabulum above the rectus femoris origin. It inserts (Figure IV) on the cranial surface of the femur near the greater trochanter. The origins (Figures IA and IB) of capsularis for the leopard and *Smilodon* are the same. The insertions (Figures IVA and

IVB) seem to be higher on the femur closer to the greater trochanter in the leopard and *Smilodon*. The capsularis flexes the thigh.

Gluteus Profundus:

The gluteus profundus in the cat has its origin (Figure I) on the ventral half of the ilium. It inserts (Figure VII) at the base of the dorsal surface of the greater trochanter on its lateral side. The origin (Figures IA and IB) for the leopard and *Smilodon* shows that it is on the ventral half of the pelvis, but it starts off rounded by the crest of the ilium and becomes skinnier on the more cranial portion of the ilium. The insertion (Figures VIIA and VIIB) is the same as the cat for the leopard and *Smilodon*. The gluteus profundus rotates the femur outward.

Rectus Femoris:

The rectus femoris in the cat has its origin (Figures I and III) on the cranial side of the acetabulum on the lateral surface of the ilium. It inserts on the outer surface of the patella in connection with the vastus lateralis. The origins (Figures IA, IB, IIIA, and IIIB) for the leopard and *Smilodon* are also on the cranial side of the acetabulum; however they have origins closer to the acetabulum than in the cat. The insertion for the rectus femoris is the same as the cat for the leopard and *Smilodon*. The rectus femoris acts as an extensor of the lower leg.

Adductor Femoris:

The adductor femoris in the cat has its origin (Figure III) on the pelvic symphisis and adjacent parts of the ramus of the ischium. It inserts (Figures VI and VII) on nearly the whole length of the linea aspera on the caudal surface of the femur. The origins

(Figures IIIA and IIIB) and insertions (Figures VIA, VIB, VIIA, and VIIB) are the same for the cat and the leopard. It is hard to see a roughened mark for this muscle on the bones of *Smilodon*, but it is estimated that it is most likely the same as in the cat and leopard. The adductor femoris is the biggest adductor of the hip joint.

Sartorius:

The sartorius in the cat has its origin (Figures I and III) from the cranial half of the crest of the ilium and the medial half of the cranial border. It inserts on the medial border of the proximal end of the tibia, the medial epicondyle, and the patella. The origins (Figures IA, IB, IIIA, and IIIB) for the leopard and *Smilodon* do not cover half of the medial border, probably only a third. The insertions are the same for the cat, the leopard, and *Smilodon*. The sartorius flexes the thigh.

Gracilis:

The gracilis in the cat has its origin (Figure III) on the pelvic symphisis. It inserts into the medial surface of the tibia near its proximal end. The origins (Figures IIIA and IIIB) and insertions are the same for the cat and the leopard. It is hard to see a roughened mark for the origin of this muscle on the bones of *Smilodon*, but it is estimated that it is most likely the same as in the cat and leopard. The gracilis adducts the thigh and extends the hip joint.

Adductor Longus:

The adductor longus in the cat has its origin (Figure I and III) from the cranial border of the pubis. It inserts (Figure VI) into the linea aspera of the femur. The origin (Figures IA and IIIA) and insertion (Figures VIA) are the same for the cat and the leopard. The origin (Figures IB and IIIB) for *Smilodon* seems to be more at an angle than in the cat and leopard, however the insertion (Figure VIB) seems to be the same. The adductor longus adducts the thigh.

Pectineus:

The pectineus in the cat has its origin (Figure I and III) from the cranial border of the pubis. It inserts (Figure V and VI) on the shaft of the femur just below the lesser trochanter. The origin (Figures IA and IIIA) and insertion (Figures VA and VIA) are the same for the cat and leopard. It is hard to see a roughened mark for the origin (Figures IB and IIIB) of this muscle on the bones of *Smilodon*, however since it is right next to the adductor longus which is at an angle in *Smilodon*, pectineus was drawn at an angle as well. The insertion (Figure VB and VIB) is the same as in the cat and leopard. The pectineus serves to adduct the thigh.

Semimembranosus:

The semimembranosus in the cat has its origin (Figures I and II) from the caudal border of the tuberosity and ramus of the ishium. It inserts (Figure V) into the medial surface of the femur on the epicondyle and into the adjacent medial surface of the tibia. The origin (Figures IA, IB, IIA, and IIB) is the same for the cat leopard and *Smilodon*. However, the insertion (Figures VA and VB) in the leopard is the same but in the *Smilodon* it seems to be lower on the epicondyle than in the cat and leopard. The semimembranosus is an extensor of the thigh and a flexor of the shank.

Obturator Externus:

The obturator externus in the cat has its origin (Figures I and III) on the lateral side of the rami of the pubis and ischium. It inserts (Figure VI) into the proximal part of the trochanteric fossa. The origin (Figures IA and IIIA) for the leopard seems to cover more area then in the cat, and the insertion (Figure VIA) is the same. It is hard to see a roughened mark for the origin (Figures IB and IIIB) of this muscle on the bones of *Smilodon*, so it is estimated. The insertion (Figure VIB) is the same as the cat and leopard. The obturator externus is a flexor and outward rotator of the thigh.

Vastus Lateralis:

The vastus lateralis in the cat has its origin (Figure IV) on a triangular area on the caudal and lateral surfaces of the shaft and greater trochanter of the femur. It inserts into the outer surface of the patella near its lateral border. The origin (Figure IVA) in the leopard seems to cover more area on the femur and is more dorsal. The origin (Figure IVB) in the *Smilodon* seems to be more dorsal. The vastus lateralis acts as an extensor of the lower leg.

Vastus Medialis:

The vastus medialis in the cat has its origin (Figure V) on the shaft of the femur in the region of the linea aspera. It inserts into the medial border of the patella and ligamentum patellae. The origins (Figures IA, IB, IIIA, IIIB, IVA, and IVB) in the leopard and *Smilodon* are the same as the cat, however part of the origin is also located on the pelvis on the ventral border of the acetabulum. The vastus medialis acts as an extensor of the lower leg.

Vastus Intermedius: ▧

The vastus intermedius in the cat has its origin (Figure IV) on the ventral three fourths of the anterior surface of the femur. It inserts into the patella. The origin (Figures IVA and IVB) for the leopard and *Smilodon* are the same. The vastus intermedius acts as an extensor of the lower leg.

Discussion

The muscle maps and descriptions seem to lead to a stronger correlation between the clouded-leopard and *Smilodon* than the cat and *Smilodon*. This could be assumed without even looking at the muscle maps just purely on the basis of size of the compared felids. The clouded leopard is a mid sized cat weighing approximately 16-23kg. Domestic cats, on one hand, are much smaller weighing around 10kg. *Smilodon*, on the other hand, were big cats weighing between 55-280kg depending on the specific species (Christiansen, 2005). From this it would be reasonable to assume that if the muscles of the domestic cat, clouded leopard and *Smilodon* were all different in some ways the *Smilodon* would be closer to the clouded leopard over the cat.

As mentioned earlier *Smilodon* had short legs built for power rather than speed. The clouded leopard also has legs that are built for power do to the fact they are a tree dwelling species. They need the power in their legs to enable them to climb into trees being as big as they are. This is another possibility leading to greater similarity between the two.

Most of the muscles are relatively the same for all three species, with only small differences in size and position. The one that really stand out is the vastus medialis, which has part of its origin on the ventral side of the acetabulum of the pelvis in the clouded leopard and *Smilodon*. This attachment seems to be nonexistent in the domestic cat leading to yet another way the clouded leopard and *Smilodon* are more closely related.

A study performed by Christiansen shows characteristics that are similar in the clouded leopard and saber-toothed cats like *Smilodon*. The skull morphology of the clouded leopard separates it from other extant felids, leading it to look more like that of a saber-tooth (Christiansen, 2006). This study analyzed nine characters considered to be characteristics of saber-toothed felids and absent in extant felids. The results showed that the combination of the posterior inclination of the facial part of the skull compared to the basicranium, the ventrally deflected jaw joint, the very long and less conical upper canines, and proportionally somewhat reduced lower canines make the clouded leopard stand out from other extant felids (Christiansen, 2006). Even though the clouded leopard shows many of the same characteristics of an extinct saber-tooth, there is little evidence that suggests it is an "extant saber-tooth" (Christiansen). It just simply shares some of the same characteristics, which would also be another way to show the *Smilodon* and clouded leopard are the more closely related species.

