CHAPTER 6

THE HYPOTHALAMO-HYPOPHYSIAL NEUROSECRETORY SYSTEM OF THE MIGRATORY STARLING, *STURNUS ROSEUS* (LINNAEUS)

The hypothalamo-hypophysial neurosecretory system in birds has been extensively studied in recent years. Several excellent studies have already been carried out on the hypothalamo-hypophysial tracts and the centres of neurosecretion in different species of birds (Wingstrand, 1951; Legait, 1955a, 1955b, 1957, 1959; Benoit and Assenmacher, 1955, 1959; Assenmacher, 1957a, 1957b, 1958; Shirley and Nalbandov, 1956a, 1956b; Kobayashi *et al.*, 1961). Investigations on the effect of photoperiodicity on the neurosecretory activity in birds have been carried out with a view to understand the role of this secretion in the stimulus for migration (Oksche *et al.*, 1959; Oksche, 1960; Laws, 1961). Farner and Oksche (1962) have reviewed previous literature concerned with neurosecretion in birds and so only works pertinent to the present investigation will be cited.

Oksche *et al.*, (1959), Farner (1962) and Farner *et al.*, (1962) showed in the white crowned sparrow that there is an increase of neurosecretion in the median eminence of the hypothalamus when the testes are regressed and a decrease when the testes are fully developed. These changes in the hypothalamus and the gonads are attributed to the influence of photoperiodic changes as from short to long day lenghh. However, it should be of interest to see whether the same changes are noticed in the case of migratory birds which spend most part of the year in the Tropics where the difference in day lengths is not so pronounced. It is also important to study the changes in neurosecretory activity in the hypothalamo-hypophysial systems in relation to changes occurring simultaneously in other organs e.g. gonads, pituitary, thyroid, adrenal and pancreas,in the same bird. In the light of these considerations the present investigation on the neurosecretory system in the Rosy Pastor, (Sturnus roseus) which arrives in Baroda (India) about September and leaves to its breeding grounds in the Middle East and Europe by the end of April, has been carried out. Observations on the other organs mentioned above are described separately (Chapter, 3, 4, 5, 7, 9).

Materials and Methods

Birds of both sexes were shot early in the morning and immediately weighed. The brain along with the intact pituitary was quickly dissected out in different fixatives e.g. Bouin's, Zenker, Carnoy and 10% neutral formalin. Paraffin sections 5-8 µ thick were cut and treated for the various histological and histochemical observations. The localization of neurosecretory cells and their tracts were studied by means of different staining techniques mentioned below. (1) Gomori's (1941) Chrome-alum haematoxylin Phloxin (CHP) as described by Pearse (1960). (2) Gomori's (1950) Aldehyde fuchsin staining as modified by Halmi (1952). (3) The performic acid alcian blue (PFAAB), PAS, Orange G methods for the neurosecretory substances and the cell types of the anterior pituitary (Adams and Sloper, 1955, 1956) as described by Pearse (1960). (4) The ferric ferricyanide method for SH-groups

(Chèvremont and Fréderic, 1943; Pearse, 1960). (5) Methyl green pyronin Y (Kurnick, 1955a; Pearse, 1960) for nucleic acids. For confirmation of neurosecretory activity in the Rosy Pastor, the released neurosecretory material in pigeons given aqueous sodium chloride (0.2 M) for a week,was tested. The neurosecretory activity in the hypothalamus, median eminence and posterior pituitary of these pigeons put under stress, was studied and compared with the neurosecretion in the Rosy Pastor.

It would have been better to use Rosy Pastors in these test experiments instead of pigeons. But in the light of the difficulties involved in maintaining them in the laboratory under natural conditions and of the fact that in captivity they rapidly lost weight and their premigratory fat store, it was decided to use pigeons instead. 5 to 6 days of treatment with (0.2 M) NaCl in drinking water, the neurosecretory cells of the hypothalamus were continuously being depleted of their neurosecretory material and these cells became hypertrophied due to excessive secretory activity. The median eminence and the pars nervosa lost almost all the stored neurosecretory material and the former became a net work of connective tissue without any secretion (Fig. 29). The ependymal pituicytes of the pars nervosa became vacuolated and the nuclei became bigger. The median eminence, though did not contain large droplets of neurosecretory material, did show the presence of some small freshly synthesized granules.

Observations

The topography and general anatomy of the hypothalamo-hypophysial neurosecretory system in the Rosy Pastor are shown in figures 1 and 2.

Neurosecretory Nuclei and Neurosecretory Cells of the Hypothalamus:

The hypothalamic neurosecretory centres in the Rosy Pastor consists of a pair each of supraoptic and paraventricular nuclei, and the anterior and posterior divisions of the infundibular nucleus. The localization of these centres in the hypothalamus was revealed by staining with aldehyde fuchsin and Gomori's CHP (Figs. 1 & 2). Better localization and sharper contrast in the staining was obtained with aldehyde fuchsin.

Nucleus Supraopticus:

The neurosecretory cells of the supraoptic nuclei are strikingly different in distribution like in the other birds described by earlier workers (Laws, 1961; Kobayashi <u>et</u> <u>al</u>., 1961; Oksche, 1962). These centres have a copious supply of blood vessels (Fig. 3). Most of the neurosecretory cells of the supraoptic nucleus are located in a group near the anterior margin of the optic chiasma (Fig. 4) and lateral to the optic recess, while a few cells extend laterally along the margin of the optic tracts(Fig. 5). The lateral supraoptic neurosecretory cells with large nucleus and nucleolus are arranged in a slightly dispersed manner along the anterior margin of the optic chiasma (Figs. 6, 7, 8), and are larger than the ordinary neurons around them. The paraldehyde fuchsin stained the large globules of neurosecretory material clumped together in

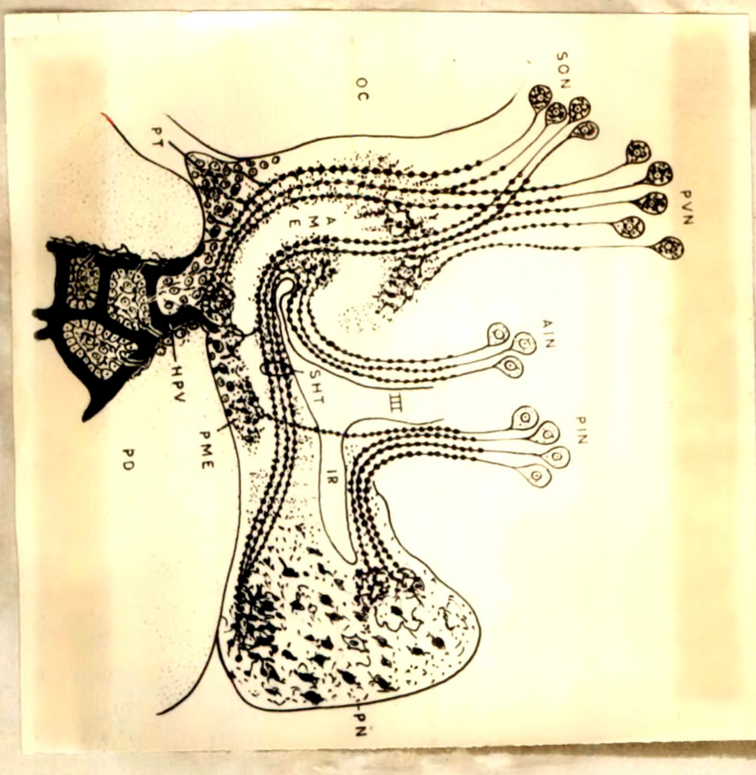


Fig. 1. Schematic sagittal section of the hypothalamo-hypophysial neurosecretory system of the Rosy Pastor. AME, anterior median eminence; HPV, hypophysial portal veins; IR, infundibular recess; OC, optic chiasma; PD, pars distalis; PME, posterior median eminence; PN, pars nervosa; PT, pars tuberalis; PVN, paraventricular nucleus; SHT, supraopticohypophysial tract; SOM, supraoptic nucleus; III, third ventricle.

