DISCUSSION

In the course of the present studies, it has been observed that all the species show behavioral and anatomical similarities with minor variations. The group as a whole shows the similar feeding and locomotory adaptations. So the common adaptive features are focused here and discussed in this chapter.

Feeding Behavior:

All the birds are omnivorous and they prefer insects, grains and tender leaves. They are quick in their feeding movements probably because they are defenseless and very often preyed upon by many enemies. They are always watchful on their feeding grounds. They use their feet and the beak for scratching the soil and to dig out the soil insects.

Epidermal Structures Of Feeding Apparatus:

In response to the specific feeding habits, the epidermal structures of bill and the tongue show wide structural modifications. The birds manipulate these structures with the utmost efficiency in the capture, transport and other mechanical processes preliminary to the digestion of the food material.
The thick, stout and larger bill is useful in scratching the soil and handling the hard coats of seeds and the beetles. The gable shape roof of the upper beak and the dorsal groove of the tongue provide larger space for the transport of the food towards the oesophagus. The smooth culmen of the bill makes it an efficient organ for probing. The slightly pointed but stout nail of the upper bill helps these birds in picking and holding the food grains and it prevents the food from falling down.

The anteriorly sharp maxillary tomia manipulate the seed. The lateral ridges of the maxillary tomia houses the mandibular tomia; such an arrangement provides grip for the closer of the bill and also it does not allow the larger prey (e.g. grasshopper) to escape. Moreover such a tight grip helps in crushing the larger prey. The sharp tomia are also helpful in scraping the viscous food from the ground.

The dorsally concave, ventrally convex, anteriorly pointed and slimy tongue helps the beak in picking up the food and must be playing the major role in drinking water. The epidermal structures of the tongue help the transport of food during linear movements of the tongue. The tongue rotates the food material in the buccal cavity with the help of its lateral surface. The posterior extremity of the tongue is divided into longitudinal ridges which channelize the food towards the oesophagus. The passing food does not enter the choanal slit as it is narrow.
1. Per cent contribution to retraction by individual muscles.

2. Per cent contribution to adduction by individual muscles.

M.A.M.I.V.A. - M.adductor mandibulae internus ventralis anterior
M.A.M.I.V.P. - M.adductor mandibulae internus ventralis posterior
M.A.M.I.D.A. - M.adductor mandibulae internus dorsalis anterior
M.A.M.I.D.P. - M.adductor mandibulae internus dorsalis posterior
M.A.M.E.S.D. - M.adductor mandibulae externus superficialis dorsalis
M.A.M.E.S.V. - M.adductor mandibulae externus superficialis ventralis
M.A.M.E.M. - M.adductor mandibulae externus medialis
M.A.M.M. - M.adductor mandibulae medius
M.A.M.E.P. - M.adductor mandibulae externus profundus
M.Ps. - M.pseudotemporalis
F.po. - Francolinus pondicerianus
F.pi. - Francolinus pictus
P.ar. - Perdicula argoondah
P.as. - Perdicula asiatica
C.cr. - Coturnix coromandelica
C.ct. - Coturnix coturnix coturnix
Av. - Average
Percent contribution to retraction by individual muscles.

Percent contribution to adduction by individual muscles.

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anteriorly, and well developed and posteriorly directed palatal spines distributed over the choanal field also prevent the food from entering the choanal slit.

The variations in the epidermal structures among these species are minor and have general adaptive significance.