Conclusion

All of the evidence seems to point toward the *Smilodon* and clouded leopard being more closely related than the *Smilodon* and domestic cat. Regardless of the outcome it is important to the understanding of an extinct animal to show how they were made up. Reconstruction allows us to tell different things about the behavior and place in the ecosystem of extinct species. Without which, we would be unable to tell how species were able to develop and evolve through out the centuries.

Figure I:
Cat
(Lateral Pelvis)

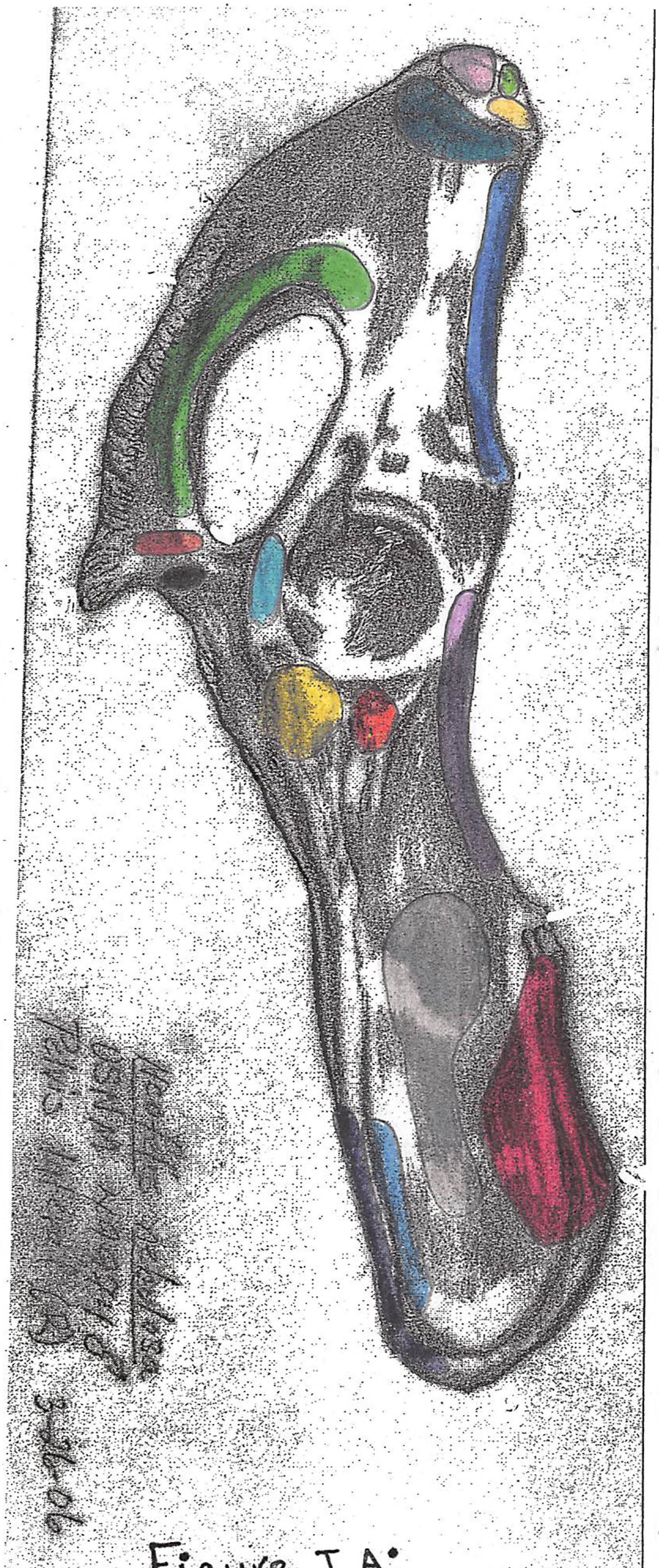

Figure IA:
Leopard
(Lateral Pelvis)

Figure IB:
Smilodon
(Lateral Pelvis)

* Estimation of muscle placement due to lack of a roughened spot.

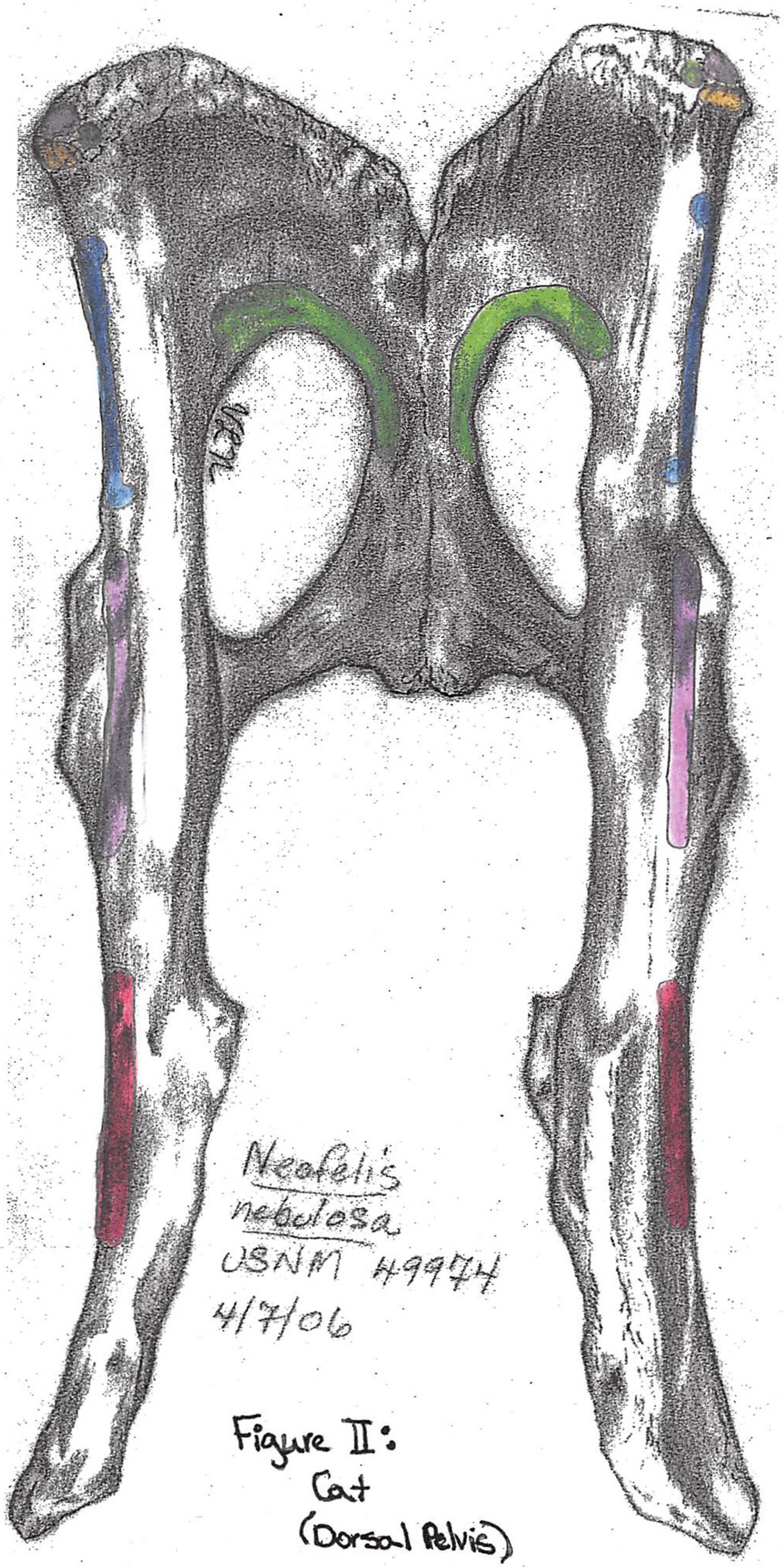

Figure II:
Cat
(Dorsal Pelvis)