Fig. 1

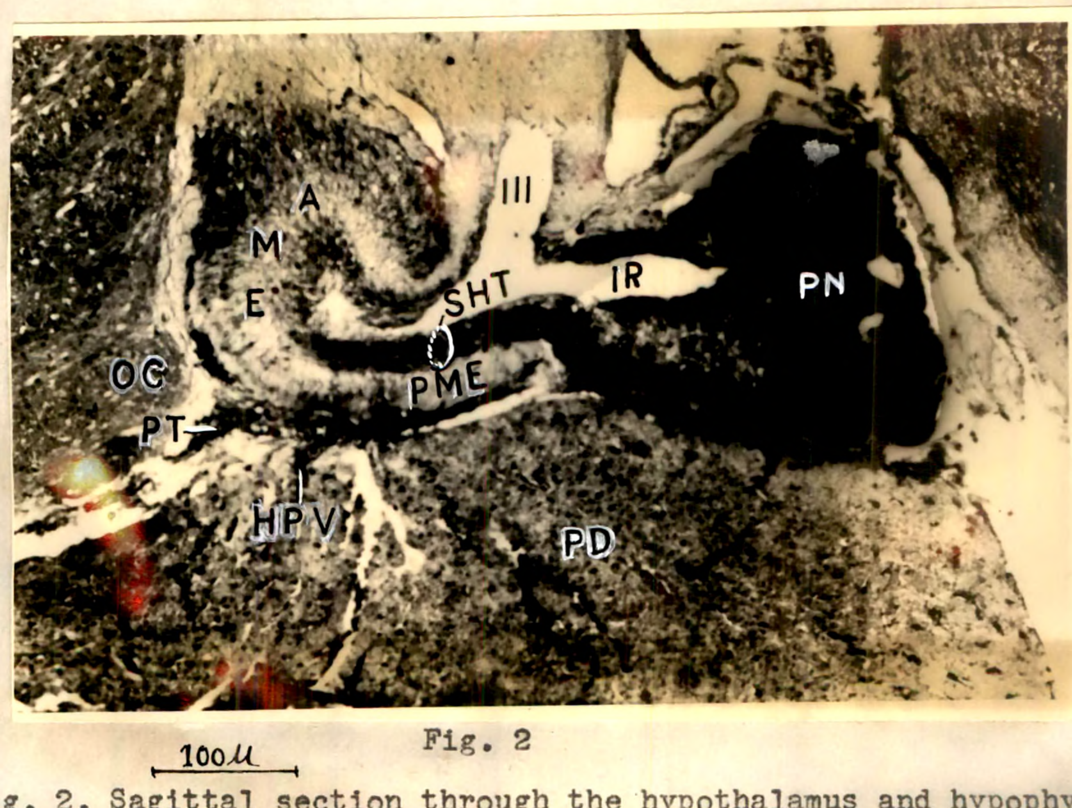
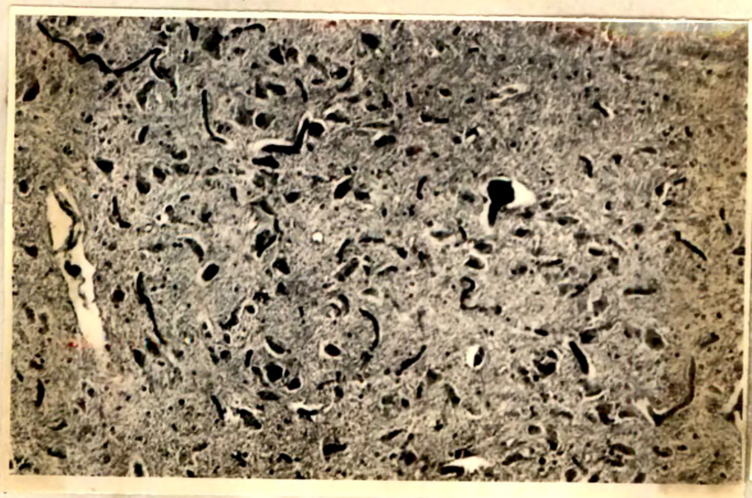
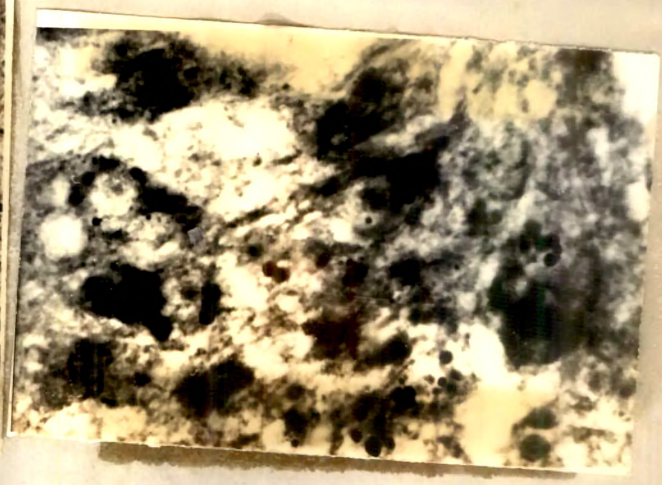


Fig. 2

100 μ

Fig. 2. Sagittal section through the hypothalamus and hypophysis of the Rosy Pastor (last week of April). The median eminence is much enlarged. Abbreviations as in Fig. 1. (Paraldehyde fuchsin stained)



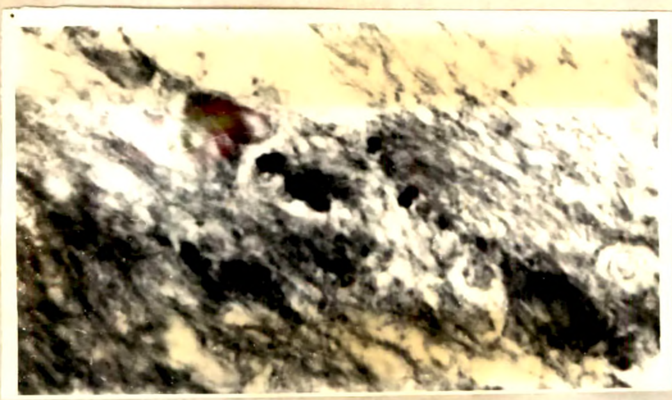


200 µ Fig. 3

Fig. 4 50 µ

Fig. 3. Photomicrograph showing the rich blood supply near the neurosecretory cells of a part of the supraoptic nucleus. (Paraldehyde fuchsin stained)

Fig. 4. Neurosecretory cells of the anterior margin of the optic chiasma. (Paraldehyde fuchsin)



