CHANGES IN THE
NUCLEIC ACID AND PROTEIN COMPOSITION OF THE
NASAL GLANDS FROM THE DUCK (ANAS
PLATYRHYNCHOS) DURING THE PERIOD OF
ADAPTATION TO HYPERTONIC SALINE*

BY W. N. HOLMES AND D. J. STEWART†
Department of Biological Sciences, University of California
Santa Barbara, California 93106

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INTRODUCTION

The early observations of Heinroth & Heinroth (1927) established that the nasal
glands in the marine eider duck (Somateria mollissima) were reduced in size when the
birds were given fresh water. These experiments were later confirmed in the domestic
duck and the glaucous-winged gull, Larus glaucescens, (Schildmacher, 1932; Holmes,
significance of the earlier observations, however, was not realized until 1958 when
Schmidt-Nielsen, Jørgensen and Osaki described the presence of an extra-renal
excretory pathway associated with the nasal glands in marine birds. The glands were
shown to excrete a fluid which contained sodium, potassium and chloride at higher
concentrations than those found in sea water. Clearly, in the absence of an adequate
renal concentrating mechanism, this excretory pathway would enable the birds to
gain osmotically free water and at the same time excrete the excess salt.

The nasal glands of the freshwater-maintained duck are inactive but the excretory
mechanism may be initiated within a few minutes after the administration of hyper-
tonic saline (Scothorne, 1958; Holmes, Phillips & Butler, 1961). If the birds are
maintained on a diet of hypertonic saline or sea water then the excretory capacity of
the nasal glands is enhanced (Fletcher, Stainer & Holmes, 1967) and simultaneously
certain structural and enzymic changes occur in the nasal gland tissue (Ellis, Goertem-

The recent studies on nucleic acids have begun to elucidate their role in the control
of protein synthesis. The changes known to occur in the developing nasal gland would
seem to implicate the nucleic acids in the control mechanisms associated with the
development of the gland and its associated active sodium-transport system. The
purpose of the present investigation, therefore, was to determine the nature of the
gross changes occurring in the protein and nucleic acid composition of the nasal
glands during the period of adaptation to a hypertonic saline diet.

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† N.D.E.A. (Title IV) pre-doctoral fellow.
MATERIALS AND METHODS

White Pekin drakes, 7 to 9 weeks old, were obtained from a commercial supplier and were maintained outdoors for at least 1 week before use. During this period each bird received an ad libitum supply of fresh water (2.0 mM/l. sodium, 0.07 mM/l. potassium) and throughout the experimental period all birds received a daily ration of 200 g. chicken grower food mixed with 310 ml tapwater.

At the beginning of the experiment a group of birds were given hypertonic saline (284 mM/l. sodium, 6.0 mM/l. potassium) as their only source of drinking water and birds were killed at intervals during the subsequent 28 days. For convenience this phase of the experiment is referred to as the 'period of adaptation'. At the end of the 28-day period of adaptation the remaining birds were returned to the freshwater dietary regimen and birds were killed at intervals during the next 22 days. This phase is termed the 'period of de-adaptation'. The birds which still remained were then returned to the saline diet and were killed at the end of 24 hr. This phase of the experiment is called the 'period of re-adaptation'. Birds of the same age class which had never been exposed to saline were killed at the beginning, after 14 days and at the end of the 51-day experimental period.

All ducks were starved for 20 hr. prior to being killed by decapitation. The nasal glands were removed immediately, trimmed of adhering connective tissue and weighed. The glands were then briefly chilled, sliced and approximately 150 mg. portions were stored in vials at −26°C. Preliminary studies indicated that samples of nasal gland tissue could be stored in this manner for periods up to 60 days without incurring any significant change in nucleic acid or protein composition. In a separate experimental series the liver, kidneys, adrenal glands, Harderian glands and samples of whole blood were taken and similarly stored from birds which had been maintained on fresh water and saline for 14 days.