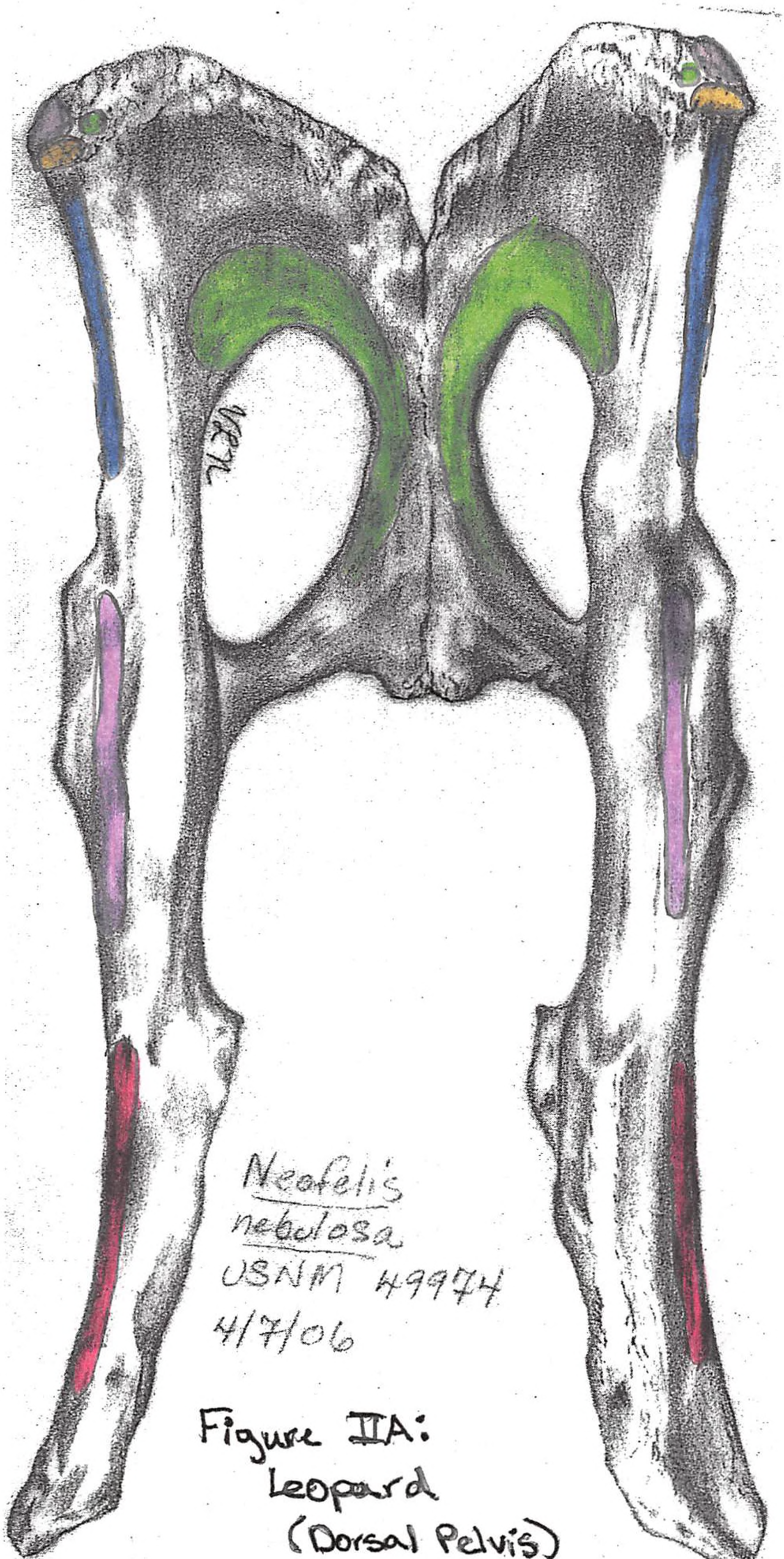

Figure IIA:
Leopard
(Dorsal Pelvis)

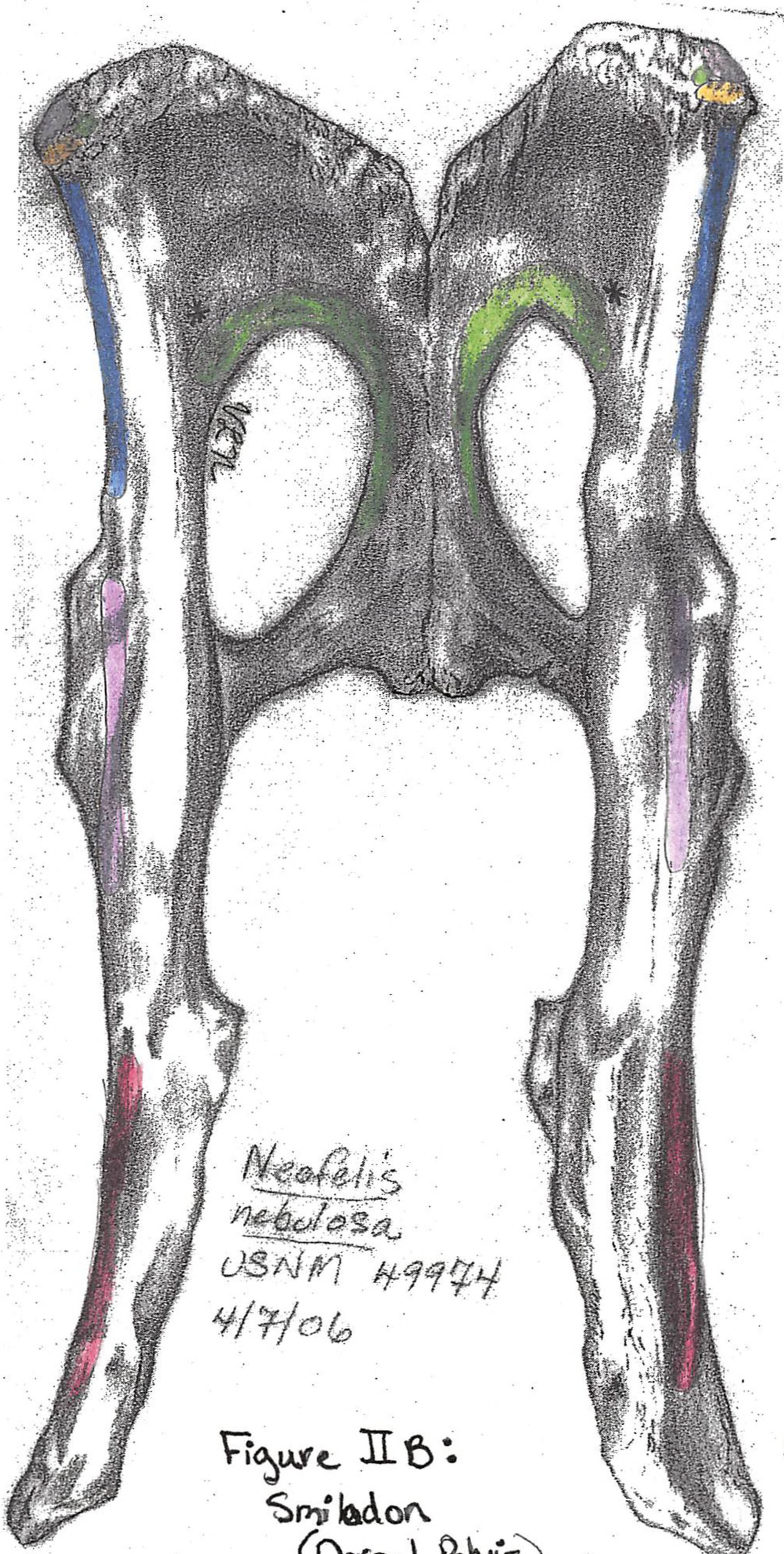

Figure II B:
Smilodon
(Dorsal Pelvis)