50 µ

50 µ

Fig. 5 Fig. 6

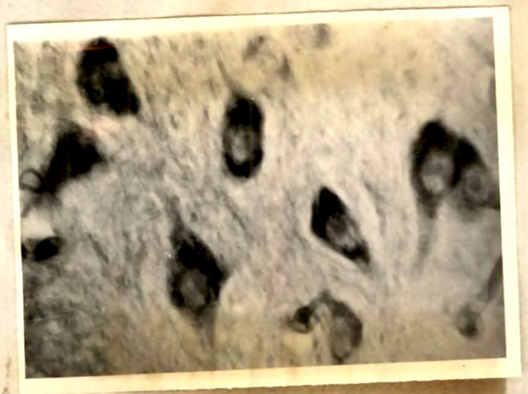
Fig. 5. Neurosecretory cells along the margin of the optic tract showing the large amount of the beaded secretion in the axon. (Aldehyde fuchsin)

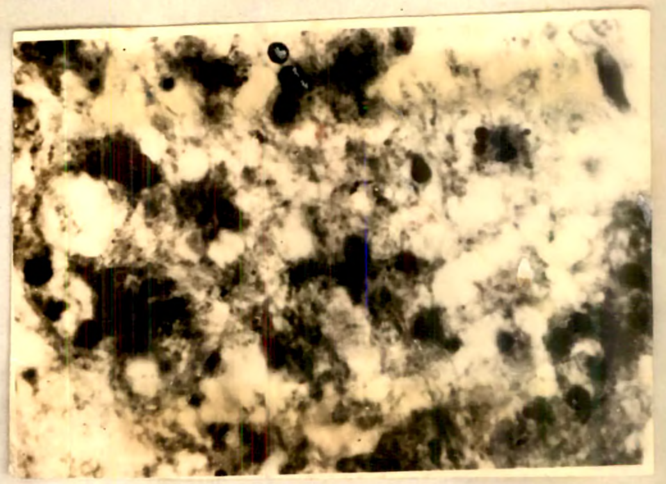
Fig. 6. The lateral supraoptic neurosecretory cells (Peraldehyde fuchsin stained) with full of clumped secretion stored before migration. (Last week of April)

Fig. 7

Fig. 8

Fig. 7. A part of fig. 6 magnified.
Fig. 8. The lateral supraoptic neurosecretory cells (paraldehyde fuchsin stained) having less secretion when compared to that of fig. 7. (February)





50µ

Fig. 9

Fig. 10

Fig. 9. Preopticus neurosecretory cells having secretion on either ends. (Paraldehyde fuchsin stained)
Fig. 10. The neurosecretory cells(paraldehyde fuchsin stained) in the optic recesses with synapsis fully loaded with secretion even in the bipolar fibre. (Third week of April)

the cytoplasm.

The cells of the preopticus are more elongated having a round nucleus and with fine cytoplasmic paraldehyde fuchsin-positive granules. These granules accumulate at either end or are dispersed in the whole cytoplasm of the cell (Fig. 9). The cells present in the optic recess are much elongated many of them of large bipolar type (Fig. 10), and are full of paraldehyde fuchsin-positive secretory granules. Such granules are also seen all along the fibre as well as the synapsis.

Nucleus Paraventricularis:

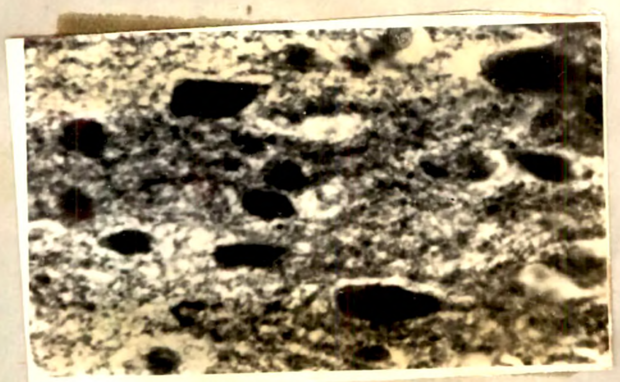
The cells of the paraventricular nucleus are smaller than those of the supraopticus and are present in evenly divided medial and lateral groups. The cells of the medial group are located close to the third ventricle (Fig. 11), while those of the lateral are located anteriorly more to the level of the supraoptic. Seasonal changes in the activity of these cells denoted by the staining reaction obtained, also distinguish them from the other neurosecretory cells (Figs. 12 & 13). The cytoplasm of the medial group of cells is stained more with fast green or light green of the triple stain and is also stained intensely with phloxin. With the methyl green pyronin Y stain the cytoplasm and nucleoli of these cells are deeply stained thereby showing that the cytoplasm as well as the nucleoli are rich in RNA. The cells of the lateral group are comparatively small with spherical nuclei and fewer cytoplasmic granules. At the time of migration there is increased activity of these cells (Figs. 14 & 15). This is denoted by the increase in

100 μ Fig. 11

Fig. 12 50 μ

Fig. 11. Distribution of neurosecretory cells in the medial and lateral parts of the paraventricular nucleus of the hypothalamus. M, medial and L, lateral. (Paraldehyde fuchsin)

Fig. 12. Medial paraventricular neurosecretory cells(Chrome-alum-haematoxylin-phloxin stained). (February)



50 μ Fig. 13

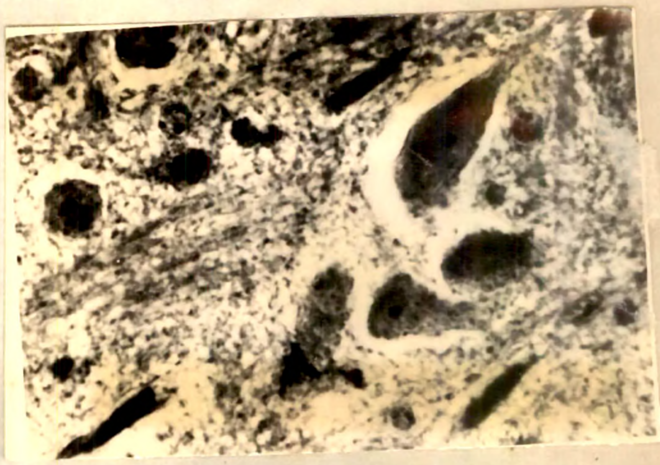


Fig. 14 50 μ

Fig. 13. Medial paraventricular neurosecretory cells(CHP stained) fully loaded with secretion. (Third week of April)

Fig. 14. Lateral paraventricular neurosecretory cells (CHP stained). (February)

size as well as an increase in the number of cytoplasmic granules.

Infundibular Nucleus:

The anterior and posterior infundibular nuclei contain some diffused neurosecretory cells which are small and contain little cytoplasm like those of the paraventricular nucleus. The activity of these cells, however, increased at the time of migration and considerable amount of their secretion is seen in the tractus tubero-hypophysis (Figs. 1 & 2).