Within a few days the ribonucleic acid (RNA), deoxyribonucleic acid (DNA) and protein were extracted from the tissue samples according to a modification of the Schmidt-Thannhauser technique (Munro & Fleck, 1966). The RNA concentration was estimated by ultraviolet absorption at 260 μM (Fleck & Begg 1965) using purified torula yeast RNA, (grade VI, Sigma chemicals) as a standard. The DNA concentration was estimated by the indole reaction of Ceriotti (1952) using pollock roe DNA (sodium salt, type VI, Sigma) as a standard. Protein concentration was estimated by the phenol method of Daughaday (1952) using bovine albumin (fraction V, grade B, Calbiochem) as a standard.

RESULTS

The weights of liver, kidney, adrenal and Harderian glands from freshwater-maintained birds did not differ significantly from the corresponding values obtained from birds maintained on saline for 14 days (Table 1). Furthermore, the RNA, DNA and protein concentrations of these tissues and of whole blood were the same in the two groups of birds (Table 1).

Freshwater-maintained birds of the same age class which were killed at the beginning, after 14 days and at the end of the experiment did not show any changes in the RNA, DNA and protein concentrations of the nasal gland tissue with time.
Table 1. Various organ weights and tissue concentrations of RNA, DNA and protein in freshwater-maintained and saline-maintained ducks (Anas platyrhynchos)

(Each bird was maintained for 2 weeks on a daily ration of 200 g. dry food mixed with 310 ml. fresh water and an *ad libitum* supply of fresh water (2.0 mM Na, 0.07 mM K) or saline (284 mM Na, 6.0 mM K). The birds were starved for 24 hr. prior to autopsy. All values are expressed as means ± S.E.)

<table>
<thead>
<tr>
<th>Tissue</th>
<th>No. of birds</th>
<th>Treatment</th>
<th>Organ weight (g./kg. body weight)</th>
<th>Concentration (mg./g. wet weight of tissue)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liver</td>
<td>6</td>
<td>Fresh water</td>
<td>18.6 ± 0.6</td>
<td>RNA 9.78 ± 0.36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Saline</td>
<td>18.2 ± 0.7</td>
<td>RNA 9.86 ± 0.26</td>
</tr>
<tr>
<td>Kidney</td>
<td>6</td>
<td>Fresh water</td>
<td>7.29 ± 0.26</td>
<td>RNA 5.05 ± 0.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Saline</td>
<td>6.98 ± 0.24</td>
<td>RNA 4.80 ± 0.09</td>
</tr>
<tr>
<td>Adrenal</td>
<td>6</td>
<td>Fresh water</td>
<td>0.677 ± 0.0048</td>
<td>RNA 4.59 ± 0.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Saline</td>
<td>0.739 ± 0.0039</td>
<td>RNA 4.64 ± 0.13</td>
</tr>
<tr>
<td>Whole blood</td>
<td>6</td>
<td>Fresh water</td>
<td>--</td>
<td>RNA 0.504 ± 0.007</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Saline</td>
<td>--</td>
<td>RNA 0.496 ± 0.006</td>
</tr>
<tr>
<td>Harderian gland</td>
<td>6</td>
<td>Fresh water</td>
<td>0.472 ± 0.017</td>
<td>RNA 7.66 ± 0.59</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Saline</td>
<td>0.505 ± 0.034</td>
<td>RNA 7.91 ± 0.27</td>
</tr>
</tbody>
</table>

Fig. 1. Percentage change in the wet weight and protein content of nasal glands from the duck (*Anas platyrhynchos*) during the period of adaptation to saline and freshwater regimens. (Each bird received a daily ration of 200 g. dry food mixed with 310 ml. fresh water and an *ad libitum* supply of saline (284 mM Na, 6.0 mM K) or fresh water (2.0 mM Na, 0.07 mM K) and all birds were starved for 24 hr. prior to autopsy. Each point represents the mean value obtained from a minimum of three birds. All values are expressed as percentage change from the corresponding freshwater value.)
A 78% increase in the wet weight of the nasal glands occurred during the first 24 hr. after exposure to saline. This increase continued at a somewhat slower rate until the 14th day when the maximum gland size was attained. The protein concentration of these nasal glands did not differ from those of the freshwater birds during the first 24 hr., but at the 7th and 14th days after exposure to saline a significant increase in the protein concentration was observed (Table 2). On the 7th and 14th days of the period of adaptation, therefore, the percentage increase in nasal gland protein was significantly higher than the percentage increase in nasal gland wet weight ($P < 0.001$).

