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Amit Singh Vishen
Department of Veterinary Anatomy, College of Veterinary and Animal Science, GBPUAT, Pantnagar, Uttarakhand, India

Meena Mrigesh
Department of Veterinary Anatomy, College of Veterinary and Animal Science, GBPUAT, Pantnagar, Uttarakhand, India

Ishwar Singh
Department of Veterinary Anatomy, College of Veterinary and Animal Science, GBPUAT, Pantnagar, Uttarakhand, India

Renu Yadav
Department of Veterinary Anatomy, College of Veterinary and Animal Science, GBPUAT, Pantnagar, Uttarakhand, India

Niddhi Arora
Department of Veterinary Medicine, College of Veterinary and Animal Science, GBPUAT, Pantnagar, Uttarakhand, India

Ruokuobeinuo Huozha
Department of Veterinary Physiology, College of Veterinary and Animal Science, GBPUAT, Pantnagar, Uttarakhand, India

Maansi
Department of Veterinary Public Health, College of Veterinary and Animal Science, GBPUAT, Pantnagar, Uttarakhand, India

Corresponding Author:
Meena Mrigesh
Department of Veterinary Anatomy, College of Veterinary and Animal Science, GBPUAT, Pantnagar, Uttarakhand, India

Gross anatomical studies on the Brain of Uttara Fowl

Amit Singh Vishen, Meena Mrigesh, Ishwar Singh, Renu Yadav, Niddhi Arora, Ruokuobeinuo Huozha and Maansi

Abstract
The present research work was performed on the gross anatomy of different parts (cerebrum, pineal gland, optic lobe, cerebellum and medulla oblongata) of the brain of six months old apparently healthy six Uttara fowl in Uttarakhand. The birds were purchased from University Poultry Farm of GBPUAT, Pantnagar. It was found that the brain was pear shaped smooth creamy pinkish coloured covered by meninges situated in the cranial cavity. It was divided into prosencephalon (Included telencephalon and diencephalon), mesencephalon (included optic lobes) and rhombencephalon (Included medulla oblongata and cerebellum). The telencephalon had cerebral hemispheres and olfactory lobes; diencephalon included thalamus as rounded eminence on the medial aspect and optic chiasma on the posterior surface. The convex cerebral hemispheres were dorsally placed and broad caudally with two rounded wide angles and separated from each other by a median longitudinal fissure and from cerebellum by a transverse fissure. The pineal gland was inverted pyramid shaped soft pinkish in colour. It was situated superficially behind the union of cerebral hemispheres in a triangular space formed between the caudal aspect of cerebral hemispheres and the cranial aspect of cerebellum. The oval to egg shaped optic lobes were originated from mid brain and bulged laterally. A lozenge shaped cerebellum represented the first part of the hindbrain and was large and laterally compressed located posterior to the cerebral hemispheres. The club shaped Medulla oblongata was the most posterior part of the brain followed by spinal cord. It had rhomboid fossa on the dorsal aspect to make the floor of the fourth ventricle.

Keywords: Uttara fowl, cerebral hemisphere, optic lobes, pineal gland, cerebellum and medulla oblongata

Introduction
In India the rural poultry production promotes self-employment that provides supplementary income in the form of protein-rich food at a reasonable cost (Singh *et al*., 2018) [54]. Backyard poultry farming is crucial for economic development, women's empowerment and nutritional security in India (Kumar *et al.,* 2021) [35]. The Uttara fowl has been registered in National bureau of animal genetic resources (NBAGR) in the year 2018 and is found in the hilly areas of Uttarakhand so named as 'Hill fowl'. This fowl have significant disease resistance and adaptability to prosper under various adverse conditions (Singh *et al.*, 2017) [53]. Uttara fowl is reared for dual purpose for both egg and meat production (Kaur *et al.*, 2010) [31]. The study on brain in birds is important because it controls physiology, gesturing, maintenance, regulation of muscle tension and function of the body (Gupta *et al.*, 2016) [21]. The avian optic lobes are well developed and highly laminated with the generation of orienting movements to stimuli of interest whether in the form of moving prey or predator in the environment (Frost and Nakayama, 1983; Frost *et al.*, 1988; Frost *et al.*, 1990; Butler and Hodos, 2005 and Wylie *et al.*, 2009) [15, 16, 17, 8, 57]. The cerebellum regulates the body movements from external stimuli to move fast and precisely and regulate higher cognitive processes (Hanzel *et al.*, 2015) [24]. Pineal gland in birds has a circadian oscillator which is responsible for temporary organisation of cerebral functions (Lazar *et al.*, 2015) [38].