* Estimation of muscle position

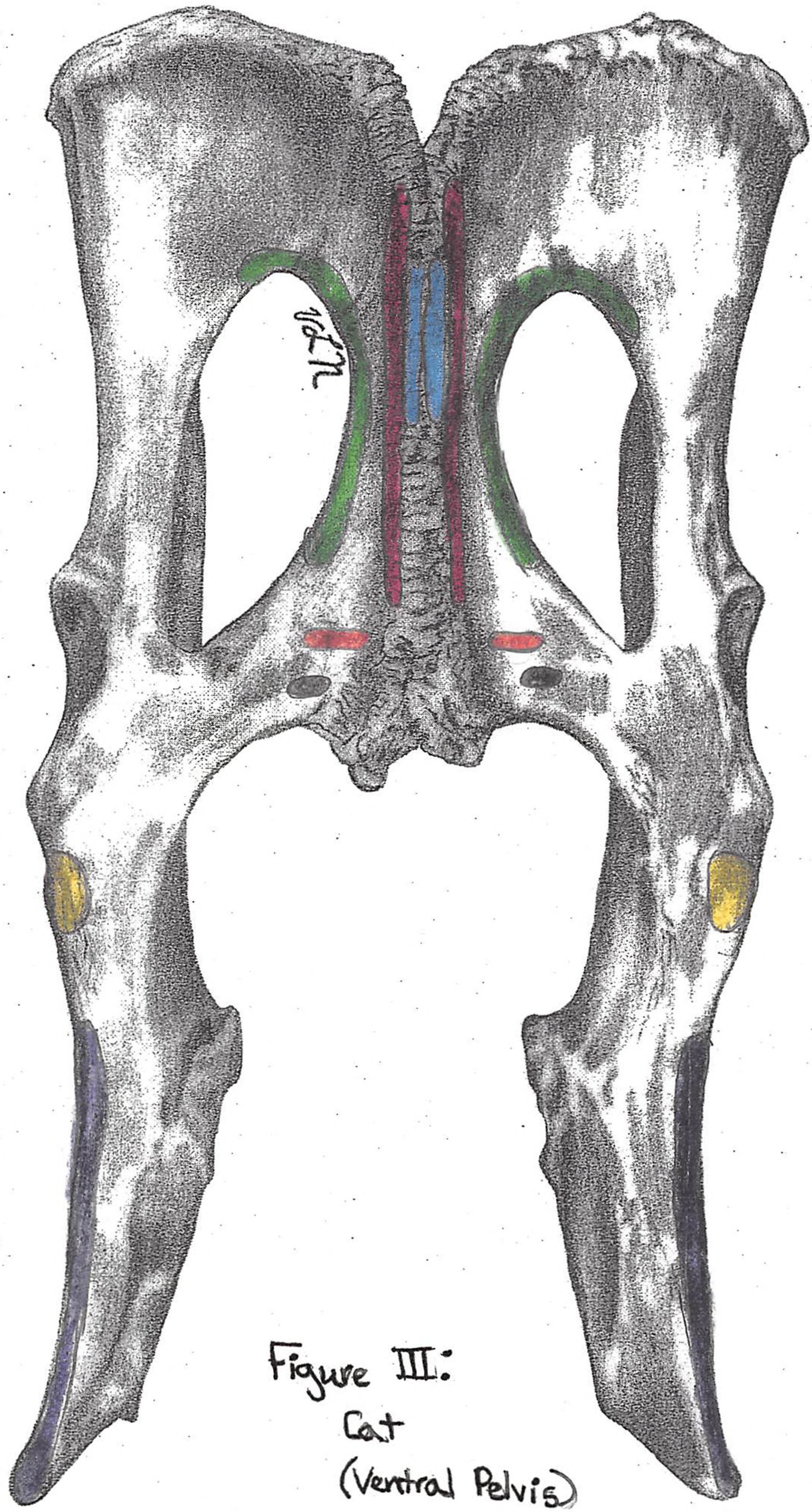

Figure III:
Cat
(Ventral Pelvis)

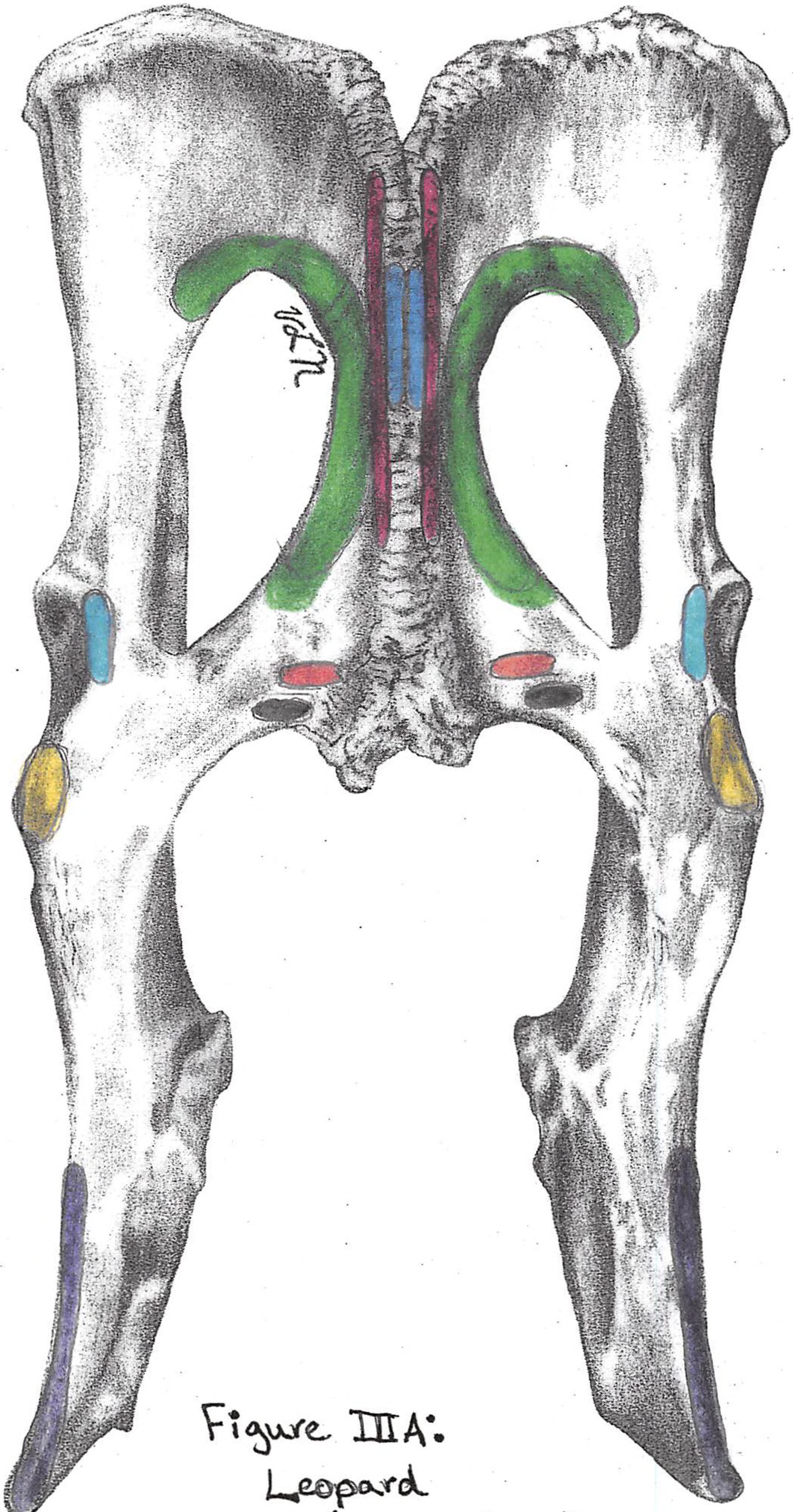

Figure IIIA:
Leopard
(Ventral Pelvis)