### Table 2. The body weights and nasal gland weights and protein composition of the nasal glands from ducks (Anas platyrhynchos) maintained for various times on saline and freshwater regimens

(Each bird received a daily ration of 200 g. food mixed with 310 ml. fresh water and an *ad libitum* supply of either fresh water (2.0 mM Na, 0.07 mM K) or saline (284 mM Na, 6.0 mM K). During the period of adaptation the birds were maintained on saline and individuals were killed at the times indicated. After 28 days the birds were returned to fresh water and again individuals were killed at various times during the 22-day period of de-adaptation. The remaining birds were returned to saline and killed after a 24 hr. period of re-adaptation. All birds were starved for 24 hr. prior to autopsy. Values are expressed as means ± S.E.)

<table>
<thead>
<tr>
<th>Period of adaptation</th>
<th>No. of birds</th>
<th>Body weight (kg.)</th>
<th>Nasal gland weight (mg.)</th>
<th>Relative nasal gland weight (g./kg. body weight)</th>
<th>Protein concentration (mg./g. wet weight)</th>
<th>Total protein (mg./kg. body weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 hr.</td>
<td>12</td>
<td>2.69 ± 0.09</td>
<td>333 ± 15</td>
<td>0.123 ± 0.005</td>
<td>0.28 ± 0.015</td>
<td>15.7 ± 0.015</td>
</tr>
<tr>
<td>7 days</td>
<td>3</td>
<td>2.68 ± 0.08</td>
<td>667 ± 15</td>
<td>0.233 ± 0.015</td>
<td>0.28 ± 0.015</td>
<td>16.0 ± 0.015</td>
</tr>
<tr>
<td>14 days</td>
<td>9</td>
<td>2.37 ± 0.10</td>
<td>773 ± 15</td>
<td>0.293 ± 0.028</td>
<td>0.31 ± 0.015</td>
<td>16.3 ± 0.015</td>
</tr>
<tr>
<td>28 days</td>
<td>4</td>
<td>2.65 ± 0.12</td>
<td>720 ± 15</td>
<td>0.315 ± 0.028</td>
<td>0.31 ± 0.015</td>
<td>16.5 ± 0.015</td>
</tr>
<tr>
<td>9 days</td>
<td>14</td>
<td>2.30 ± 0.13</td>
<td>503 ± 15</td>
<td>0.201 ± 0.014</td>
<td>0.21 ± 0.014</td>
<td>14.9 ± 0.014</td>
</tr>
<tr>
<td>22 days</td>
<td>9</td>
<td>2.47 ± 0.18</td>
<td>504 ± 15</td>
<td>0.213 ± 0.016</td>
<td>0.21 ± 0.016</td>
<td>15.2 ± 0.016</td>
</tr>
<tr>
<td>28 days</td>
<td>4</td>
<td>2.74 ± 0.10</td>
<td>720 ± 15</td>
<td>0.320 ± 0.028</td>
<td>0.32 ± 0.016</td>
<td>15.5 ± 0.016</td>
</tr>
</tbody>
</table>

During the first 4 days of the period of de-adaptation there was a significant and abrupt parallel decline in both the wet weight and the protein content of the nasal glands when compared to the freshwater controls. This decline was less pronounced during the next 18 days and at day 22 both values were approximately 40% higher than the freshwater values ($P < 0.001$). The protein concentration of the nasal gland tissue, however, remained unchanged during this period (Table 2).

Upon re-adaptation of the birds to saline the increment in wet weight and protein content of the nasal gland was similar to that observed during the period of adaptation. These values were initially higher at day 22 of the period of de-adaptation and therefore the increments when expressed as a percentage of the freshwater values appeared
greater than the corresponding increases observed during the period of adaptation (cf. Fig. 1 and Table 2). The protein concentration of the nasal gland tissue did not differ from either the freshwater value or the value observed at the end of the period of de-adaptation (Table 1).