Osteology of the Skull:

Brain-case:

It provides important sites for the attachment of the jaw-muscles. Various depressions in it lodges the adductor muscles. In the birds of Phasianidae family the orbit of the brain-case is separated by interorbital septum. Such arrangement provides extra strength to the skull and also it provides extra support for the enlarged jaws and the palate (Zusi, 1962). As Sims (1955) has pointed out, the interorbital septum is of great advantage to the skull in reducing and nullifying the force generated at the bill before they are transmitted to the cranium. The dorso-lateral surface of the skull is obliterated by a deep temporal fossa and a shallow rudimentary squamosal fossa. The suprametal and lamboidal ridges are well marked and the zygomatic process is also well developed. The postorbital process of the frontal and the large zygomatic process of the squamosal provide strong support for the attachment of the thick postorbital ligament. In the quails the
postorbital and zygomatic processes join together and project laterally into the spine and the entire structure provides wide area for the origin of adductor muscles. In case of *F. pondicerianus* such structure is met only with the males and not with the females. The supramaetal and the lamboidal ridges are well raised which provide an increased surface for the origin of A.M.E.M. muscle. The fronto-nasal hinge is comparatively wide and well developed with deep notch in the middle. The well developed frontonasal hinge works as an ideal pivot in the kinetic movements of the upper jaw.

The lacrimal is fairly large in the partridges and quails though Cracraft (1967) states that the lacrimal in Phasianidae family, is poorly developed and possibly lacking in smaller species. The lacrimal contributes to the formation of large area for orbit.

The Upper Jaw:

The premaxilla has sharp cutting edges, which not only helps the bird in picking grains but also helps in crushing the larger insects. The highly angulated commissure of premaxilla and the quadrato-jugal bar gives a greater power and speed at the tip of the bill (Beecher, 1962). Rudimentary maxilla contributes little to the margin of the upper jaw (Jollie, 1957). The laterally bent quadratojugal bar provides greater area for the passage of the adductor muscles. The ball and socket joint of the
quadrato-jugal bar with the quadrate also enhance the free movement and rotation of the upper beak during retraction.

The quadrate is well developed and articulated more or less vertically with the cranium. The longer orbital process runs medially over the pterygoid and provides greater area for the origin of pseudotemporalis muscle.

The length from the tip of the premaxilla to craniofacial hinge constitute an important factor in the lever system of the retractor muscles (Table: 13 to 16). This length affects in the production of effective forces of the retractor muscles. In the birds of family Phasianidae the length of the upper bill when compared with the total skull length, (Table: 2) is generally less than 50% whereas in the fish eating birds like Anhinga and Cormorant, the percentages are more than 50% (Owre, 1967 p.109) and in the waders which feed upon variety of invertebrates and fishes, the above ratio is approximately double or more than that (Burton, 1974, p.39). The equal length of the upper bill and skull has been observed in vegetarian birds like Columba, Eudynamys, Psittacula etc. whereas double length of bill than the cranial length has been observed in Merops and Upupa by Rawal (1966 p.75). In the domestic fowl, this ratio is less than half (Murlidharan, 1971, pp.69, 71).

Thus the length of upper bill when compared to the skull length is less than half in omnivorous birds, more than half in fish eaters, and double in insectiverous
birds whereas equal length is seen in grain eaters. Though the shape of the bill is dependent on the feeding habits of the birds the length of the upper bill suits the type of food they take.

The Lower Jaw:

The ratio of the length of the lower jaw to that of skull length is about 70% in all the birds (Table: 2) whereas it is about 95% in fish-eaters like Anhinga and Cormorant (Owre, 1967, p.109) and more than 100% in seed-eaters like Columba and Eudynamys whereas more than 200% in insect eaters like Merops and Upupa (Rawal, 1966, p.75). The 70% length ratio is also confirmed with fowl-Gallus domisticus by Murlidharan (1971, pp.71, 74).

The Lower Jaw:

Due to early embryonic fusion of the various skeletal elements, the mandible appears more or less as a single piece. Mandible is best suited for seed and insect diet of these birds. The mandibular foramen is narrow and deep. The highly arched rami of the mandible fit tightly with those of the upper jaw in the closed bill. The low triangular depression on the surangular provides a concave surface for the insertion of the M.A.M.E. medialis muscle. The well developed coronoid process forms a hard bony support for the insertion of the strong tendon of the
M.A.M.E. superficialis dorsalis. The height ranges from 3 to 4 millimeters in the taxa studied (Table 1).