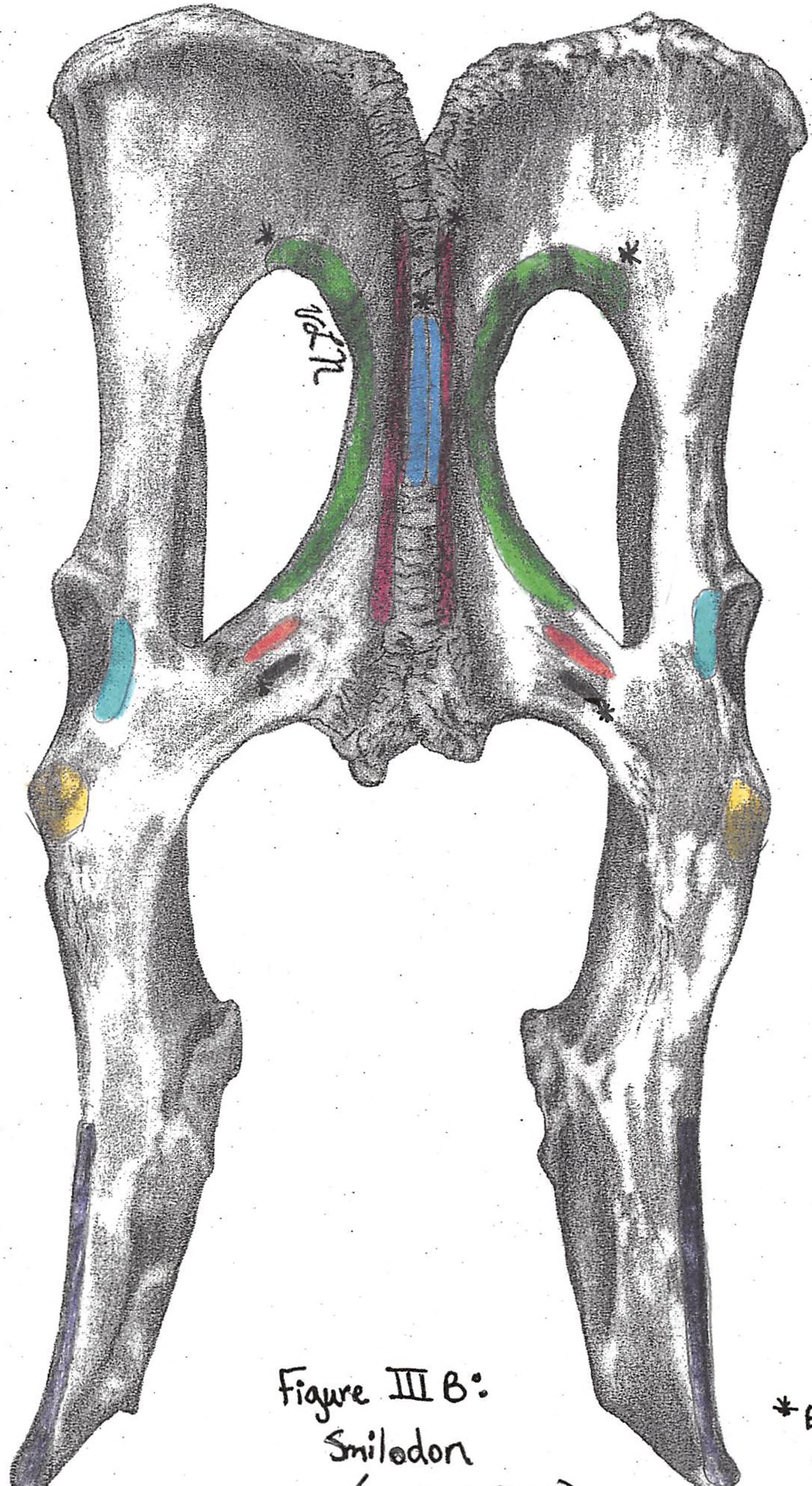

Figure III B:
Smilodon
(ventral Pelvis)

* Estimation of muscle position

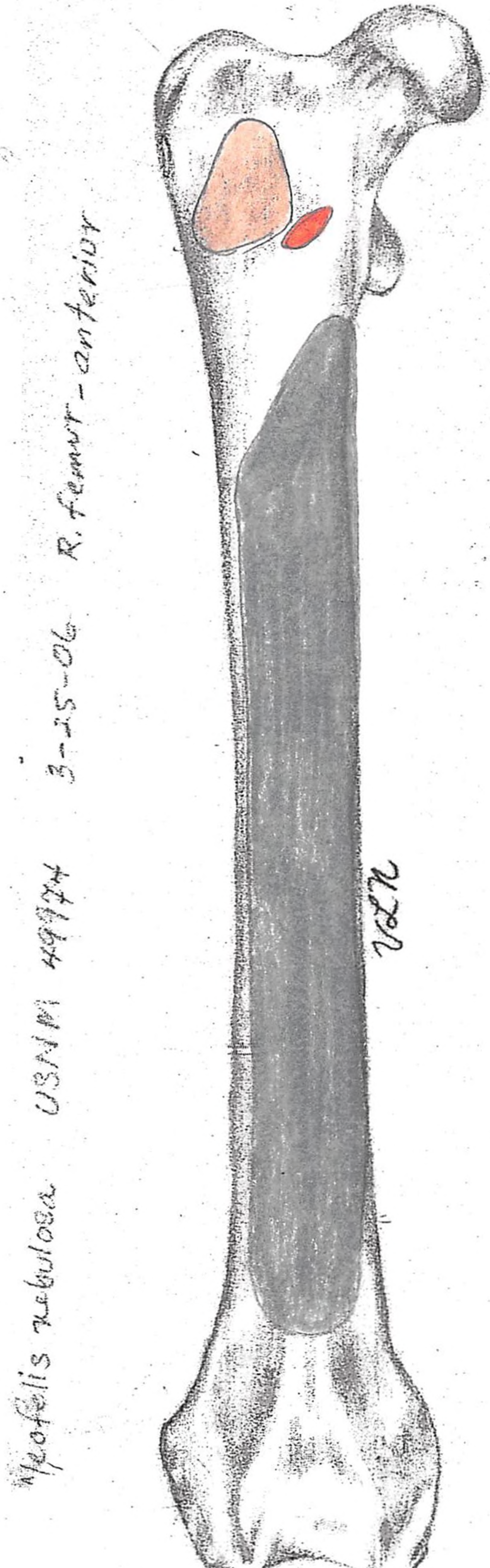

Figure IV:
Cat
(Anterior Femur)

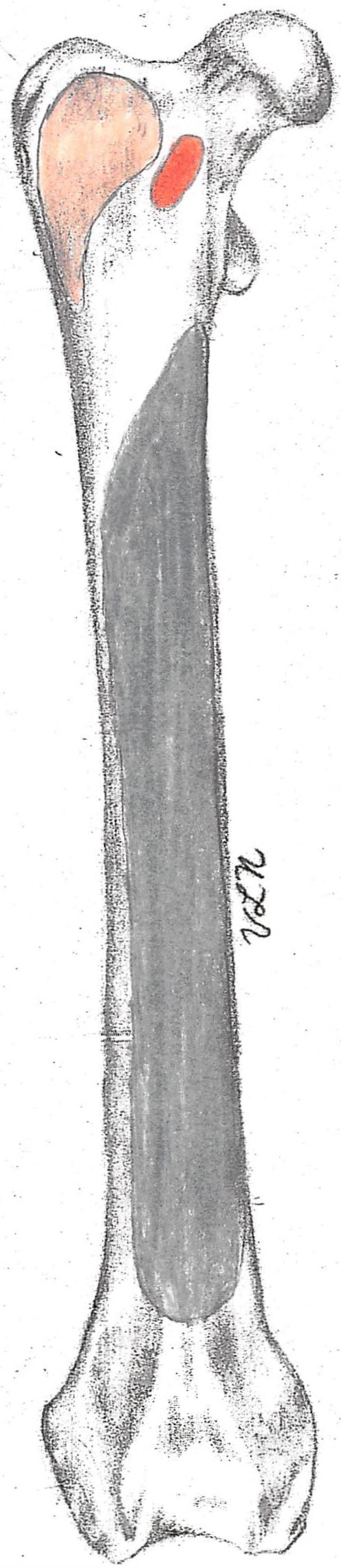

Figure IVA:
Leopard
(Anterior Femur)