**DNA composition** (Figs. 2 and 3)

During the first 24 hr. of exposure to saline the total DNA content of the nasal glands showed a 30% increase over the freshwater values. This increase continued, although at a somewhat slower rate, until the 7th day when the total DNA content was 56% higher than that of the control nasal glands. Throughout the remainder of the period of adaptation no significant change occurred in the total DNA composition of the nasal glands (Table 3). The concentration of DNA declined very markedly during the first 24 hr. and throughout the remaining period of adaptation the concentration remained approximately 40% below that observed in the glands from freshwater birds.

When the birds were returned to fresh water the total DNA content of the nasal glands remained approximately 45% higher than the original freshwater level. Also, at no time during the 22-day period of de-adaptation was the value significantly different from the values observed during the period of adaptation. The DNA concentration, however, showed a steady rise throughout the period of de-adaptation until at 22 days the concentration equalled the initial freshwater value (Table 3).

During the 24 hr. period of re-adaptation to saline no significant increase in the total DNA content of the nasal glands occurred. Simultaneously, the concentration
of DNA in these nasal glands showed a 27% decline compared to the freshwater value, a reduction similar to that observed during the first 24 hr. of the period of adaptation (Table 3).

![Percentage changes in total RNA and DNA contents of nasal glands](image)

**Fig. 3.** Percentage changes in the total RNA and DNA contents of nasal glands from the duck (*Anas platyrhynchos*) during the period of adaptation to saline and freshwater regimens. (Each bird received a daily ration of 200 g. dry food mixed with 310 ml. fresh water and an *ad libitum* supply of saline (284 mm Na, 6.0 mm K) or fresh water (2.0 mm Na, 0.07 mm K) and all birds were starved for 24 hr. prior to autopsy. Each point represents the mean value obtained from a minimum of three birds. All values are expressed as percentage change from the corresponding freshwater value.)

**RNA composition (Figs. 2 and 3)**

The total RNA content of the nasal glands commenced to increase very soon after the birds were exposed to saline. At hour 9 of the period of adaptation the total RNA content was 61% higher than in the freshwater controls, and by 24 hr. a maximum increase of 145% had occurred. This high level was sustained until day 7 when a slight decline commenced and continued throughout the remainder of the period of adaptation. The concentration of RNA in the nasal glands increased by 45% during the first 24 hr. of exposure to saline and steadily declined thereafter until at day 14 the concentration was only slightly, but significantly, higher than in the freshwater control (Table 3).

During the first 4 days of the period of de-adaptation the total RNA content of the nasal glands declined to a level which was approximately 35% higher than the initial freshwater level. This somewhat higher RNA content was significantly different from the freshwater value (*P* < 0.01) and was sustained throughout the remainder of the period of de-adaptation. The RNA concentration of the nasal gland tissue was significantly lower than the freshwater value throughout the first 9 days of the period of de-adaptation. By day 22, however, the initial freshwater concentration had been restored (Table 3).

Upon re-adaptation to saline the total RNA content of the nasal glands increased
Nucleic acids and protein in the nasal gland during the first 24 hr. by an increment similar to the one observed at the beginning of the period of adaptation to saline. Similarly, a significant increase in the RNA concentration of the nasal gland tissue was observed (Table 3).

Table 3. The nucleic acid and protein composition of nasal glands from ducks (Anas platyrhynchos) maintained for various times on saline and freshwater diets

(Each bird received a daily ration of 200 g. dry food mixed with 310 mL fresh water and an ad libitum supply of either fresh water (2.0 mM Na, 0.07 mM K) or saline (284 mM Na, 6.0 mM K). During the period of adaptation the birds were maintained on saline and individuals were killed at the times indicated. After 28 days the birds were returned to fresh water and again individuals were killed at various times during the 22-day period of de-adaptation. The remaining birds were returned to saline and killed after a 24 hr. period of re-adaptation. All birds were starved for 24 hr. prior to autopsy. Values are expressed as means ± s.e.)