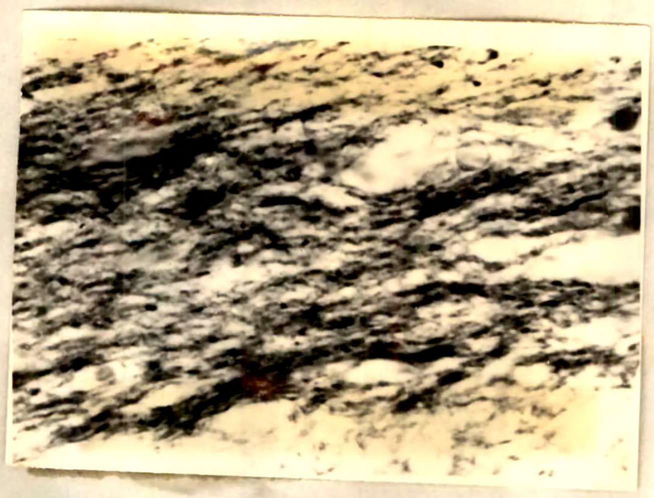
The neurosecretory cells showed a positive reaction for SH-groups when treated with ferric ferricyanide and also for S-S-groups with PFAAB (Adams and Sloper, 1955, 1956). With both the above mentioned reagents the results obtained were more or less the same as with paraldehyde fuchsin as well as Gomori's CHP stains. All the reactions revealed the granular neurosecretory material in the axon fibres, thus rendering it possible to follow up the neurosecretory pathways from the hypothalamus to the posterior pituitary (Fig. 16).

Neurosecretory Pathways:

The neurosecretory pathways were also studied by the same stain and reagents as were used for neurosecretory cells. The neurosecretory pathways from the supraoptic and paraventricular nuclei and the tubero-hypophysis could be detected very easily (Figs. 2). The axons from both the lateral as well as medial groups of the supraoptic nuclei, however, could not be traced completely. The axons of most of the cells of the supraopticus as well as the paraventricular nuclei were observed passing behind the optic chiasma as thick bands of fibrils (Figs. 17 & 18). Some of the fibrils are seen to run into the median eminence and some to pass straight through the upper region of the median eminence towards the pars nervosa and pars tuberalis (Figs, 2 & 19). Under the high power of the microscope the neurosecretory granules could be clearly detected in the axons of the tract. Besides these there are parallel rows of nerve cells on this tract which also joined with these fibres and contribute their secretion to the median eminence, pars nervosa and pars tuberalis. Most of the cells which are found on the tract were very active with full of secretion while the others were empty (Figs. 5 & 10). The secretion in these cells presented a beaded appearance in the axons. The neurosecretory cells of the infundibular nucleus when stained were seen to send their secretion to the tubero-hypophysis and neurohypophysis through their individual tracts (Figs. 1 & 2).

Median Eminence:

Histologically the median eminence consists of two lobes, an anterior one loaded with neurosecretion and a posterior containing little secretion (Figs. 2 & 30). Pronounced cyclic changes were observed in this region. The median eminence contained fine granules of secretion occurring in radial rows referred to as the palisade layer by Kobayashi et al., (1961). At the base of the median eminence are few glial cells which form small clefts near which are present fine blood vessels. Some of these glial cells were very active and contained large nucleus with numerous cyto-



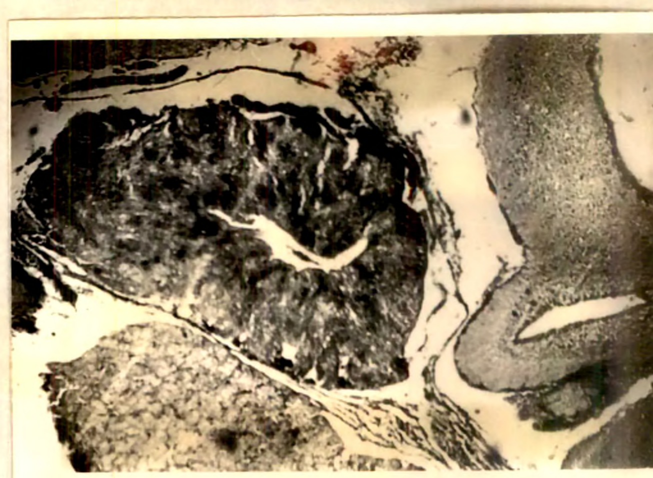


Fig. 15

Fig. 16

Fig. 15. Lateral paraventricular neurosecretory cells (CHP stained). (Third week of April)

Fig. 16. Photomicrograph of the median eminence, posterior and a part of the anterior pituitary in the month of March showing the accumulation of the neurosecretory material.(PFAAB stained)

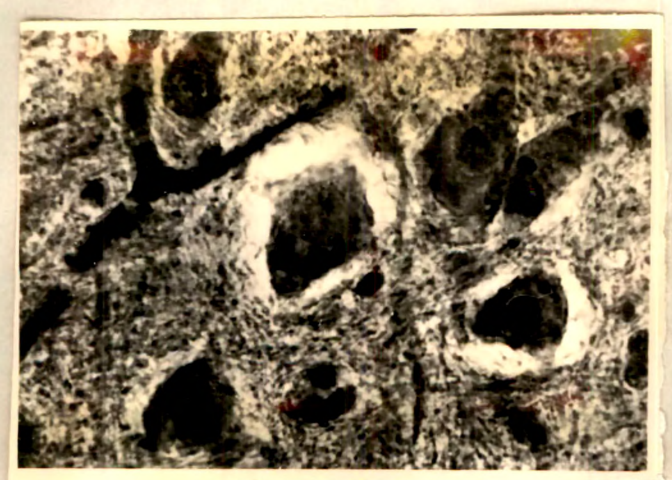


Fig. 17

Fig. 18

Fig. 17. Hypothalamo-hypophysial tract showing the neurosecretory material (Paraldehyde fuchsin stained) in the axon fibres in a beaded pattern. (Just before migration)

Fig. 18. Same as fig.17. (Last week of March)

plasmic granules. Others were small, each with a small nucleus and fewer cytoplasmic granules. Below the base of the median eminence is present a thin band of pars tuberalis (Fig. 2). In this region there are a few layers of epithelial cells probably having some sort of a hormonal secretion. In the palisade layer the upper region contains more glial cells than the lower ones. Above this layer is the fibrous layer of tractus supraoptico-hypophysis through which the neurosecretory material is conducted from the hypothalamus to the pars nervosa. At the entry of the median eminence this bundle separates roughly into two tracts (Fig. 2), one of which proceeds directly to the pars nervosa and the other directed downward towards the palisade layer of the median eminence. Some of the fibres proceed posteriorly in the upper part of the layer while others run to the outer surface of the median eminence. At the inner sections, more neurosecretory granules accumulated so as to form certain characteristic patterns in the distribution of the granules in the median eminence. The fibres which run directly towards the neurohypophysis contain plenty of Herring bodies (Figs. 20, 21 & 22). These fibres stored more secretion at the junctions of the pars nervosa and thus became wider and prominent.

