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2	Functional morphology of the tongue and laryngeal entrance and scanning electron
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43 ABSTRACT

44 There is insufficient information about the migratory Eurasian teal, Anas crecca. The 45 study provides the first anatomical description of lingual adaptations and their relationship with the species-specific feeding behavior of Anas crecca collected near Egyptian Lake 46 47 Nasser. Our investigation was applied with the help of gross, scanning electron microscopy 48 (SEM), and morphometric analysis. The study focused on the feeding filtering apparatus that 49 depends on eight lingual papillae. The spatula-shaped nail is adapted for food particle 50 pecking, while the lingual combs, rostral border of the prominence, unique papillary crest, 51 median groove, and papillary system aid in intra-oral transportation. The feeding apparatus is 52 formed by the lateral and dorsal papillary systems. The lateral papillary system had conical 53 papillae with numerous long filiform and hair-like filiform papillae to constitute the food filtration apparatus, while the dorsal papillary system had ridged-like and rod-like papillae in 54 addition to the small papillae of the papillary crest and spinated border of the root to help in 55 moving the food particles with water to the lateral sides of the prominence. The laryngeal 56 region exhibited papillary (pre-glottic) and non-papillary (glottic) areas. The papillary area 57 had two lateral papillary portions and a median smooth portion, while the non-papillary area 58 had an ovoid laryngeal mound with a median glottic opening that was bordered by a papillary 59 60 border. The papillary portion had three slightly oblique longitudinal papillary rows. 61 62 Keywords: Anas crecca; Filter feeding apparatus; Laryngeal mound; Lingual comb; Lingual

63

papillae.

64 **1- Introduction**

65 Anas crecca, also known as the Eurasian teal, common teal, or Eurasian green-winged teal, is a common migratory waterbird duck that breeds in Asia and Europe before migrating 66 67 to the Mediterranean during winter. The Nile Valley, particularly Lake Nasser, is a significant 68 wintering destination, according to BirdLife International (2020). A. crecca, a species in the 69 Anas genus, belongs to the Anatidae family and is covered under the Agreement on the Conservation of African-Eurasian Migratory Waterfowl (AEWA). In the spring and summer, 70 71 A. crecca primarily feeds on mollusks, worms, insects, and crabs, occasionally diving for 72 prey while submerging its head, and typically consumes through dabbing, upending, or 73 grazing (Madge & Burn, 1988). In winter, it adopts a granivorous diet, consuming grass seeds 74 and aquatic plants like sedges and grains. During the breeding season, despite winter 75 nocturnal habits, diurnal feeding habits are present.

76

77 The feeding process in vertebrates involves ingestion, intra-oral transport, and swallowing, with evolutionary differences between neognathous and paleognathous bird 78 79 groups identified through behavioral analysis (Schwenk & Rubega, 2005; Tomlinson, 2000). 80 Paleognathous birds adopt a cranioinertial mechanism, where food is directly transported into 81 the esophagus without using the tongue. The beak and hyolingual apparatus's intricate 82 movements are linked to the lingual feeding mechanism utilized by neognathous birds. 83 Neognathous birds occasionally employ a catch-and-throw system for swallowing large food 84 particles, requiring intricate movements of the hyolingual apparatus. Toucans, hornbills, and 85 southern cassowaries are outliers in neognathous birds due to their development of ballistic transport (Baussart & Bels, 2011; Bels & Baussart, 2006). Wild ducks have the ability to pick 86 87 up and toss grains smaller than a pea, remove grass blades, and maintain their ability to do so (Kooloos et al., 1989). 88

89

90 Wild ducks use a filter-feeding strategy to consume food submerged in water, as per 91 various studies (Abumandour et al., 2019; Kooloos et al., 1989; Tomlinson, 2000). Filtration 92 demonstrates typical neognathous bird behaviors, such as ducks using lingual feeding and 93 under-tongue conveyance (Kooloos et al., 1989; Tomlinson, 2000). Most published articles 94 focus on the anatomical description of the tongue of avian species other than the Anatidae 95 family, with little attention given to the study of the laryngeal mound and its role in food particle movement (Abumandour, El-Bakary, et al., 2021; Abumandour, Farrag, et al., 2021; 96 97 Bassuoni et al., 2022; El-Mansi et al., 2020; El-Mansi et al., 2021; Gewaily & Abumandour, 98 2020). Published data on the tongue of certain Anatidae family birds has been found to 99 completely ignore the laryngeal mound (Abumandour et al., 2019; Jackowiak et al., 2011; Skieresz-Szewczyk & Jackowiak, 2014; Skieresz-Szewczyk & Jackowiak, 2016; Skieresz-100 Szewczyk et al., 2014; Skieresz-Szewczyk et al., 2014; Tawfiek & Mahmoud, 2020). The 101 102 previous published data indicated that a bird's tongue's structural properties can adapt to its 103 eating habits, providing insight into its environment and lifestyle (Gewaily & Abumandour, 104 2020). Ostrich and Eurasian hoopoe tongues are adapted for swallowing and moving food 105 particles (Abumandour & Gewaily, 2019b; Tadjalli et al., 2008), while piscivorous species like penguins have stiff, pointed, caudally oriented lingual papillae that are specialized for 106 107 gripping and handling food, allowing them to retain slippery prey (Abumandour et al., 2019).