<table>
<thead>
<tr>
<th>No. of birds</th>
<th>DNA concentration (mg./g. wet weight)</th>
<th>Total DNA (mg./kg. body weight)</th>
<th>RNA concentration (mg./g. wet weight)</th>
<th>Total RNA (mg./kg. body weight)</th>
<th>RNA:DNA</th>
<th>RNA:Protein</th>
<th>Protein:DNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh water</td>
<td>12</td>
<td>1.04 ± 0.2</td>
<td>1.37 ± 0.04</td>
<td>3.62 ± 0.07</td>
<td>0.477</td>
<td>0.023</td>
<td>0.348</td>
</tr>
<tr>
<td>24 hr.</td>
<td>3</td>
<td>7.74 ± 1.77</td>
<td>2.16 ± 0.52</td>
<td>5.29 ± 0.19</td>
<td>1.25</td>
<td>0.019</td>
<td>0.619</td>
</tr>
<tr>
<td>7 days</td>
<td>3</td>
<td>7.70 ± 1.77</td>
<td>1.85 ± 0.25</td>
<td>4.38 ± 0.25</td>
<td>1.4</td>
<td>0.008</td>
<td>0.769</td>
</tr>
<tr>
<td>14 days</td>
<td>4</td>
<td>6.34 ± 1.77</td>
<td>2.16 ± 0.14</td>
<td>3.91 ± 0.07</td>
<td>1.23</td>
<td>0.006</td>
<td>0.685</td>
</tr>
<tr>
<td>28 days</td>
<td>3</td>
<td>7.09 ± 1.77</td>
<td>1.84 ± 0.12</td>
<td>3.60 ± 0.05</td>
<td>1.14</td>
<td>0.006</td>
<td>0.659</td>
</tr>
<tr>
<td>Period of de-adaptation</td>
<td>4</td>
<td>9</td>
<td>22</td>
<td>24</td>
<td>hr.</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>24 hr.</td>
<td>4</td>
<td>9.14 ± 0.52</td>
<td>2.05 ± 0.05</td>
<td>3.22 ± 0.07</td>
<td>0.59</td>
<td>0.030</td>
<td>0.352</td>
</tr>
<tr>
<td>7 days</td>
<td>3</td>
<td>9.76 ± 0.62</td>
<td>0.65 ± 0.12</td>
<td>3.25 ± 0.19</td>
<td>0.335</td>
<td>0.019</td>
<td>0.341</td>
</tr>
<tr>
<td>14 days</td>
<td>4</td>
<td>10.6 ± 0.76</td>
<td>3.23 ± 0.03</td>
<td>3.58 ± 0.05</td>
<td>0.34</td>
<td>0.018</td>
<td>0.353</td>
</tr>
<tr>
<td>28 days</td>
<td>3</td>
<td>7.72 ± 0.41</td>
<td>2.00 ± 0.02</td>
<td>4.44 ± 0.10</td>
<td>0.615</td>
<td>0.015</td>
<td>0.619</td>
</tr>
<tr>
<td>Period of re-adaptation</td>
<td>22</td>
<td>9</td>
<td>22</td>
<td>24</td>
<td>hr.</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>24 hr.</td>
<td>4</td>
<td>2.37 ± 0.14</td>
<td>0.67 ± 0.08</td>
<td>1.7 ± 0.08</td>
<td>0.657</td>
<td>0.015</td>
<td>0.678</td>
</tr>
<tr>
<td>7 days</td>
<td>3</td>
<td>2.88 ± 0.12</td>
<td>0.60 ± 0.05</td>
<td>1.72 ± 0.12</td>
<td>0.685</td>
<td>0.015</td>
<td>0.697</td>
</tr>
<tr>
<td>14 days</td>
<td>4</td>
<td>3.26 ± 0.10</td>
<td>0.65 ± 0.04</td>
<td>1.73 ± 0.03</td>
<td>0.685</td>
<td>0.015</td>
<td>0.697</td>
</tr>
<tr>
<td>22 days</td>
<td>3</td>
<td>2.76 ± 0.11</td>
<td>0.65 ± 0.04</td>
<td>1.73 ± 0.03</td>
<td>0.697</td>
<td>0.015</td>
<td>0.697</td>
</tr>
<tr>
<td>28 days</td>
<td>4</td>
<td>3.27 ± 0.11</td>
<td>0.65 ± 0.04</td>
<td>1.73 ± 0.03</td>
<td>0.697</td>
<td>0.015</td>
<td>0.697</td>
</tr>
</tbody>
</table>

* P < 0.05, ** P < 0.01, *** P < 0.001 with respect to the corresponding value for freshwater-maintained birds.