The Palate:

One of the main functions of the palate in birds is the transmission of the force and direction of the movements of the muscles of the upper beak. The well ossified palatines and pterygoids give more strength and rigidity to the palate and prevent disarticulation during and kinetic movements. These bones also provide a considerable larger area for the attachment of the M.A.M. internus set of the muscles. The vomer is thin and rudimentary but holds the palatines close together anteriorly.

The Hyoid Apparatus:

The basihyal is bony but it has a cartilagenous paraglossus. The basibranchial is also a bony rod. Ceratohyal, ceratobranchials and urohyals are fairly developed. The epibranchial is formed of two rod shaped parts.

Myology of the feeding apparatus:

The bird manipulates the bill in a great variety of ways to seize the prey with utmost efficiency. Myology of feeding apparatus has striking correlations with the specific feeding habits of the birds.
1. Per cent contribution of thigh extension by individual muscles.

2. Per cent contribution of shank extension and flexion by individual muscles.

3. Per cent contribution of foot extension by individual muscles.

Abbreviations as in Plates: XIX, XX, XXI, XXXII.
Percent contribution of shank extension & flexion by individual muscles.

90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%

Fpa, Fpl, Par, Pas, Ccr, Cct, Av

Percent contribution of thigh extension by individual muscles.

60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%

M. IL FEM.
M. ADD. LONG. EXT
M. ADD. LONG. INT
M. ISCH. FEM.

Percent contribution of foot extension by individual muscles.

60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%

M. GAS. P. INT.
M. GAS. P. EXT.
M. PER. LONG.

PL.XXXIII
Based on the primary function, the jaw muscles are divided into three categories.

I. MUSCLES OPERATING THE BISAK
   A) Adductors of the Lower Jaw
      1. M.A.M.E. superficialis dorsalis
      2. M.A.M.E. superficialis ventralis
      3. M.A.M.E. medialis
      4. M.A.M. medius
   B) Adductors of the Lower Jaw And Retractors of The Upper Jaw
      1. M.A.M.E. profundus
      2. M. pseudotemporalis
      3. M.A.M.I. dorsalis posterior
      4. M.A.M.I. dorsalis anterior
      5. M.A.M.I. ventralis posterior
      6. M.A.M.I. ventralis anterior
   C) Abductors of The Lower Jaw
      1. M. depressor mandibulae
      2. M. gularis
   D) Protractors of The Upper Jaw
      1. M. sphenopterygo-quadratus

II. MUSCLES WHICH RAISE THE BUCCAL FLOOR
   1. M. intermandibularis dorsalis
   2. M. intermandibularis ventralis

III. MUSCLES OPERATING THE TONGUE
   A) Depressors
1. Hypoglossus-anterior
2. Hyoglossus

B) Levators
1. Gularis posterior
2. Interkeratoideus
3. Cricohyoideus

C) Protractors
1. Branchiomandibularis

D) Retractors
1. Gularis anterior

It may be mentioned here that a muscle can function in more than one way. For instance, some retractors of the upper jaw, like the M.pseudotemporalis also serves secondarily as adductor of the lower jaw. The functions attributed here refer to main functions performed by various muscles.

Adductors of the Lower Jaw:

The group of four muscles take part in adduction of the lower jaw. The muscles of this group are well developed and usually fan shaped. Their origin is either fleshy or tendinous or mixed. These muscles either arise from squamosal and its process or latero-sphenoid. They insert on the various elements of the mandible.

Abductors of The Lower Jaw And Retractors of The Upper Jaw:
These muscles perform the dual functions of abductor of the lower jaw and retractor of the upper jaw. To fulfil these functions their both the ends are attached with movable bones like quadrate, pterygoid, palatine and articular. They arise mainly or partly by tendinous fibers. The movable joints of quadrate-pterygoid and the palatine cause the retraction of the upper jaw.

**Abductors of the Lower Jaw:**

The chief abductor is M. depressor mandibulae. It is very massive and arises from the occipito-mandibular ligament from the postero-lateral surface of the skull. The origin may be fleshy, tendinous or mixed. The muscle inserts on the articular. This is the most compicuous muscle in the entire jaw-musculature. The development of this muscle varies from genus to genus. M. Gularis also assists in the abduction of the lower jaw.