Meanwhile, the elongated tongue of grain-, insectivore-, and carnivore-feeding species allows
for selective, rejecting, accepting, catching, and manipulating feeding materials
(Abumandour, Farrag, et al., 2021; El-Mansi et al., 2020; El-Mansi et al., 2021).

111

The morphological characteristics of the tongue and laryngeal mound of the Eurasian Teal *A. crecca* are insufficiently understood, with limited information available on their role in feeding mechanisms. Therefore, our study utilized gross and scanning electron microscopic (SEM) examinations to study the structural adaptations of the tongue and laryngeal mound in the feeding filtering apparatus of migratory Eurasian Teal *A. crecca* collected around Lake Nasser in Egypt. Then, the findings are compared to existing published information on various avian species.

119

120 2. Materials and Methods

121 2.1. Collection of samples and gross anatomical examination

This study was carried out according to the Institutional Animal Care and Use 122 123 Committee (IACUC) protocols of Laboratory Animals, Faculty of Veterinary Medicine, 124 Alexandria University (Approval No.: 11/3/2023/231). Ten Eurasian Teal (A. crecca) duck 125 weighting averages of 2.73 kg were obtained from a local hunter near Lake Nasser in Aswan 126 (Egypt). The collected ducks were kept in the animal housing following the guidelines 127 established for the 'Sampling protocol for the pilot collection of catch, effort, and biological data in Egypt' (Dimech et al., 2012). The Anas crecca included in the study had no 128 129 oropharyngeal anatomical abnormalities. The Anas crecca were anesthetized with pentobarbitone sodium administered through the internal carotid artery with warm 130 131 physiological saline (35 °C). The tongues and larvngeal mounds obtained by dissecting the oropharyngeal cavity longitudinally (n = 5) were examined grossly to determine their 132 morphological and morphometric features and were photographed on five samples using a 133 134 digital camera (Canon IXY 325, Japan). The anatomical terminology was used according to 135 Baumel et al (1993).

136

137 2.2. SEM examinations

138 To study the ultrastructure characterizations five samples were used from the different lingual parts (apex, body, lingual prominence, root) and the two parts of the laryngeal 139 140 entrance, according to (Abumandour et al., 2024); Alruhaimi et al. (2024). The samples were fixed at 4 °C in 2% formaldehyde and 1.25% glutaraldehyde in a 0.1 M sodium cacodylate 141 142 buffer (pH 7.2). The samples were washed in 0.1 M sodium cacodylate containing 5% sucrose, processed through tannic acid, and finally dehydrated in increasing concentrations of 143 ethanol (50, 70, 80, 90, 95, and 100% ethanol, 15 min each). After critical point drying in 144 carbon dioxide, the samples were attached to stubs with colloidal carbon and coated with 145 gold palladium in a sputtering device (Elghoul et al., 2022; Kandyle et al., 2022; Massoud et 146 147 al., 2023). Specimens were examined and photographed with a JEOL SEM operating at 15 148 KV at the Faculty of Science, Alexandria University, Egypt.

149

150 2.3. Digital coloring of scanning electron microscopic images

151 We digitally colored the SEM images using the Photo Filter 6.3.2 program to identify 152 the various structures. This technique was previously described by (Abumandour et al., 153 2023); Kandyel et al. (2023); Roshdy et al. (2021).

154

155 2.4. Gross and SEM Morphometric Analysis

The different dimensions of tongue with its parts and laryngeal mound with its parts were measured using an electronic ruler with an accuracy of 0.1 mm (Abumandour & Hanafy, 2024; Kandyel, El Basyouny, Albogami, et al., 2024; Kandyel, El Basyouny, El-Nagar, et al., 2024). The obtained SEM images were processed by the ImageJ software to determine the different measurements of the tongue and its anatomical structures (Schneider et al., 2012). Then, the data were presented as the mean \pm standard error (SE).