Materials and Methods
The present work was executed on the brain of six apparently healthy Uttara fowl of six months old of either sex. The birds were purchased from University Poultry Farm of GBPUAT, Pantnagar and sacrificed in accordance with CPCSEA/IAEC guidelines by separating the jugular vein and common carotid artery and after that the birds' heads were separated cautiously at the level of second cervical vertebrae. Then the cavity of the brain of birds was opened through the middle with the help of scissors. While opening cranial cavity the nasal and temporal bones of cranium were detached at the level of base of skull.

The intact brain was removed from the cavity of brain for detailed anatomical study after separating it from the spinal cord at the level of the foramen magnum.

Results and Discussion

On observation, the brain was divided into three main regions from rostral to caudal direction, the first one was the forebrain or prosencephalon, the second one was the mid brain or mesencephalon and the third one was the hind brain or rhombencephalon as described earlier by Nickel *et al.*, 1977 [44] in avian; Abid and Al- Bakri, 2016 [2] in quail; Balkaya and Toprak, 2018 [5] in sparrow hawk; Al-Nakeeb and Jasim, 2018 [4] in *Columba livia domestica*; Nathaniet *et al*., 2019 [43] in grey breasted helmeted guinea fowl; Gupta *et al.*, 2019 [22] in fowl; Jasim, 2020 [28] in Iraqi babbler and Kumar *et al.*, 2022 [33] in chick of *Gallus gallus domesticus*). The brain consisted of olfactory bulbs, cerebral hemispheres, pineal body, optic lobes and cerebellum when seen from the dorsal surface (Fig. 1A). It had olfactory bulb, optic chiasma, optic tract, optic lobes, hypophysis cerebri, midbrain and medulla oblongata on ventral surface, from cranial to caudal end, which were continued into the spinal cord as shown in Fig. 2. Optic lobes were partially visible from dorsal and ventral surfaces but clearly discernible from lateral surface (Fig. 1A, 2 & 3). The olfactory lobes were very small or not well developed and partially visible from dorsal and clearly visible from ventral side (Fig. 1A, 2 & 3). The olfactory lobes were partially fused together and appeared to be one (Fig. 2 & 3). The parallel observations were reported in African ostrich, vencobb broiler, Vanaraja chickens and Kadaknath birds by Peng *et al.* (2010) [48]; Gupta *et al.* (2016) [21]; Panigrahi *et al.* (2017) [47] and Sharma *et al*. (2022) [51], respectively who found the poorly developed olfactory bulb at the foremost head of the brain. In contrast to the present finding, Healy and Guilford (1990) [25] emphasized that the nocturnal birds had larger olfactory bulbs than diurnal birds. This might be due to species difference.

The brain was located in the cranial cavity covered by meninges (Fig. 1B) as noticed earlier by as highlighted by Batah *et al.* (2012) [7]; Al-Nakeeb and Jasim (2018) [4]; Gupta *et al.* (2019) [22] and Jasim (2020) [28], Kumar *et al.* (2020) [34]; Kumar *et al.* (2022) and Sharma *et al*. (2022) [51], in locally breed chicken, *Columba livia domestica*, fowl, Iraqi babbler, guinea fowl, chicks of *Gallus gallus domesticus* and Kadaknath, respectively. The brain was pear shaped pinkish white in colour (Fig. 1A, 2 & 3) which is in accord with the observation of Batah *et al.* (2012) [7] in locally bred chicken; Abd- Alrahman (2012) in barn owl; Al-Nakeeb and Jasim (2018) [4] in a wild bird; Joshi *et al.* (2019) in Kadaknath fowl and Gupta *et al.* (2019) [22] in fowl. In contrast to the present finding, Frahm and Rehkamper (1998) [14] found the hour-glass shaped brain in white crested polish chicken. Gupta *et al.* (2016) [21] in Vencobb broiler and Mohammed *et al.* (2018) [42] in laughing dove reported the brain as a playing card symbol of a "spade." However, Karkoura *et al.* (2015) [30] in African ostrich indicated a brain as rhombus shaped.