**Protractors of the Upper Jaw:**

The action is achieved by the function of a single muscle, M. Spheno-pterygo-quadratus which arises from the latero-sphenoid and inserts on the pterygoid and the quadrate which are movably articulated. The muscle assumes fan's shape; the contraction of such muscles may produce the powerful drag and as a result the powerful grip at the tip of the bill is achieved.
The Muscle Operating the Buccal Floor:

Two parts of M. intermandibularis help in this movement. These muscles are quite extensive and covers most of the medial surface of the dentary. The fibres are parallel and facilitate raising of the buccal floor and make the gaping easier.

The Muscles Operating the Tongue:

The main function of the tongue in birds involves adjustment of food in a proper direction and its transport towards the gullet. In male bird, it also helps to a certain extent in the production of sound. Various movements of the tongue during the feeding operations are the levation, depression, extension and retraction.

Depressors of the Tongue:

Mm. hypoglossus anterior and hyoglossus bring depression of the tongue by their contraction. By the movement of the tongue the food is properly guided towards the oesophagus. M. hyoglossus is well developed, multipinnate muscle. Its unilateral contraction depresses the tongue on the ipsilateral side and thus helps in this function. This movement also helps these birds in collecting the food.

Leverors of the Tongue:
The raising of the tongue is brought about by Mm. gularis posterior, interkeratoideus and cricohyoideus. These are strap like muscles having parallel arrangement of the fibres. Their high degree of development reflects the ability for more effective raising of the tongue. As stated by Goodman and Fisher (1962), the muscles which are responsible for raising of the buccal floor also simultaneously bring about the levation of the tongue.

Protractors of the Tongue:

The extension of the tongue is brought about by a single muscle the M. branchiomandibularis. It is a very strong muscle and also helps the tongue in side way movements for quick collection of the food.

Retractors of the Tongue:

This movement is also brought about by a single muscle, the M. gularis anterior. It is a strap like muscle and arises from articular and inserts on the urohyal and thus helps in withdrawal of the tongue. It also abducts the lower jaw.

Considering the percentage weight of the muscles (Table: 3) the adductors of the lower jaw collectively show the highest development (in terms of weight) in P. asiatica, C. coromandelica and C. c. coturnix whereas moderate development in P. argoondah and F. pictus while the
The lengths of the pelvic elements expressed as per cent of the length of the pelvis.

A - preacetabular ilium
B - acetabulum
C - postacetabular ilium
D - ischium

Other abbreviations as in Plate: XXXII
lower in *F. pondicerianus*. Adductors of the lower jaw and retractors of the upper jaw collectively show their highest development in *F. pondicerianus* which, much less in rest of the species. The *M. depressor mandibulae* shows high development in *F. pictus* and *P. argoondah*, moderate development in *F. pondicerianus* while the low development in rest of the species.

**Kinetics of the feeding apparatus:**

The quantitative analysis of the jaw muscles, kinesis of the skull and mechanical advantage of the bill are studied mainly to understand the efficiency of the feeding-apparatus.

The effective force exerted by the bill of the bird during its feeding operations depends upon several factors. Since, the feeding behavior of birds show immense variations among different groups, the feeding mechanism is suitably modified for the purpose. The various structural components of the lever system and the muscle which supplies the power for their operation are structurally and physiologically equipped to play specific roles. As stated earlier, several investigators (Goodman and Fisher, 1962, Malhotra, 1968, Mansuri, 1969, Murlidharan, 1971 etc.) have described the structural variations which are observed in the lever systems in relations to the specific feeding behavior of the birds or the bird group concerned.
The potential strength of the force exerted at the tip of the bill varies inversely as the length of the work arm. On the other hand, the torque varies directly with the length of the moment arm. This explains why the seed eating birds have a shorter bill with a larger moment arm. Conversely, the fish eaters possess a longer beak. The fish eating birds generally use the anterior and the middle part of the bill to hold the prey and hardly require to exert any force towards the bill tip.