The RNA:DNA ratio was maximal at the end of the first 24 hr. of the period of adaptation to saline and throughout the remaining 28 days the value was significantly higher than that of the freshwater controls. This value rapidly declined to the freshwater value during the first 4 days of the period of re-adaptation to fresh water and showed a 68% increase during the first 24 hr. of the period of re-adaptation (Table 3).

During the first day of exposure to saline the RNA:protein ratio of the nasal gland tissue increased by 52% and thereafter declined until at 14 days the ratio was similar to that of the freshwater birds. When the birds were returned to fresh water the RNA:protein ratio remained unchanged but a significant increase in the ratio occurred once more during the first 24 hr. of the period of re-adaptation to saline (Table 3).

The protein:DNA ratio increased steadily during the first 14 days of the period of adaptation and declined somewhat during the remainder of the period. This decline continued, although somewhat more rapidly, during the period of de-adaptation until at day 9 the value had returned to that of the freshwater birds. A rapid and significant increase in the protein:DNA ratio again occurred during the period of re-adaptation (Table 3).
DISCUSSION

The nasal glands of marine birds are an extra-renal route for the elimination of the excess salt which cannot be excreted by the kidney. The domestic duck, although not a marine bird, possesses functional nasal glands which may be activated within a few minutes of receiving a salt load. Initially, the glands are small and have a limited capacity to secrete salt. But, if the birds are maintained on saline drinking water the glands eventually exhibit a two-fold increase in size and a six-fold increase in their capacity to secrete salt (Fletcher et al. 1967). On the basis of histological studies both hypertrophy and hyperplasia of the tubular secretory cells have been reported to contribute to this growth (Ellis et al. 1963). The measurements of the DNA composition of the nasal gland in the present work confirm these observations. Assuming the amount of DNA per cell nucleus remained constant (Vendreley, 1955) then about a 42% increase in cell number and about a 58% increase in cell size (i.e. gland volume per unit DNA) occurred.

Since the percentage dry weight of the nasal gland remains essentially constant throughout the period of adaptation to saline (Fletcher et al. 1967), the gland enlargement must have reflected an accumulation of synthesized materials and did not simply result from fluid imbibition. Furthermore, the protein comprised an almost constant percentage of the wet weight of the nasal gland throughout the whole of the experimental period. During the period of growth, however, the amount of protein per cell increased until a maximum was attained after 2 weeks. With the higher sodium secre-
Nucleic acids and protein in the nasal gland

In the fully developed gland it would be expected that the metabolic pathways supplying the energy necessary for the active transport of sodium would also have a higher capacity and perhaps contribute to the observed increase in cell protein. Indeed, the histochemical studies of Ellis et al. (1963) have shown increased activities of the mitochondrial enzymes cytochrome oxidase and succinic dehydrogenase in the nasal glands of ducklings maintained on saline. Also, Fletcher et al. (1967) have observed large increases in the activity of the Na-K-dependent ATP-ase, an enzyme which is thought to be involved in the active transport of sodium.

Upon return of the saline-adapted birds to fresh water all observable secretory activity of the nasal glands ceased and a decline in nasal gland weight was soon apparent. By 22 days the glands, in a number of aspects, appeared to have reverted to the initial freshwater conditions. For example, the size of the cells, as indicated by the DNA concentration, returned to the same size as those in the freshwater controls. Furthermore, the amount of protein and RNA per cell declined to the freshwater values. Decreases in the Na-K-dependent ATP-ase activity and the maximum inducible sodium secretory capacity of the glands have also been observed at this time (Fletcher et al. 1967). When the ducks were returned to the saline regimen the developmental changes were re-established and concomitant increases in the Na-K-dependent ATP-ase activity and sodium secretory capacity of the nasal gland have also been observed in these laboratories (Fletcher et al. 1967). In contrast to the initial rise in glandular size when an increment in the total DNA content of the glands occurred, no significant changes in the total DNA content accompanied the subsequent fall and rise in glandular size. This suggests that the secondary size shifts were produced not by changes in cell number but rather by changes in cell volume and possibly by changes in volume of connective tissue and extracellular fluid (Holmes et al. 1963; Bellamy & Phillips, 1966). Although an increased glandular vascularization accompanies secretory activity (Thesleff & Schmidt-Nielsen, 1962) the increase in the total DNA content during the period of adaptation to saline may not be attributable to the presence of erythrocytes, since no significant decline in the total DNA content occurred when the glands became inactive during the period of de-adaptation.