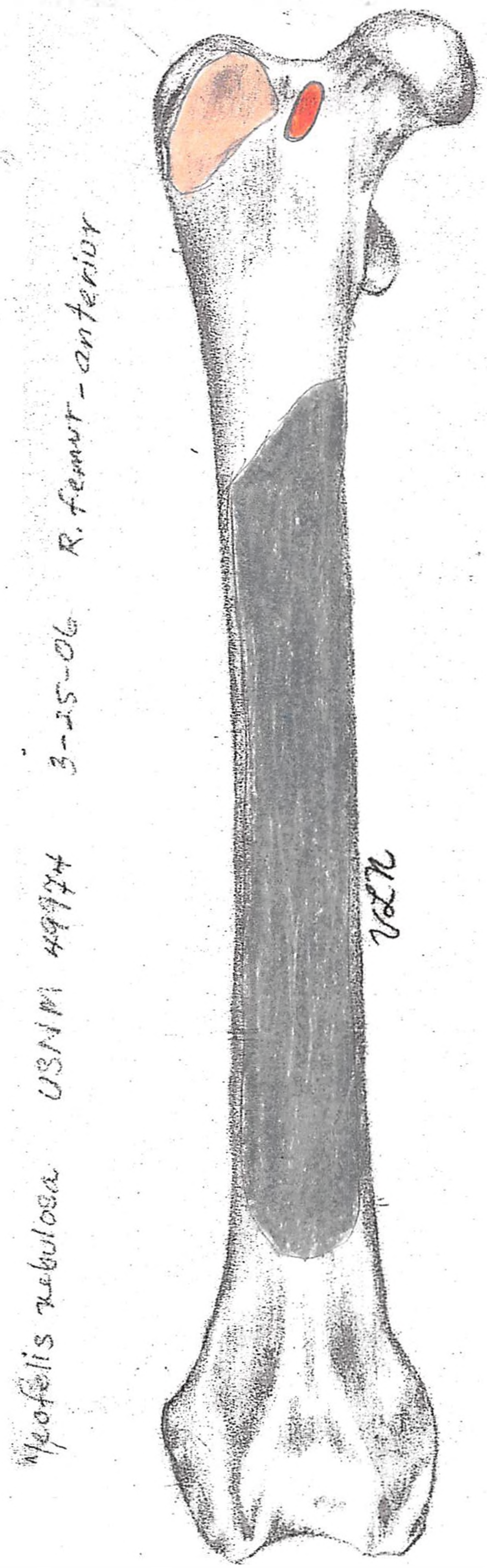

Figure IV B:
Smilodon
(Anterior Femur)

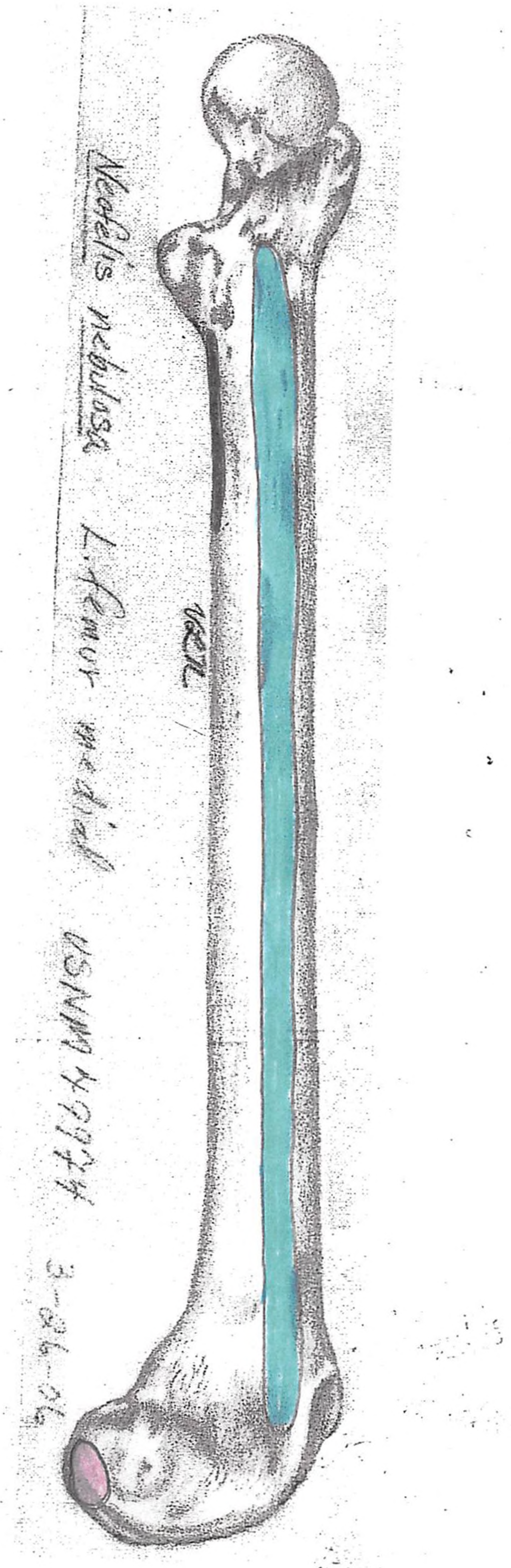

Figure V:
Cat
(Medial Femur)

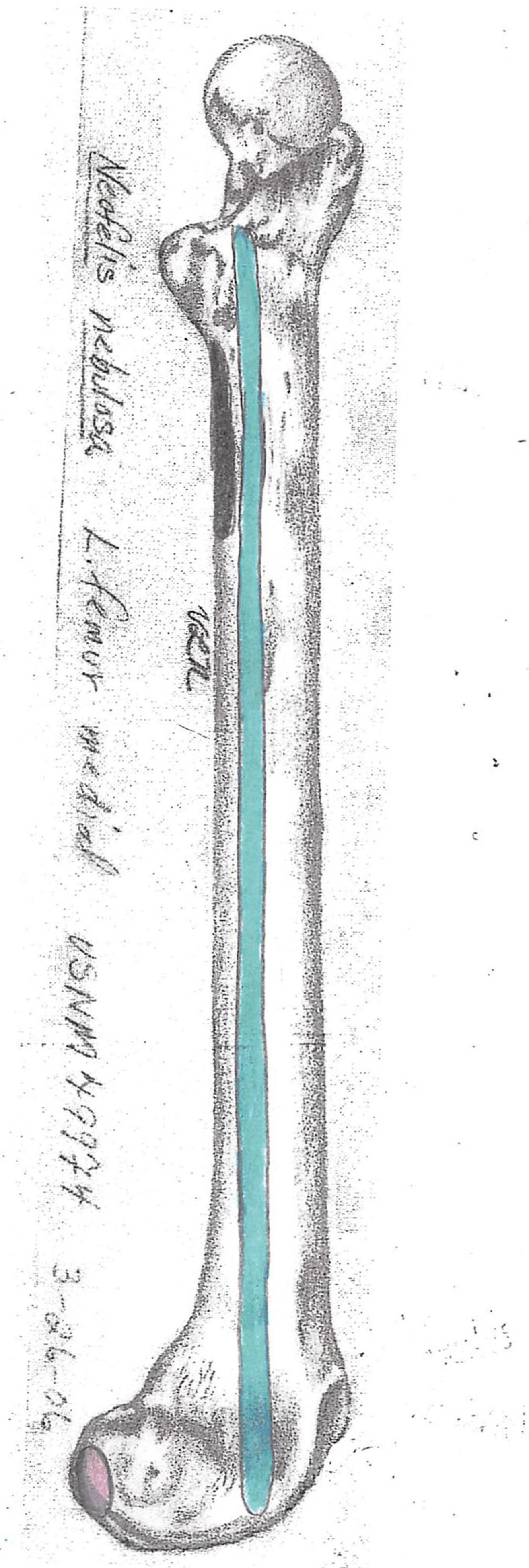

Figure V A:
Leopard
(Medial Femur)