The force of the adduction, abduction, protraction and retraction is also highly dependent on the morphological and physiological set up of the individual muscle fibre. However, for the general consideration and relative study of the dependent muscle, the total mass of the muscle may be taken approximately as a general index of the muscle power. Equally important is the angle of the muscle which it makes with the force arm. Since wider the angle higher the value of its sine. Adductors and abductors generally play an important role in feeding operations and it is interesting to note that most of the birds examined here and by earlier workers show a high value of the sine $\angle Fd$ for their insertions are close to the pivot. However, birds such as $D. autumnalis$, $B. nigricans$, etc., studied by Goodman and Fisher (1962) are feeding mainly on seeds and invertebrates, have low values of Sine $\angle Fd$ ($D. autumnalis = 0.484$, $B. nigricans = 0.475$). The total effective forces of
adduction in the birds studied here, the higher values are found within *Francolinus* whereas moderate within *Perdicula* and lower within *Coturnix* species (Table: 11). The highest average per cent contribution to adduction is by the Mm.A.M.E. superficialis ventralis and dorsalis (Table: 10). They play very important role in bill adduction in seed-eaters.

Unlike in most of the other birds, the protraction and retraction do not seem to play a very significant role in the feeding operations. In birds such as hoopoe which thrusts its beak into the soil and then makes the gape wider, the animal has to use a greater force in the protraction of the upper beak because the bill has to operate against the resistance exerted by the soil. The retraction of the upper beak is made easier, on the other hand, by the resistance of the soil. No such forces interplay in the feeding operations in the birds of family *Phasianidae*. Among all the retractors, the Mm.A.M.I. ventralis anterior and posterior contribute the highest per cent contribution which help the beak to act as the grasping arm against the adduction forces on the lower beak.

The mechanical advantage ranges from the 0.23 to 0.33 in these birds whereas the kinesis of the upper beak varies from $5^\circ$ to $8^\circ$. This is correlated with the food of these birds, as the food consists of smaller size the wide gape is not required. Thus these birds possess high,
short but stronger beaks.

**Locomotion:**

All these birds are ground living. They run fast. Usually they fly for shorter distances. They walk with a moderate gait. They scratch the ground with the foot in search of the food. The males are known for their fighting qualities. These birds are alert to run at any alarm.

The locomotor adaptations of the birds are related to their terrestrial mode of life. Further the modifications in the limbs are associated with the living-grounds, food, feeding habits, and defensive capacities etc. The problem of the balance is also more critical for the bipeds. In the bipeds the center of gravity must lie between or over the feet. According to Storer (1971) the birds like *Struthio* takes longer strides and can run for larger distance; on the other hand, the smaller cursorial birds which have short legs, move very rapidly while running for short distances and 'freeze' as they are 'cryptically' coloured.

**Epidermal Structures of the Foot:**

These birds have anisodactyl type of the foot where the hallux is posterior, short, elevated and does not touch the ground. The IIInd, IIIrd, and the IVth toes are comparatively shorter and anterior in the position. The
shorter toed condition is the well known adaptation for running. These birds are living on the hard surfaces so they do not require larger planter surface for support. For example, the long toes of the herons support them on the soft mud but make the rapid running impossible (Storer, 1971).

The spur is mainly meant for fighting and present in some males of these species. It is single in these birds but in some cases two or more spurs are found. Sometimes even females are equipped with the spurs.

The claws are short, slightly curved, moderately pointed which are helpful in scratching the soil. In running they also provide the grip to the foot against ground and prevent the toes from slipping backward. In perching birds, the claws are greatly curved. The toes and the claws are longer in the birds which walk over the soft ground like jacana. The cornification of the claws and their downward protrusion probably play very important role in the protection of underlying keratin from the cursorial habits and scratching activity of these birds.