Below the median eminence the fine loops of the neurosecretory axons described by Benoit and Assenmacher (1959) in the duck, are seen. Near these loops are numerous blood capillaries and neurosecretory material was also more in these fibres (Figs. 2, 20 & 22). The transverse section passing through the posterior median eminence in the region of the tractus supraoptico-hypophysis shows more of the secretion which varied in quantity in the different

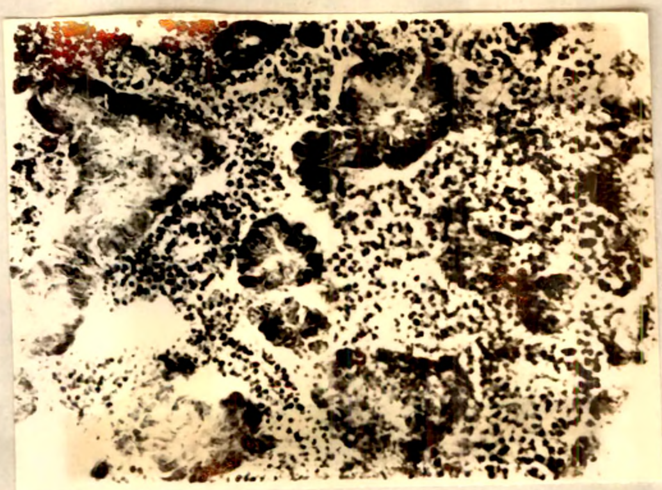


Fig. 19

Fig. 20

Fig. 19. Large accumulation of (P.F.Stained) neurosecretory material in the anterior median eminence. The darkly stained and curved path is the hypothalamo-hypophysial tract containing the neurosecretory material and the secretion seen below in form of radial rows is of the cells of the median eminence. (Last week of April)

Fig. 20. The median eminence showing the Herring bodies (P.F. stained) and the localization of the neurosecretory material. (Third week of April).

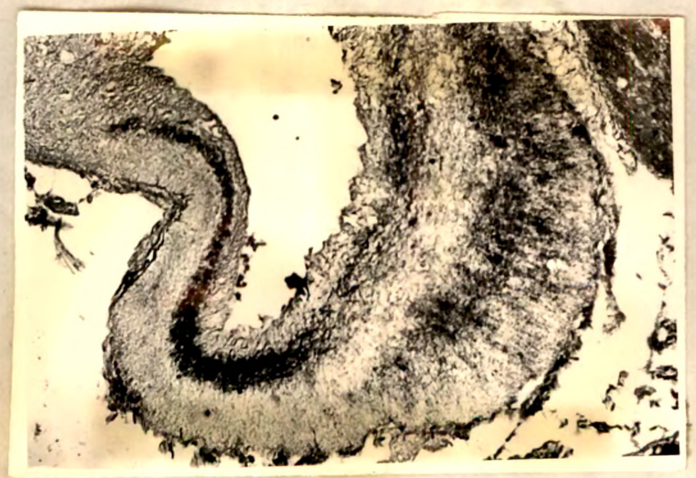


Fig. 21

100 μ

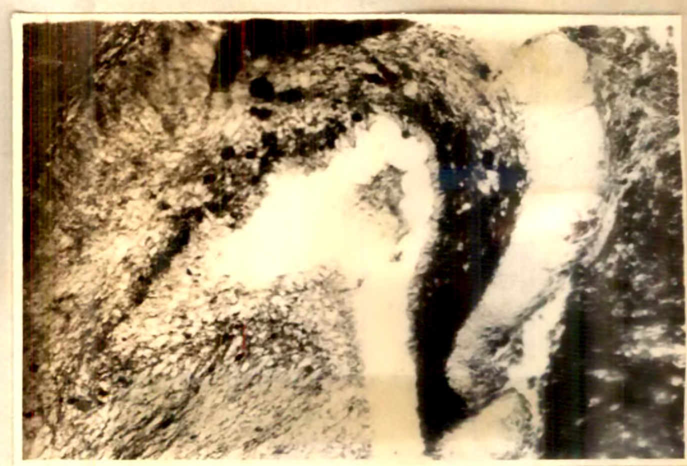


Fig. 22

Fig. 21. Median eminence showing Herrings bodies(P.F.stained). (End of March)

Fig. 22. Median eminence (P.F.stained) showing the Herring bodies with greater accumulation of neurosecretory material (last week of April) than that seen in fig. 21.

seasons. When the secretory activity was low this region contained secretion in the form of granules in radial rows, whereas during high activity numerous large and small Herring bodies were seen (Figs. 20 & 22). From the proximal part of the posterior median eminence some of the nerve fibres enter the anterior pituitary. These axons reach the superficial layer of the anterior pituitary (Fig. 2). Towards the time of migration these axons became prominent with the storage of the secretion while at other times they appeared diffused. These axons are always associated with blood vessels. Some fibres spread themselves on the acini cells of the pituitary while those of the median eminence are very close to the portal system which reaches the hypophysis (Figs. 23, 24 &25).

Pars Tuberalis:

Below the median eminence is present a projected pars tuberalis which is covered over by connective tissue on the ventral side and a net work of blood vessels on the dorsal. Together with blood vessels are also present nerve fibres on the posterior side of the median eminence where it joins the pars nervosa. The pars tuberalis is extended as an outgrowth projecting above the anterior pituitary. The anterior tip of the pars tuberalis is more glandular and the central part is copiously supplied with blood and nerve fibres (Fig. 26).

Infundibular Stalk:

The posterior median eminence is continued further and joins the infundibular stalk (Figs. 1 & 2). There is no special structural difference between the posterior median eminence and

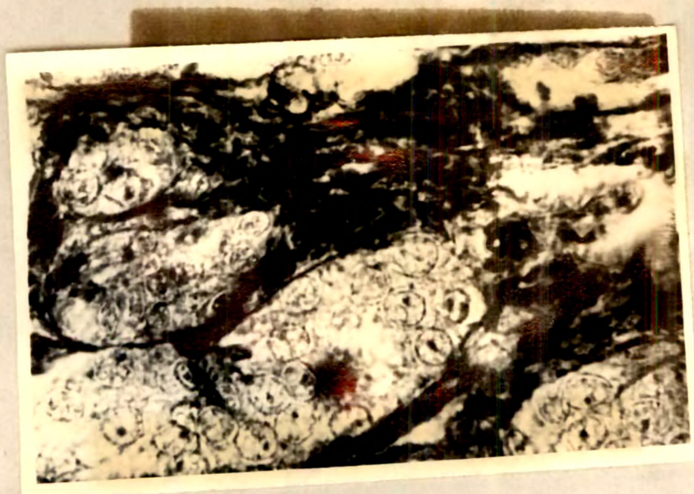
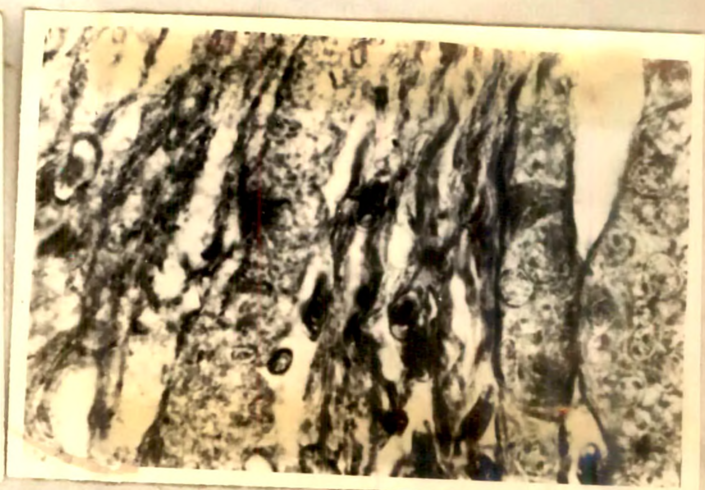


Fig. 23 50μ Fig. 24

Fig. 23. Photomicrograph of the superficial layer of cells (P.F.stained) of the anterior pituitary showing the distribution of neurosecretory material through the axon fibrils. (Last week of April).