In the light of current theories on genetic expressive mechanisms the synthesis of new protein would be expected to require the synthesis of new RNA. A significant rise in the total RNA content of the nasal glands has been measured even after only 6 hr. exposure to hypertonic saline (unpublished observation). After 24 hr. on saline the total RNA content of the nasal glands was maximal but the gland continued to grow for another 2 weeks. This phenomenon may be analogous to the 'shift-up' and 'shift-down' experiments performed on bacterial cultures (Maaloe & Kjeldgaard, 1966). In these cultures a positive correlation existed between the amount of RNA per unit protein and the growth rate. A similar situation was observed in the nasal gland where the RNA:protein ratio was maximal by 24 hr., and at about this time the most rapid accumulation of protein occurred. The stimulus to accelerate the growth rate of the bacterial cultures during the 'shift-up' phase was a higher concentration of nutrients in the medium. The specific stimulus to nasal gland growth in the duck maintained on saline has yet to be demonstrated. An increased availability of nutrients, however, may be necessary to permit growth. Certainly, increases in the tissue vascularization (Thesleff & Schmidt-Nielsen, 1962) and extracellular fluid volume (Bellamy...
& Phillips, 1966) have been shown to accompany the onset of nasal gland secretion. In this regard, it is of interest to note that changes in blood supply to the liver have been demonstrated to regulate liver size in the rat (Brauer, 1963).

The low RNA concentrations in the nasal glands of the saline-adapted duck are also found in many tissues which have a high physiological activity but do not synthesize large amounts of protein. Such is the case for cardiac muscle and kidney tissue (Brachet, 1955). Low RNA concentrations are probably also to be found in the nasal glands of other species of birds. For instance, the nasal glands from a seagull (Larus sp.) recently captured on a local beach, had an RNA concentration of 2.44 mg./g. wet weight and a DNA concentration of 4.40 mg./g. wet weight. Furthermore the nasal glands of this particular specimen had an Na-K-dependent ATP-ase activity consistent with the high levels we have previously observed in the saline-maintained duck (Fletcher et al. 1967).

**SUMMARY**

1. After transfer of the freshwater-maintained ducks to a hypertonic saline regimen the wet weight, the protein content and the RNA content of the nasal glands showed a two-fold increase.

2. The RNA content of the nasal glands was maximal after approximately 24 hr. whereas the maximum wet weight and protein content did not occur until after approximately 14 days of exposure to hypertonic saline.

3. The DNA content of the nasal glands increased by approximately 42% during the period of adaptation to hypertonic saline and at the same time the weight of gland per unit DNA increased by about 58%.

4. The wet weights, nucleic acid concentrations and the protein concentrations of Harderian glands, liver, kidney and adrenal glands did not change upon adaptation of the ducks to the hypertonic saline regimen for 14 days.

5. Upon return of the birds to the freshwater diet, the weight, protein content and RNA content of the nasal gland declined. No loss of DNA was apparent. The weight of the gland per unit DNA and the protein content per unit DNA and the total RNA content of the nasal glands all returned to the level observed in the freshwater-adapted birds.

6. When the birds were again transferred to the hypertonic saline diet the nasal glands returned to the state of development previously observed when the birds were maintained on the hypertonic saline regimen.

7. The significance of these data in relation to the changes known to occur in the active sodium-transporting properties of the nasal gland are discussed.

**REFERENCES**


Nucleic acids and protein in the nasal gland