The pads on the planter surfaces are well developed. The elevated pads and shorter interpad spaces provide better grip against the ground in running. The elevation of the pads can be correlated with the ground nesting habits of these birds. According to Lucas and Stettenheim (1972), the pads are best developed in birds whose nests are made on the ground or in the interior of
According to Fisher (1946) the shape of the synsacrum is a good indicator of the build of entire body. The pelvis of these birds is comparatively broad. The preacetabular ilium is approximately double in length than the postacetabular ilium, whereas in the aquatic birds like Anhinga and Cormorant the postacetabular ilium is either approximately same or longer in the length (Owre, 1967). Likewise the postacetabular part is found longer in New World Vultures by Fisher (1946). Thus the ratio of pre- and postacetabular lengths becomes very significant. In birds like partridges and quails the preacetabular length is significantly high than the postacetabular length. This fact also can be confirmed from the studies of Fisher (1946, Table: 24) where he has tested the same fact with the Gallus.

In birds of the family Phasianidae anteriorly the longer preacetabular part and the broader posterior pelvic elements provide greater area for the muscle attachment. According to Dabelow (1925: 308) the elongation of postacetabular elements in comparison with precetabular ones and the reduction of width of the postacetabular region are the characteristics adaptations for swimming. On the another hand during present studies, it has been confirmed that
elongation of preacetabular elements in comparison with
postacetabular ones and the enlargement in the width of the
postacetabular region are the necessary adaptations for
running.

The greatest distance between widest ischial
points is comparatively long in females (Soni and Rawal,
1975); this can be associated with the egg-laying.

The Femur:

The femur is moderately long. The trochanteric
width is highly increased (Table: 24). According to Dabelow
(1925: 308) reduction in femoral length and increase in
size of the trochanteric crest are the adaptations for
swimming. But in swimming birds like Anhinga femoral length
is 55.6 mm. and the width of the trochanteric crest
expressed as percentages of femoral length is 16.7 (Owre,
1971: 65) whereas in F.pondicerianus the former length is
45 mm. while the latter ratio is 16.2 (Table: 24) which
is considerably greater while considering the measurements
in swimming bird. Thus great increase in trochanteric width
may be associated with the running.

The anterior bowing of the femur in the birds of
Phasianidae family is very significant when compared with
the femora of the birds of other families. The femora
of fowl, patridges and quails show greater degree of
anterior bowing. Fisher (1946) noted that the femoral
shaft in Gallus is bowed anteriorly to a greater degree
than any other genus examined.

The distal end of the femur of *F. pictus* is greatly rotated medially so that the distal segments of the limb are directed more toward the median line. This also has been confirmed by Fisher (1946: 643) in case of *Gallus*. Such a modification is associated with the running style of both these species. While running they carry the tail partly cocked and tilt the body on the opposite side of the lifted leg.

The wide and deep rotular groove lodges the larger patella on which many crus extensor muscles are attached. The ridges are high on the edges of rotular groove. The fibular groove is also deeper. Wide, deep rotular groove, the deep fibular groove and both with high ridges bordering them are associated with dexterity of movement of the lower leg, since they aid in the prevention of dislocations of the bones and of the tendons passing over the knee (Fisher, 1946). These features are associated with the walking and running ability.

The Tibiotarsus and Fibula:

The tibiotarsus is moderately long and occupies about 33-36 per cent length of the length of total leg elements. The width of the proximal head is comparatively high, it ranges from 13.3 to 14.9 per cent of the tibiotarsus length in the birds of present study (Table: 26)
while in swimming bird like Cormorant it is 10.7 which is very low when compared with the length of the bone (Owre, 1967: 67). The cnemial crests are moderately developed which may be the adaptation for terrestrial locomotion. In contrast they are highly developed in diving forms (Storer, 1971, 193). In case of *F. pondicerianus*, in male birds both the cnemial crests are sharp and highly elevated than in the females (Soni and Rawal, 1975). This may be associated with the fighting behavior of the cocks. However, this is the predominant sexual dimorphic character in Grey Partridge. Such a sexual dimorphic character is not observed in other birds of this family. The fibula also show moderate development and serves for the attachment of some muscles of the thigh and the crus.