Fig. 24. Photomicrograph showing large accumulation of neurosecretory material (P.F.stained) outside the acini cells of the anterior pituitary. (Last week of April)



50μ Fig. 25

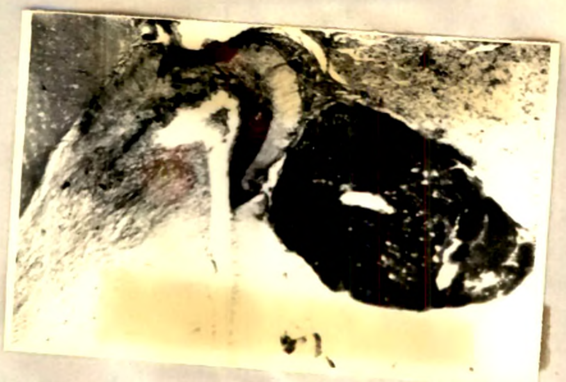
Fig. 26 100μ

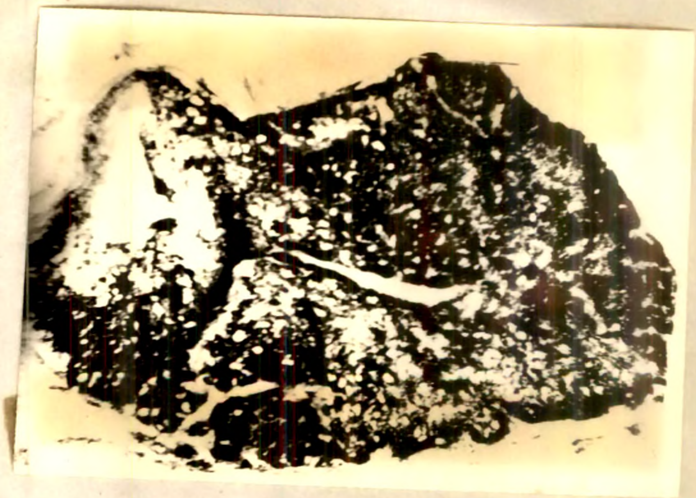
Fig. 25. Same as fig. 23. Fig. 26. Photomicrograph of the projected pars tuberalis (PT) showing the blood supply and the neurosecretory material in the central It is attached to the pars nervosa on the right and the anterior pituitary is seen below.

the infundibulum. It includes the tractus supraoptico-hypophysis containing fine neurosecretory granules and the Herring bodies. Near the pars nervosa the infundibular stalk forms a tube where the neurosecretory fibres pass around the infundibular recess. The glial cells are also present in the infundibular stalk. The amount of neurosecretory material in this region is subjected to considerable seasonal variation.

Pars Nervosa:

The pars nervosa in this bird corresponds to the pars nervosa of the second type described by Wingstrand (1951) and Oksche et al., (1959). The narrow infundibular recess is continued into the lumen of the pars nervosa (Fig. 2), which is subdivided into several large and small chambers. The wall of the lumen is covered by the ependymal cells and the glial pituicytes. The secretory storage activities of the pars nervosa showed seasonal variation. Where there was greater activity, ependymal as well as glial pituicytes became large and compact with more secretion. At the same time the lumen of the pars nervosa provided additional space for the active cells and thus the lumen got considerably reduced. The neurohypophysis thus became extremely active showing considerable increase in vascularization and secretion (Figs. 27, 28 & 30). The secretion of the ependymal and glial pituicytes were similar to those of the median eminence. The pituicytes near the blood vessels were bigger and contain large amounts of the secretion. The cell bodies of some of them are in direct





300 μ Fig. 27

100 μ Fig. 28

Fig. 27. The hypothalamo-hypophysial tract showing the ample neurosecretory material (P.F.stained) in the median eminence and the posterior pituitary. (Third week of April)

Fig. 28. Photomicrograph showing the depletion of the neurosecretory material (P.F.stained) 3-4 days prior to migration as is indicated by the numerous empty spaces.

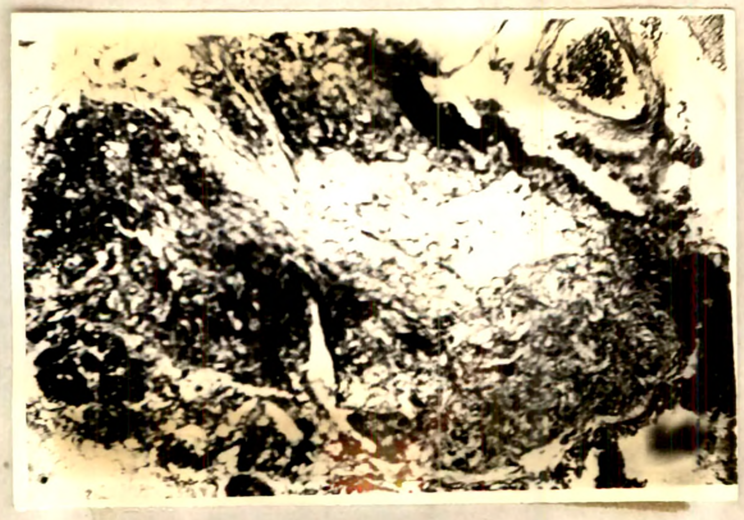


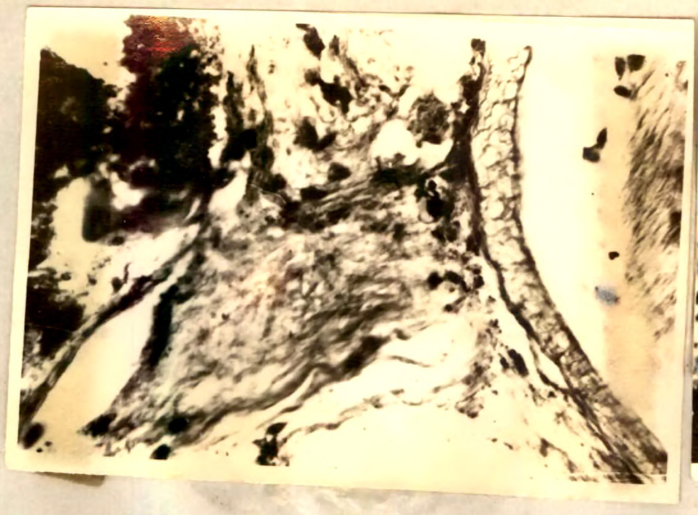
Fig. 29 100 μ

Fig. 29. Photomicrograph showing the depletion of neurosecretory material in the posterior pituitary of the sodium chloride treated pigeon. The empty spaces denote lack of secretion. (For comparison with Fig. 28, Paraldehyde fuchsin stained)

contact with the blood vessels but most of t ire located at a considerable distance from the blood vesse d thus possess extended axons (Figs. 30 & 31). Some of the e fibres run parallel to the blood vessel inside as well a itside the neurohypophysis. In some places these nerve fibres ipear to end blindly accumulating the secretion in the regi i of the large as well as small blood vessels (Fig, 31). In s ae places the axon fibres were seen to bulge out and the secretion was in clumps. In places where these fibres extended out towards the blood vessels in the neurohypophysis, the store of secretion was scanty and empty spaces without secretion were seen. The existence of these empty spaces was not due to the absence of pituicytes. These cells did exist but contain very little cytoplasm. However, when secretory activity was resumed these spaces were again filled with secretion.