The cerebrum was obscuring fully the diencephalon and to a large extent the midbrain and consisted of two uniform hemispheres (right and left) called cerebral hemispheres (Fig. 1A, 2 & 3). These findings were akin with the finding of Nickel *et al.* (1977) [44] in avian and Karkoura *et al.* (2015) [30] in African ostrich, Gupta *et al.* (2016) [21] in vencobb broiler; Panigrahi *et al.* (2017) [47] in male and female Vanaraja chickens; Balkaya and Toprak (2018) [5] in sparrowhawk; Mohammed *et al.* (2018) [42] in laughing dove; Joshi *et al.* (2019) [29] in Kadaknath fowl; Kumar *et al.* (2020) [34] in guinea fowl; Gautam *et al.* (2020) [18] in post hatch broiler chicken and Kumar *et al.* (2022) [33] in chick of *Gallus gallus domesticus.* The right and the left hemispheres were separated by a median longitudinal fissure and the cerebral hemispheres were separated from cerebellum by a transverse fissure. Moreover, the cerebrum was convex dorsally and broad caudally with two rounded wide angles (Fig. 1A). Similarly, Peng *et al.* (2010) [48] and Karkoura *et al.* (2015) [30] in African ostrich; Panigrahi *et al.* (2017) [47] in male and female Vanaraja chickens; Gupta *et al.* (2016) [21] in vencobb broiler; Gautam *et al.* (2020) [18] in post hatch broiler chickens. There were faint sagittal eminences (elevations) and indistinct valleculae (depressions) on the dorsal surface of the brain. This finding was akin with the finding of Martin *et al.* (2007) [39] in Kiwi and Gautam *et al.* (2020) [18] in broiler chicken. This observation was contrary with the observation made by Nickel *et al.* (1977) [44] in avian and Costa *et al.* (2018) [10] in great rhea who observed very clear two sagittal eminences (elevations) and valleculae (depressions) on the dorsal surface of the brain.

In present study three striata and two pallium of cerebrum were visible medially. The outer most part was in the form of faint swelling called neopallium (painted orange in photograph) and the caudal most part was archipallium (painted brown in photograph). The outer most striata below the neopallium was hyperstriatum (painted green in photograph) below which neostriatum (painted blue in photograph) and paleostriatum (painted black in photograph) were present (Fig. 4). Abd-Alrahman (2012) in barn owl; Dhage *et al*. (2013) [11] in *Sturnus vulgaris;* Abid and Al-Bakri (2016) [2] in quail; Al-Nakeeb and Jasim (2018) [4] in a wild bird; Jasim (2020) [28] in Iraqi babbler and Gautam *et al.* (2020) [18] in post hatch broiler chickens divided the cerebrum into two areas: the pallium and the subpallium. The pallium was formed by the outer cortical area called as hippocampus, while the inner cortical area was composed of three parts, first one was mesopallium, second one was nidopallium and the third one was called archopallium.

The pineal gland was situated superficially behind the union of cerebral hemispheres in a tri angular space formed between the caudal aspect of cerebral hemispheres and the anterior aspect of cerebellum (Fig. 1B). The parallel observations were made by Nickel *et al.* (1977) [44] and Haldar and Bishnupuri (2001) [23] in birds; Vollrath (1981) [55] and Dursun (2002) [12] in avian; Batah *et al.* (2012) [7] in chicken; Karkoura *et al.* (2015) [30] in African ostrich; Gupta *et al.* (2016) [21] in vencobb broiler; Balkaya and Toprak (2018) [5] in sparrowhawk and Joshi *et al.* (2019) [29] in Kadaknath fowl. In contrary to our finding, the Swiss mice pineal gland was located below the splenium of the corpus callosum just inferior to the third ventricle and dorsal to the habenular commissure as observed earlier by Matsunaga *et al*. (2011) [40].