The Tarsometatarsus:

The long tarsometatarsus is an adaptation for swift locomotion. The tarsometatarsus is comparatively longer in the birds of family Phasianidae. The intercondylar area is projecting and the medial ridge of the proximal internal cotyla is elevated. This suggests the firm articulation. The hypotarsus is well developed and contains one bony canal and grooves through which the flexor tendons pass. The better development of hypotarsus provides support and the grooves are meant for the better maintenance of the position of the tendons. Such a mechanism is helping the bird in quick movement of the leg.
The gastrocnemius tendon covers the flexor tendons in the region of tarsometatarsus and thus aids the above said mechanism.

The trochea for the digit II is the most proximal and posterior in the position. Its articular end faces the medial side. The trochea for the digit III is slightly medial and elevated of all. The trochea for the digit IV is slightly lateral in position. Such an arrangement of trochea holds the digits nearer to each other which helps the bird in swift locomotion and also in scratching the soil. All the trochea are comparatively shorter which is also an adaptation for better locomotion.

The metatarsus I is a very rudimentary structure. The length of the metatarsus I in the birds studied here ranges from 2.2 mm to 3.6 mm (Table: 28). The metatarsal length as percentages of the tarsometatarsus length ranges from 7.8 to 13.4 in the birds of family Phasianidae whereas in the swimming birds like Anhinga and Cormorant it is 31.0 and 24.6 respectively (Owre, 1967: 69) which is considerably higher than partridges and quails. Rudimentary metatarsus I is one of the modifications for running in birds.

The Digits:

Digit I does not touch the ground, but it helps in perching. The length of the second and fourth digits as percentages of the length of the IIIrd digit ranges from
The length of the IIIrd digit ranges from 17.5 mm to 34.5 mm (Table: 29). Thus the length of the digits is considerably less. The short toe is necessary adaptation for running.

The Myology of The Locomotor Apparatus:

The myological formula of birds of Phasianidae family is complete. The formula is ABCDEFGXYAmV. The main muscle mass in the pelvic limb is chiefly situated at the proximal end of the limb. Such a placement of the bulk of muscles on the limb helps the cursorial forms in eliminating the weight at the distal end of the limb which must be swung through a wide area in locomotion (Fisher, 1946). In the following description the muscle groups are discussed from their volume and functional points of view.

Movements of the Femur:

Mm. iliotrochantericus posterior, anterior and medius are important flexors of the femur. Among them M. iliotrochantericus posterior is very bulky and the only powerful flexor. Its percentage volume of leg muscles ranges from 2.51% to 6.09% in the studied taxa, (Table: 34). The effective force for the flexion of the femur is as high as 0.0602 in both the partridges. It inserts on the entire trochanter and hence performs dual function of flexion and femoral rotation. Both these actions of this
muscle are opposed directly by Mm. obturator internus, ischiofemoralis and piriformes pars iliofemoralis. The femoral extension is also caused by the muscles like adductor longus pars externa and interna. The volume indicated in table: 34 for M.isch.fem. ranges from 0.94% to 1.52% whereas for M.obt.int. it ranges from 0.60% to 2.15%. The volumes of Pars interna and externa of M.pir. are also quite considerable which range respectively from 0.95% to 1.95% and 2.47%. The average per cent contribution for femur extension (Table: 41) is 26.41% by M.il.fem., 33.05% by M.add.long. p.ext., 20.75% by M.add. long.p.int., and 18.64% by M.isch.fem. Thus the total percentages force for extension at the proximal femoral end is 45.05% by Mm. il.fem. and isch. fem. while at the distal end of the femur, it is 53.80% by M.add.long.p.ext. and int. The two-joint muscle like M.sartorius also acts as the femoral flexor at the distal end of the femur which compensate with the femoral extensors and helps in the rapid movements of the thigh during locomotion.