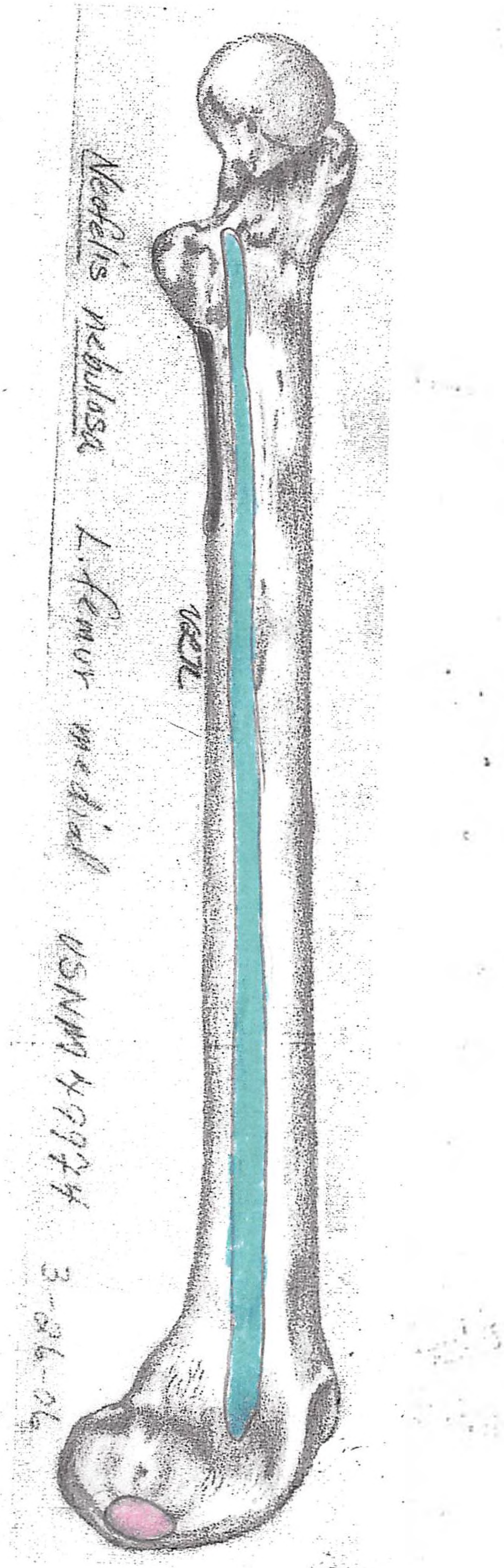

Figure V B:
Smilodon
(Medial Femur)

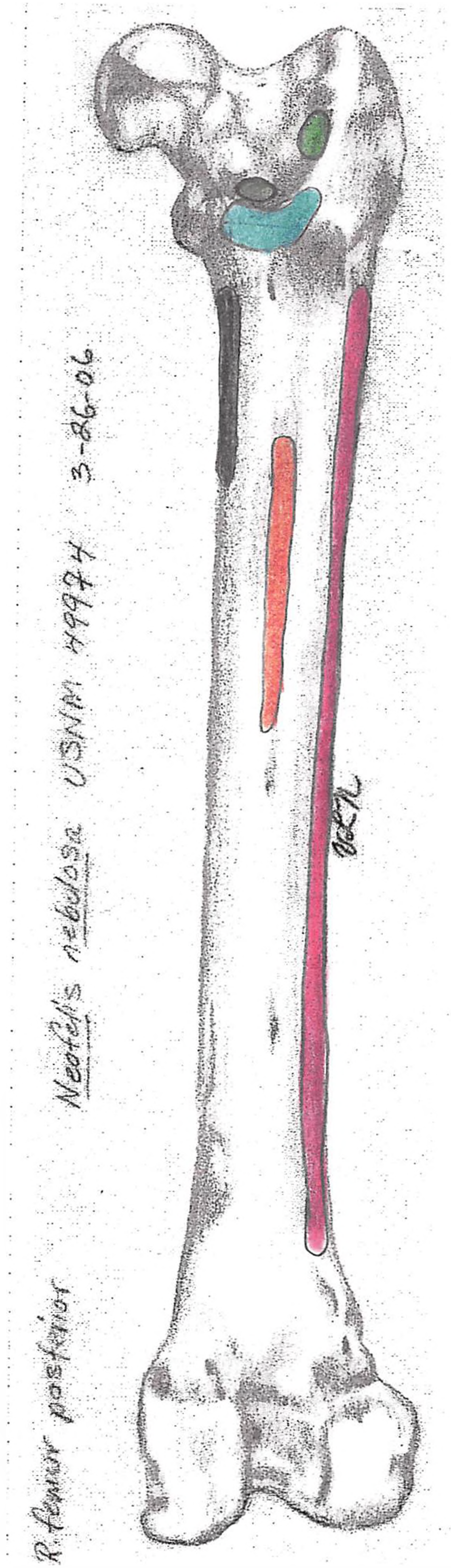

Figure VI:
Cat
(Posterior Femur)

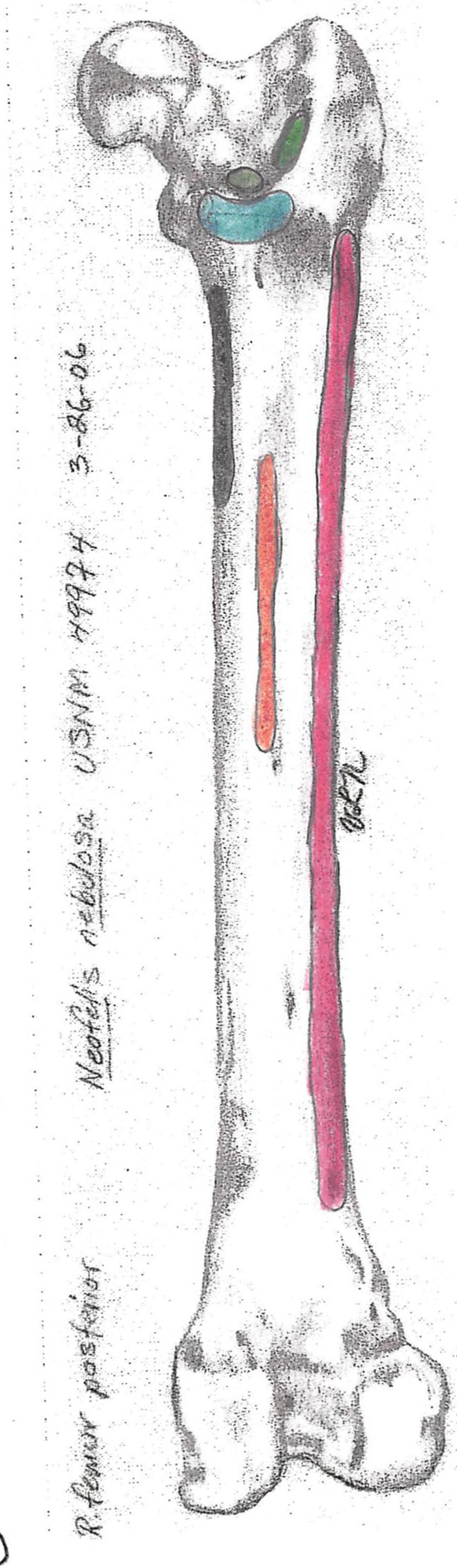

Figure VIA:
Leopard
(Posterior Femur)