Neurosecretory Material:

The neurosecretory material in cells, axons and storage depots was studied using different stains and reagents. Most satisfactory results were obtained with paraldehyde fuchsin, PFAAB for S-S- groups and ferric ferricyanide for SH- groups. Equally good results were obtained with these three reactions in locating the neurosecretory material in the cells as well as axons, median eminence and neurohypophysis. However, with Gomori's CHP method, the intensity of staining was moderate towards the migratory phase. Especially in the paraventricularis there was pronounced increase in the phloxin staining. Similar increase in the intensity of staining was obtained in the same region with light green and fast green of the Mallory's triple stain. When tested for RNA

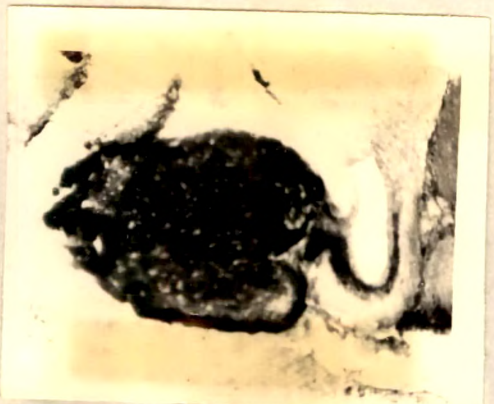


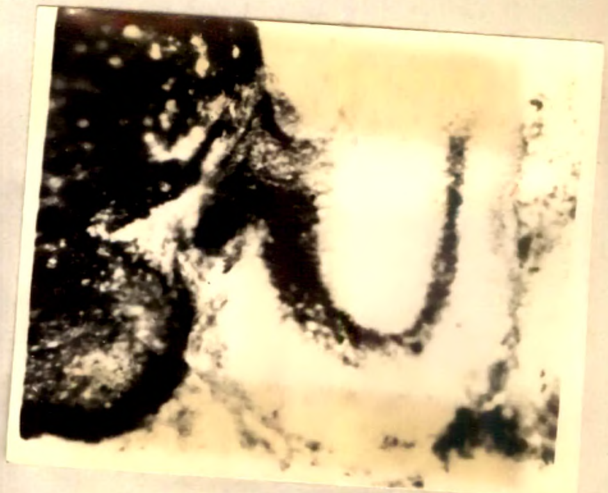
100 µ Fig. 30

Fig. 31 50 µ

Fig. 30. Photomicrograph showing depletion of the neurosecretory material (P.F. stained) in the posterior pituitary 3-4 days prior to migration. The beaded structure nerve fibres indicate the conduction of the neurosecretory material towards the blood vessel where it is seen accumulated.

Fig. 31. A portion of fig. 30 magnified.





300 µ

Fig. 32

100 µ Fig. 33

Fig. 32. Photomicrograph of a sagittal section through the median eminence and the posterior pituitary(last week of March) showing less secretion(paraldehyde fuchsin stained).

Fig. 33. A portion of fig. 32 magnified.

with methyl green pyronin Y this region was intensely stained indicating the presence of large amount of RNA. With PAS staining, however, there was no reaction in the neurosecretory cells as well as in the median eminence and neurohypophysis.

Cyclic changes in neurosecretion:

Observations on the hypothalamo-hypophysial neurosecretory system in the Rosy Pastor were made from October to April (both months inclusive). Neurosecretory activity was found to be less in the supraoptic and paraventricular nuclei, the median eminence and the neurohypophysis during the period October to November. Thereafter there was a slight increase in the secretion in these parts which lasted upto February. There was no perceptable change from February to the end of March(Figs. 16, 32, 33 &34). From the last week of March there was sudden increase in neurosecretory activity and storage. This increase was particularly high in the supraopticus and paraventricularis nuclei and the tractus tubero-hypophysis. The neurosecretory cells become slightly large with increase in the content of the nucleus, nucleolus and the cytoplasm. The axons of all these cells were completely filled with the secretion and in most of them the secretion had a beaded appearance. It was therefore easy to trace the hypothalamo-hypophysial tract. In this particular phase all the axons contained their secretion in the whole of the neural tract from the optic chiasma and the tractus tubero-hypophysis became clearly discernible (Figs. 2, 20, 35). Simultaneously RNA in all the cells increased slightly but the maximum

Fig. 34

Fig. 34. T.S. of the median eminence(last week of March) showing considerably less of the neurosecretory material(paraldehyde fuchsi

Fig. 35

100 μ

Fig. 35. T.S. of the median eminence(third week of April) showing increase in the amount of the neurosecretion in the tract as well as in the median eminence (paraldehyde fuchsin stained).

increase was seen in the paraventricularis. The S-S- and SH-groups as well as the paraldehyde fuchsin-positive material in these cells also increased. In the anterior median eminence the glial cells synthesized considerably more of the secretion and at the same time there was an overall increase in the neuro-secretion transported from the supraopticus and paraventricularis nuclei. In the posterior part of the median eminence also accumulation of the secretion caused an increase in number as well as the size of the Herring bodies (Figs. 20 & 22). In the third week of April the posterior part of the median eminence as well as the pars nervosa accumulated maximum amount of neurosecretion. Most of the fibres leading to the adenohypophysis from the median eminence became conspicuous with the abundant flow of the secretion. In the region of the median eminence there was increased portal circulation. An increase in the number of axon fibres containing maximum secretion in them was also noted. This suggests the possibility of increased diffusion of neurosecretion into the portal ciculation for direct transport to the adenohypophysis. Towards the end of the premigratory phase the accumulation of neurosecretory material reached the maximum level in the cells, tracts and also in the neurohypophysis where this material was finally mobilized. In the final stage the neurosecretory material was released and rapidly dispersed into the different parts of the adenohypophysis through the axons and also the blood stream.

Discussion

The observations reported in this paper have confirmed the observations of others in other species of birds that the neurosecretory material appears with considerable regularity in the neurons of the supraopticus, paraventricularis and the posterior division of the infundibular nuclei (Wingstrand, 1951; Bargmann and Jacob, 1952; Stutinsky, 1955, 1958; Duncan, 1956; Laws, 1961; Kobayashi et al., 1962).

Wingstrand (1951) observed in the pigeon brain, that the tractus supraopticohypophysis originated from the large cells of the supraoptic nucleus and the tractus hypophysis anterior including fibres leaving from the paraventricular nucleus. He stated that these tracts proceed to the pars nervosa through the median eminence. Scharrer and Scharrer (1954) and Benoit and Assenmacher (1955), also opined that these fibres originated from the supraoptic and paraventricular nuclei, proceeded further to be in close association with the net work of blood vessels around the median eminence and then continued to the pars nervosa. Benoit and Assenmacher (1959) have pointed out in the duck that numerous fibres of the tractus supraopticohypophysis end in loops around the blood vessels in the median eminence. Associated with these loops are present the Gomori-positive granules. Oksche et al., (1959) observed that in the white crowned sparrow, due to lack of neurosecretory material in the proximal part of the axon, this part of the axon was rarely detectable. Farner and Oksche (1962) in their recent review have pointed out that the exact origins of the neurosecretory tracts in birds are much more difficult to ascertain than in other groups of vertebrate animals. According to them, in many species it is not possible to detect neurosecretory material in the proximal part of the axon of the neurosecretory ganglionic cells because they are scattered among the fibres of other tracts and that it is only possible to trace the neurosecretory tracts at the level of the posterior margin of the optic chiasma. They have also mentioned that the differentiation between a supraoptico-hypophysis tract and a paraventricular hypophysial tract is possible only in species such as the domestic fowl and Coturnix coturnix which possess a well developed paraventricular nucleus and in which a marked selective staining of neurosecretory material in the proximal section of the axons, is possible.