Movements of the tibiotarsus:

Mm. sartorius, iliotibialis, femorotibialis medius and externus are extensors of the tibiotarsus where Mm. biceps femoris, semitendinosus and semimembranosus are flexors of the tibiotarsus. Extensors and the flexors of tibiotarsus in these birds are well developed. The percentage volumes shown in the table: 34 for Mm. sartorius,
iliotibialis and femorotibialis medius are quite high and reflects their powerful actions. Former two muscles are associated with the actions of femur too but M. femorotibialis medius acts as very powerful extensor of the tibiotarsus and its percentage volume ranges from 9.34% to 15.58%. However, the disposition of M. femorotibialis medius is not suitable to calculate the forces by the method used during this work. The effective forces for the extension of the tibiotarsus by other two muscles - Mm. sartorius and iliotibialis are approximately the same (Table: 45).

The main flexor of the tibiotarsus are Mm. semitendinosus and biceps femoris which are quite bulky; and their per cent volumes respectively ranges from 7.26% to 11.12% and 3.41% to 4.97%. The average per cent contribution to tibiotarsus flexion by M. semitendinosus is 40.36% whereas by M. biceps femoris is 59.64% (Table: 49).

Considering tables: 44 and 48 the total effective forces for the flexion of tibiotarsus are far higher than the forces for extension of the tibiotarsus. In fact, for terrestrial locomotion, the extension of the tibiotarsus is caused to put forward the lifted leg which requires less amount of energy while the flexors of the tibiotarsus are really propelling the body by pulling the crus backward when the leg is on the ground. So, for running, the powerful flexors of the tibiotarsus becomes a necessary equipment for an animal.
Movements of the Foot:

The important foot extensors are Mm. gastrocnemius par interna and externa, and peroneus longus whereas the chief foot flexor is M. tibialis anterior. All these muscles are bulky and the main bulk lies towards the proximal end of the leg. The percentage volumes shown in table: 34 for M. gas. p. int. are ranging from 7.34% to 12.42%, for M. gas. p. ext. are ranging from 5.27% to 6.61% and for M. per. long. are ranging 2.80% to 5.31%. Though pars interna and externa of M. gas. are acting collectively on the foot, but the effective forces by pars interna are higher than, those of pars externa (Tables: 50 and 51). An average per cent contribution of tarsometatarsus extension by pars ext. of M. gas. is 30.70% by pars int. of M. gas. is 49.07% and by M. per. long. is 20.24% (Table: 54). The effective forces for the flexion of tarsometatarsus by M. tibialis anterior are very low when compared to those of extensors of tarsometatarsus (Table: 53).

For quick and powerful locomotion the back stroke of the leg on the ground requires greater force whereas in lifting and forwarding the leg, less force is required. Looking to the volumes and the effective forces of the muscles, the extensors of femur, flexors of the tibiotarsus and the extensors of the tarsometatarsus are found very voluminous and also can produce greater effective forces which help the leg in the backward stroke which ultimately
Movement of the Digits:

M. extensor digitorium longus is an important extensor of the digits. The sustained extension of the toes is very helpful to these birds while scratching the ground.

Mm. flexor perforans et perforatus digiti II, III, flexor perforatus digiti II, III and IV, and flexor digitorium longus are the chief flexors which make the bulk of the crus musculature. In all the species studied these digit-flexors possess good volume (Table: 34). These muscles produce the force which effects against the ground and ultimately helps the body to propel and finally flexion of the digits when the leg is lifted up from the ground.

In addition to the above said digital extensor and flexors, there are intrinsic muscles of the foot which help the digits in their extension, flexion, adduction, abduction etc. The hallux is operated by Mm. extensor hallucis longus, flexor hallucis longus, flexor hallucis brevis etc.

Kinetics - Locomotor Apparatus:

The technique employed here for the analysis of the effective forces of the extensors and flexors of various elements of the leg contributes greatly to the
interpretations of various adaptations of running birds of Phasianidae family. The effect of the forces in the locomotion has been discussed along with the former part of myology. This technique can be used elsewhere for similar investigations.