The pineal gland had three parts viz. proximal part, middle part and distal part. The proximal part or apex was attached via the choroid plexus to the diencephalon, the middle part or stalk connected proximal part with distal part and body or base of the distal part which was located superficially. The superficially located distal part was closely adhered to the duramater (Fig. 1B). These observations were akin with the observations of Kwiecinska *et al*. (2017) [36] in Muscovy duck. In contrast to the present findings, Chauhan and

Ambadkar (1984) [9] in Indian house crow recognized two parts of pineal gland: a proximal narrow stalk and a dorsally located broad distal part. Quay and Renzoni (1967) [49] in birds and Gornowicz *et al.* (2005) [20] in some species of turkey reported that the pineal gland composed of accessory pineal tissue including pineal gland.

The pineal gland was inverted pyramid shape soft pinkish in colour (Fig. 1B). Contradictory to this, Nickel *et al.* (1977) [44] in fowl described the shape of pineal as club shaped and Karkoura *et al.* (2015) [30] in African ostrich reported the pineal body as inverted tube like structure with an obtuse triangle; Lazar *et al.* (2015) [38] in turkey found that the pineal gland was cone shaped with the base pointing towards skull; Peng *et al.* (2010) [48] in African ostrich investigated a small rod-shaped tuber, the conarium (pineal body) and Barcelos *et al.* (2015) [6] found the bludgeon-shaped pineal gland in Magellanic penguin.

In present study grossly there was no lobulation on the surface of pineal gland but Withyachumnarnkul *et al.* (1985) [56] in swamp buffalo and Sharma *et al.* (2019) [52] in Jaffarabadi buffaloes reported lobulation on the surface of pineal gland. According to Vollrath (1981) [55] five anatomical types of the pineal gland were identified according to their shape and localization in mammals. A solidfollicular transitional type (an intermediate between tubulofollicular and solid lobular type) of the pineal organ has been identified in birds (Ohshima and Hiramatsu, 1993 [45] in Japanese quail and Haldar and Bishnupari, 2001 [23] in diurnal and nocturnal birds of tropics).

In our present study well developed optic lobes were found originating from mid brain and bulged laterally (Fig. 1A, 2 & 3) as noticed previously by Martin *et al.* (2007) [39] in the emu and pigeon; Iwaniuk (2003) [27] in parrots; Karkoura *et al.* (2015) [30] in African ostrich and Costa *et al.* (2018) [10] in great rhea; Balkaya and Toprak (2018) [5] in sparrowhawk; Nathaniel *et al.* (2019) [43] in helmeted guinea fowl and Sharma *et al.* (2022) [52] in Kadaknath birds. In contrary to our observation, the lobus opticus in coturnix quail (Fitzgerald, 1969) [13]; avian (Nickel *et al.*, 1977) [44] and Kiwi and Barn Owl (Martin *et al.*, 2007) [39] was very small and visible in ventral view only. The shape of the optic lobes was oval to egg shaped in present study (Fig 7). In contrary to this, Husband and Shimizu (2001) [26] in pigeons and Koushafar and Mohammadpour (2019) [32] in ostrich indicated that these optic lobes were prominently spherical bodies of the midbrain on the lateral aspect. Batah *et al.* (2012) [7] in chicken reported the oval shaped optic lobe whereas, Peng *et al.* (2010) [48] revealed stylistic shaped optic lobes in African ostrich. Gupta *et al.* (2016) [21] in vencobb broiler; Joshi *et al.* (2019) [29] and Sharma *et al.* (2022) [52] in Kadaknath fowl found rounded or spherical bodies of optic lobes. However, Panigrahi *et al.* (2017) [47] in Vanaraja chickens observed spherical to ovoid optic lobes. The optic lobe's dorsal surface was strongly convex with pointed front end and broader caudal end (Fig. 7). This observation was parallel with the observation made in *Sturnus vulgaris*, African ostrich and ostrich by Dhage *et al.* (2013) [11]; Karakoura *et al.* (2015) and Koushafar and Mohammadpour (2019) [32], respectively.