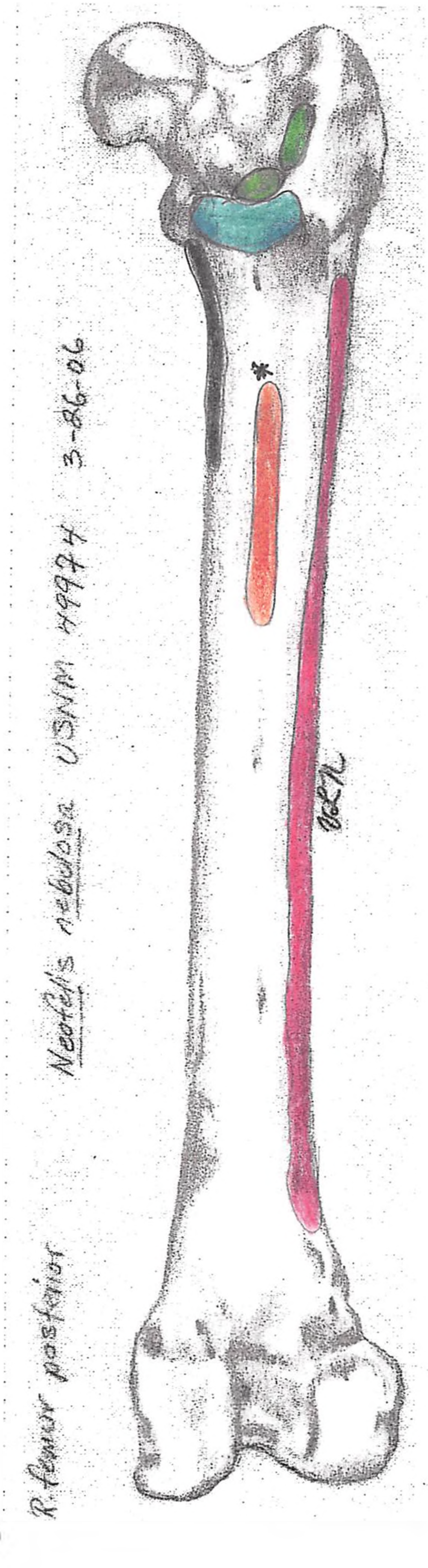

Figure VI B:
Smilodon
(Posterior Femur)

*Estimated position of muscle

anterior
Lateral

Neofelis nebulosa left femur lateral USNM 49774

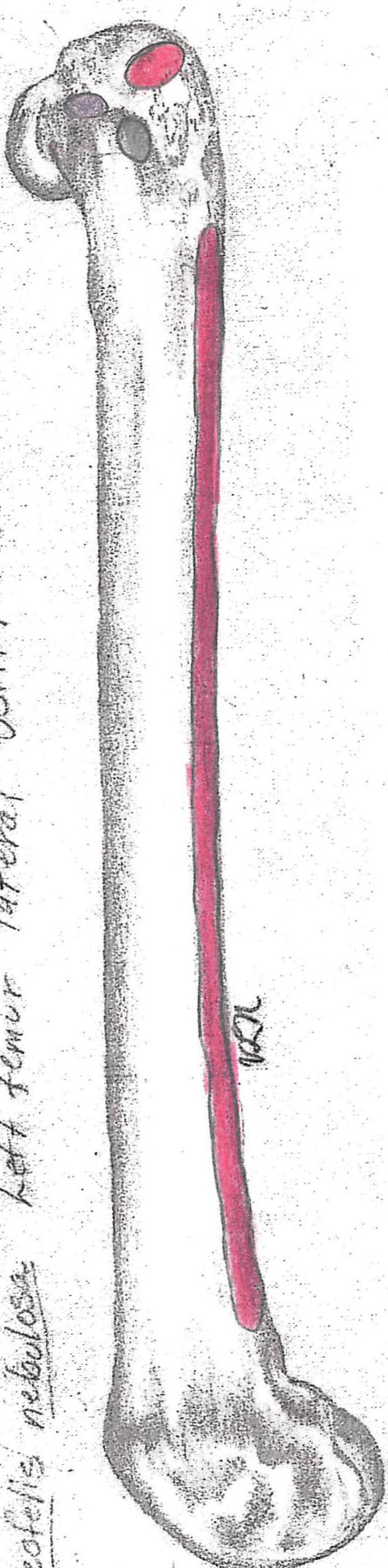

Figure VII:
Cat
(Lateral Femur)

anterior
Lateral

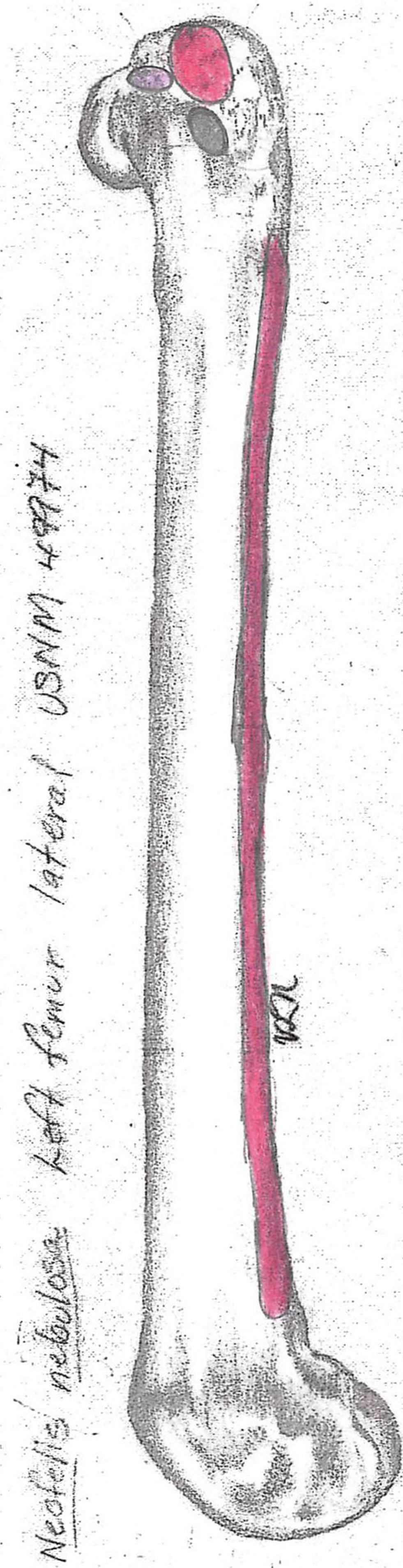

Figure VII A:
Leopard
(Lateral Femur)

anterior
Lateral

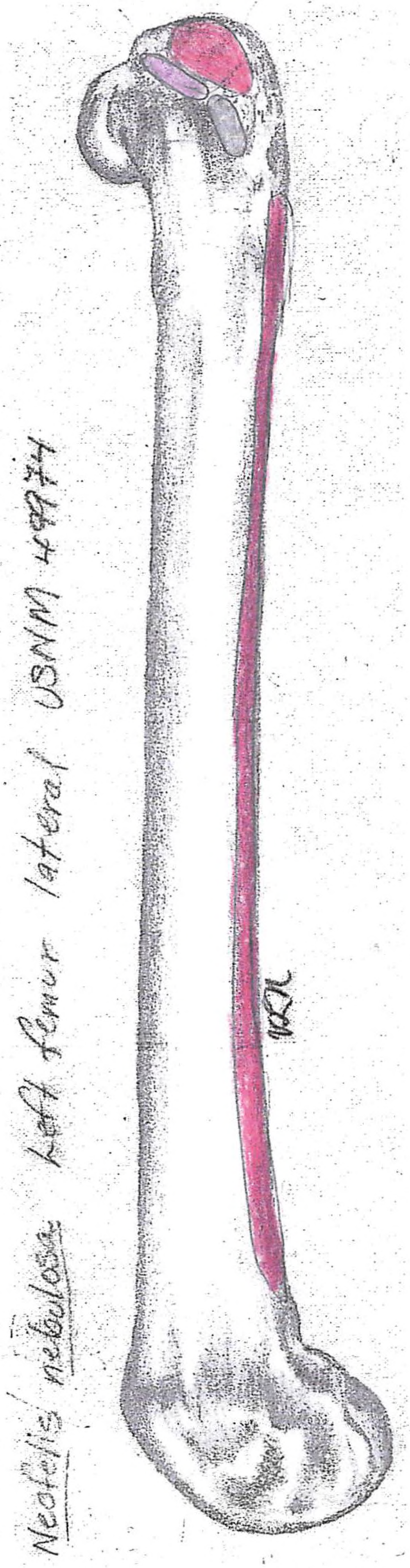

Figure VII B:
Smilodon
(Lateral Femur)

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