In the present study , however, it was possible to trace many nerve fibres from the supraopticus and paraventricularis forming a large bundle of nerve fibres. Behind the optic chiasma these fibres proceeded straight upto the median eminence. In some enlarged neurosecretory cells behind the optic chiasma, a large amount of secretion which was carried into their axons was observed. These axons also joined the fibres of the supraopticus and paraventricularis on the anterior part of the median eminence. Majority of the nerve fibres directly entered the infundibulum and then the pars nervosa. Towards the time of migration the secretion was considerably increased and the whole tract of nerve fibres were loaded with it. Some of the fibres in the median eminence turned towards the ventral side of the median eminence to form a net work along with the blood capillaries. A few fibres entered the pars distalis and spread themselves in the peripheral part of the adenohypophysis carrying in them fine granular secretion. These fibres carrying neurosecretory material to the pars distalis cells could be clearly distinguished from connective tissue fibres.

Wingstrand (1951) observed that since no direct hypothalamic innervation of the pars distalis and vascular connection between the posterior lobe and the pars distalis could be seen, the adenohypophysial and neurohypophysial components of the hypophysis are anatomically separate entities. But Metuzals (1955, 1956), pointed out that in the duck there are hypothalamic nerve fibres which penetrate the pars distalis. Green (1951a) failed to observe nerve fibres in the pars distalis in any of the large number of species investigated. Stutinsky (1958) on the other hand detected the penetration of nerve fibres from the infundibulum into the pars tuberalis of the adenohypophysis. Okamota and Ihara (1960) pointed out that there are neurosecretory fibres from the neural lobe which penetrate into the adenohypophysis in the domestic fowl. The penetration of nerve fibres from the median eminence, infundibulum and pars nervosa into the adenohypophysis and the projected pars tuberalis were also seen clearly in the Rosy Pastor. The supply of neurosecretion through the axon fibrils from the anterior median eminence as well as from the infundibulum was more clearly seen at the time of migration in the form of very fine granules. From the present work, it can be concluded that the majority of fibres of the tractus supraopticohypophysis and tractus tuberohypophysis joined the portal circulation of the anterior median eminence and then terminate in the adenohypophysis as already described. While some fibres enter the pars tuberalis which is immediately below the median eminence, the rest of them go to the pars nervosa.

In the Rosy Pastor too, the median eminence could be clearly divided morphologically into two parts as observed in the case of the white crowned sparrow (Oksche _et_ _al_., 1959). The anterior median eminence is rich in neurosecretion while the posterior part contains very little. These two parts of the median eminence is clearly demonstrated by shallow clefts. The above workers, however, did not find considerable activity in the posterior median eminence unlike in the anterior median eminence. In the present work, however, substantial amounts of secretory material subject to seasonal variation, was found to be present in the two parts of the median eminence. The anterior median eminence in the Rosy Pastor is capable of both secretion as well as storage. In the period September to March end, there was no detectable difference in the secretory activity between the anterior and posterior parts of the median eminence. However, there was a tremendous increase of neurosecretory material in the tract as well as in the glial cells of the anterior median eminence. It should be specially mentioned that the posterior median eminence was filled with the secretion and showed the presence of large Herring bodies (Figs. 20 & 22). This increased storage prior to migration was completely depleted just a few days before migration. A depletion in the neurosecretory material was also noticed in the neurohypophysis during the same time (Figs. 28 & 30).

Studies of the portal blood vessels has been carried out by Assenmacher (1951, 1952) in the duck, Wingstrand (1951) and Grignon (1956) in the domestic fowl. The portal circulation of the pigeon is supplied by a special infundibular artery and the drainage is into the venous sinus (Wingstrand, 1951). The pars tuberalis of the adenohypophysis not only covers the capillary region but rostrally and in part also caudally. In the case of the Rosy Pastor the blood capillaries along with the nerve fibres from the anterior median eminence enter the adenohypophysis.

Assenmacher and Benoit (1958) reported the presence of ganglionic cells in the hypothalamus of the duck, containing small amounts of paraldehyde fuchsin-positive materials. They suggested that the bulk of the substance came from the supraoptic and paraventricular nuclei while the rest of it from the tuberal and infundibular nuclei. In Zonotrichia leucophrys gambelii, Farner and Oksche (1962) found no evidence of neurosecretory material in the tuberal and infundibular regions. But in the Rosy Pastor the material was definitely present in this region and increased considerably towards migration.

The release of neurosecretory material from the neurohypophysis as well as the median eminence just a few days prior to migration, may be compared with the release of the material in the NaCl administered pigeons. NaCl brings about dehydration of the body thereby subjecting the animal to a state of stress.

In the rosy pastors, the release of the neurosecretory material from the median eminence and neurohypophysis was quickly followed by changes in the other endocrine systems described in other chapters (3, 4, 7 and 9). This release of the neuro-secretory material is therefore to be regarded as the trigger for migration, which takes place within three or four days prior to migration. The above mentioned sequence of events has been observed in both male and female birds but in the latter the whole process is delayed by five or six days. According to the statistical data available, the males migrate about five to six days earlier than the females.

Summary

1. The hypothalamo-hypophysial neurosecretory system, in a migratory starling, Sturnus roseus, was studied in the different months from October to April with special reference to the premigratory phase.

2. The neurosecretory centres consist of paired supraoptic and paraventricular nuclei and the anterior and posterior divisions of the infundibular nuclei. The different types of cells in each of the nuclei are described. These neurosecretory cells stain SH- and S-S-groups positive. The paraventricular median group of neurosecretory cells show increased staining for phloxin and light green positive material as well as RNA towards migration. The anterior and posterior infundibular nuclear cells become highly secretory towards the migratory phase and the secretion is carried by the tracts into the median eminence as well as the pars nervosa. The significance of the cyclic changes in the neurosecretory activity of the different regions, is discussed.

3. The neurosecretory axonal tracts arising in the nuclei proceed first towards the median eminence and the hilar region and branch into two tracts. One tract proceeds directly to pars nervosa along with the anterior infundibular tract from the upper region of the median eminence and terminates in the pars nervosa. The other tract proceeds to the lower surface of the median eminence. Some fibres terminate in this region, while others enter the region of the acini cells in the anterior pituitary and the pars tuberalis, closely running parallel to the blood vessels and terminate there.

4. The anterior median eminence like pars nervosa is a region where neurosecretory material is secreted as well as stored. The posterior median eminence on the other hand is mainly a site for the storage of the neurosecretory material which accumulates considerably towards migration.

5. Pars nervosa is a region for secretion and storage of the neurosecretory material. Prior to migration this organ is completely packed with the neurosecretory material and its release through the nerve fibre ending at the blood vessels is observed three to four days prior to migration. Another site where the material is released is the region of blood sinuses and the acini cells in the anterior pituitary.

6. The release of neurosecretory material is compared to a similar release of neurosecretion in NaCl administered pigeons. The release of the neurosecretory material before migration is considered as a trigger for the coordinated action of other endocrine glands in migration.