The cerebellum was placed on ventral surface of the cerebral hemispheres (Fig. 1A) as revealed earlier by Gupta *et al.* (2016) [21] in vencobb broiler; Balkaya and Toprak (2018) [5] in sparrowhawk and Joshi *et al.* (2019) [29] in Kadaknath fowl. The cerebellum had median part called vermis and lateral part called cerebellar auricle or flocculus (Fig. 5) as mentioned earlier by Nickel *et al.* (1977) [44] in avian, Peng *et al.* (2010) [48] in African ostrich, Batah *et al.* (2012) [7] in chicken, Gupta *et al.* (2016) [21] in vencobb broiler, Balkaya and Toprak (2018) [5] in sparrowhawk, Joshi *et al.* (2019) [29] in Kadaknath fowl and Maulana *et al.* (2021) [41] in chicken. The shape of cerebellum was lozenge (diamond) shaped (Fig. 5 A & B) as reported earlier in African ostrich by Peng *et al.* (2010) [48]. However, Gupta *et al.* (2016) [21] in vencobb broiler; Balkaya and Toprak (2018) [5] in sparrowhawk and Joshi *et al.* (2019) [29] in Kadaknath fowl found the wedge shaped cerebellum. The cerebellum was found to be a curled worm like structure which represented the vermiform lobe of mammals (Pal *et al*., 2003 [46] in white leghorn fowl and Gupta *et al*., 2016 [21] in brain of Vencobb broiler birds). Karkoura *et al.* (2015) [30] in African ostrich reported the diamond shaped cerebellum.

The vermis had anterior, posterior and vestibulocerebellum lobes (Fig. 7). However, Abid and Al-Bakri (2016) [2] in adult quail reported that the cerebellum had anterior, posterior and flocculonodular lobe. Costa *et al.* (2018) [10] in great rhea and Abid (2022) [3] in *Pycnotus leucotis* reported that the cerebellum was composed of three lobes (anterior, middle and posterior) separated by the ventricle. The vermis consisted of ten primary folia out of which VIIIth folia further divided into two parts i.e. VIIIab and VIIIcd (Fig. 7). The first part of VIIIth Folia (VIIIab) was further sub divided into two parts i.e. VIIIa and VIIIb as mentioned in Fig. 7. Folia I-V formed anterior lobe and folia VI-VIII comprised the posterior lobe. Folia VIIIcd and X formed the vestibulocerebellum (Fig. 7). However, in contrast to the present finding, Larsell (1967) [37] in generic bird reported that there were eleven primary folia with IX divided into IXab and IXcd. Folia I-V and VI-IX comprised the anterior and posterior lobes, respectively. Folia IXcd and X comprised the vestibulocerebellum. Abid and Al-Bakri (2016) [2] in adult quail reported that the vermis was consisted of nine folds called cerebellar-folia and separated from each other by sulci.

Medulla oblongata was the most caudal part of the brain with slight convexity on the caudo dorsal surface followed by the spinal cord and cranio dorsally it had rhomboid like fossa to form the base of the IVth ventricle (Fig. 6A) as noticed earlier in chicken by Batah *et al.* (2012) [7] and in African ostrich by Karkoura *et al.* (2015) [30]. There was club shaped medulla oblongata in Uttara fowl brain (Fig. 6B) as told by Nickel *et al.* (1977) [44] in avian and Karkoura *et al.* (2015) [30] in African ostrich. The medulla oblongata texture was creamy white (Fig. 6B) as found earlier by Sharma *et al.* (2022) [52] in Kadaknath birds.

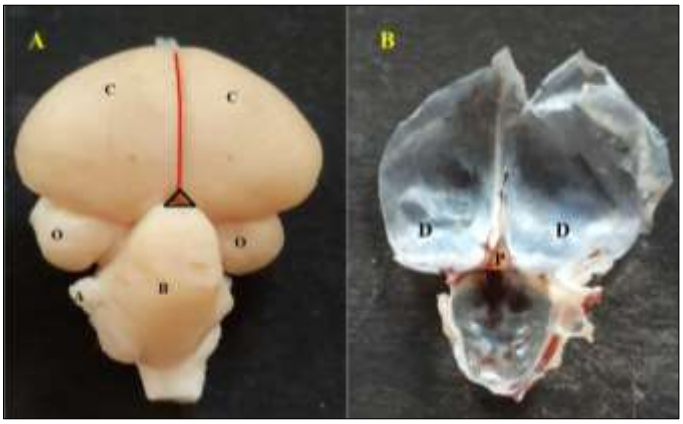

Fig 1: A. Photograph showing dorsal view of Uttara fowl brain showing Cerebral hemispheres (C), median longitudinal fissure (red line), pineal gland position (black triangle), optic lobes (O), cerebellum (B) and cerebellar auricle (A). B. showing meninges Duramater (D) and pineal gland (P) attached to brain.

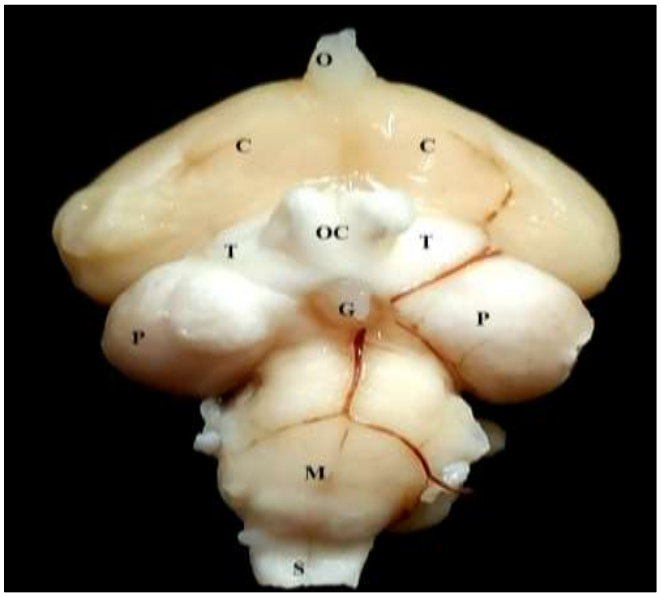

Fig 2: Photograph showing ventral view of Uttara fowl brain showing olfactory bulb (O), cerebral hemispheres (C), optic chiasma (OC), optic tract (T), optic lobes (P), body of pituitary gland (G), medulla oblongata (M) and spinal cord (S).

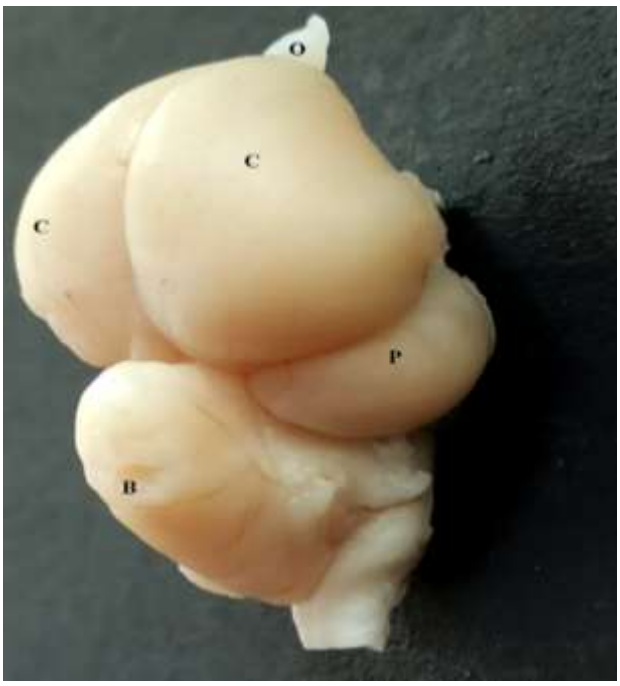

Fig 3: Photograph showing dorso lateral view of brain showing olfactory bulb (O), cerebral hemispheres (C), optic lobes (P) and cerebellum (B).

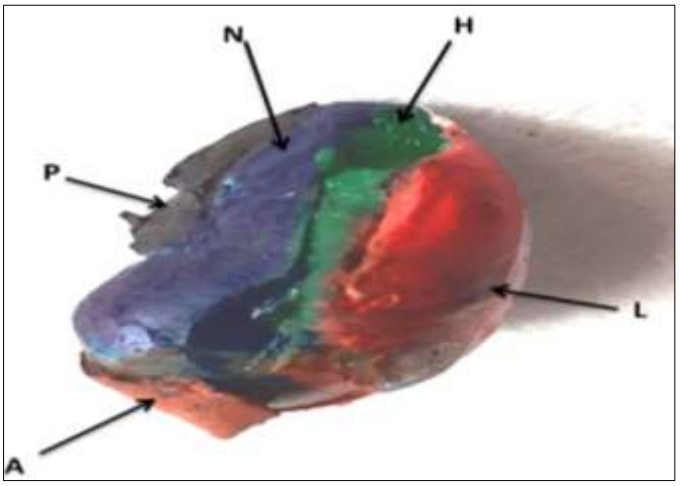

Fig 4: Photograph showing median longitudinal view of neopallium (painted orange), archopallium (painted brown), Hyperstriatum (painted green), neostriatum (painted blue) and paleostriatum (painted black).

Fig. 5: A. Photograph showing dorso caudo lateral view of cerebellum showing folia from 5 to 9 and cerebellar auricle (A). B. Showing folia from 1-6 and cerebellar auricle (A) in caudo lateral view of cerebellum of Uttara fowl brain

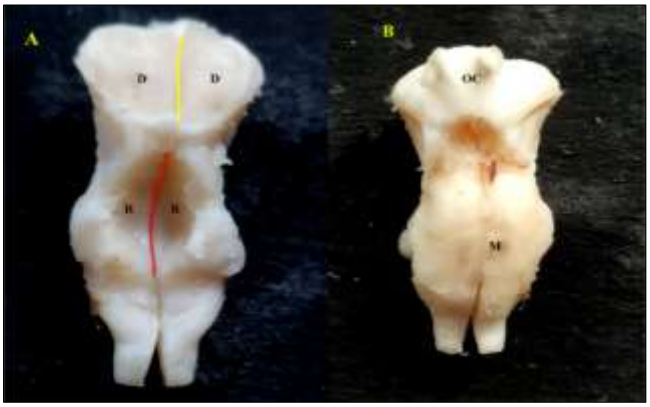

Fig 6: A. Photograph showing dorsal surface of diencephalon (D) having 3rd ventricle (yellow line) and rhomboid fossa (R) having 4th ventricle (red line). B. ventral surface of brain showing optic chiasma (OC) and club shaped medulla oblongata (M)

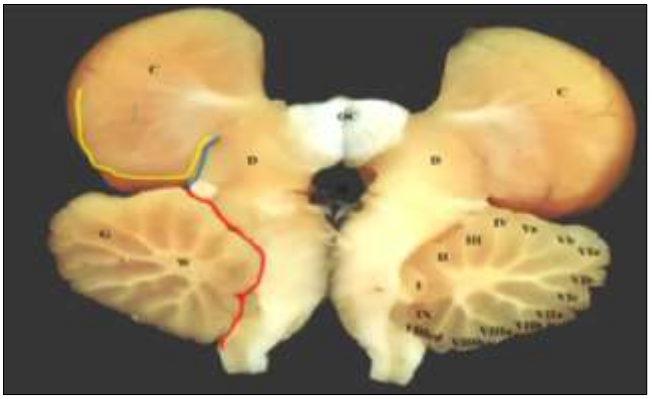

Fig. 7: Photograph showing median section of brain showing cerebral hemispheres (C), optic chiasma (OC), diencephalon (D), grey matter (G) and white matter (W) of cerebellum and folia from I to IX.

Conclusion

The present study will form a baseline data on the gross morphological architecture of Uttara fowl bird which can be further applied to diagnose any deficiency syndrome (Vacuolar myelinopathy syndrome etc.) and detection of any abnormality (cerebral hernia, chronic ischemic lesions and Brain dysplasia etc.) in the brain.

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