162

163 **3. Results**

164 The filter-feeding apparatus of the migratory *Anas crecca* is primarily formed from 165 the tongue and its papillary system. The floor of the oropharyngeal cavity consisted of the 166 tongue and laryngeal entrance, as depicted in various figures (Figs. 1A, 2A, and 5A).

167

168 *3.1. Tongue*

169 <u>3.1. 1. Gross Morphometric Analysis</u>

170 The tongue consists of the free rostral and fixed caudal parts. The rostral lingual part 171 represented 67% and the caudal part 33% of the tongue length (Table 1). The lingual nail 172 represented 9.5%, the apex 33%, the body 57%, and the root 9.5% of the tongue length (Table 1). The body is the widest and thickest part (0.85 \pm 0.32 cm and 0.5 \pm 0.1 cm, 173 174 respectively), while the lingual nail is the narrowest and least thickest part (0.6 ± 0.10 cm and 0.2 ± 0.01 cm, respectively), as shown in (Table 1). The lingual groove was represented by 175 33%, the lateral serrated border of the root 6%, the papillary crest 33%, and each half part of 176 177 the dorsal spinated border of the root 7% of the tongue length (Table 1). The papillary 178 triangular area represented 30%, and the non-papillary glottic elevated area (Laryngeal 179 mound) represented 70% of the pharyngeal cavity length (Table 2). The equatorial diameter of the laryngeal mound reached 2.8 ± 0.54 cm, while the axial diameter of the laryngeal 180 181 mound reached 1.52 ± 0.64 cm (Table 2). The glottic opening represented about 38% of the 182 pharyngeal length. The laryngeal mound had different widths, reaching 0.45 ± 0.12 cm at its 183 rostral part, 0.61 ± 0.24 cm at its middle part, and 0.3 ± 0.11 cm at its caudal part (Table 2).

184

185 <u>3.1. 2. Gross observations</u>

Grossly, the oropharyngeal cavity floor enclosed the elongated, flattened, nonprotrusible tongue, which was fixed inside the deep sublingual space by a lingual frenulum at its caudal part, just at the level of the lingual prominence (Figs. 1A, 1D, 3H/LF and SLS). The three lingual areas were the apex, body, and root (Fig. 1A–D/AP, LB, and LR). The lingual groove was clear and extended from the rostral border of the lingual nail to the papillary crest, in which it was shallow on the nail and lingual prominence but deep on the apex and deepest on the body (Figs. 1A-B, 2A, 3A, 4A, 5A, 6A, 7A, and 9A/LG).

194 The lingual apex consists of a round anterior spatula-like portion (lingual nail) and a caudal portion, separated by a short lateral transverse fissure (Figs. 1B-C, 2A, 3A, 4A, 195 196 5A/LA, LT, LN, AC, TG). It carried numerous papillae on its dorsal and lateral surfaces, 197 except for the nail (Figs. 1B, 2A, 3A, 4A, 5A/AC, HP). The lingual body consisted of two 198 regions: the rostral pyramidal region and the caudal elevated triangular lingual prominence 199 (Fig. 1A/LB, BP, LP). The rostral pyramidal region carried the lingual comb on its dorsal surface and numerous papillae on its lateral surface (Figs. 1A-C, 2A, 3A, 3H, 4A, 5A, 6A, 200 201 7A, 9A/PYS, LB, BP, LP, SCP), while the lingual prominence carried conical papillae and 202 filiform papillae on its rostral part, while its caudal part of the lateral portion carried some filiform papillae and a lateral serrated border (Fig. 1B/LP, LCPT, red star, PFP, PB). 203

204

The short lingual root consisted of two portions (right and left) separated by a narrow space, and it is surrounded by spinated borders from all directions. It is separated rostrally from the lingual prominence by the papillary crest and laterally by a lateral serrated border, and it is separated caudally from the laryngeal entrance by the dorsal serrated border, which consists of two portions (right and left) separated by a narrow space (Figs. 1A, 7A, 8A, 9A, and 10A-B/LR, PB, SB, PC, and blue arrowheads).

211 212

3.1. 3. Scanning electron microscopic observations

213 The anterior spatula (cranial portion of apex) had a round apex and was demarcated 214 laterally from the rest of the apex by a short lateral transverse fissure (Figs. 1E, 2B/LN, TG), and its dorsal surface had a shallow median longitudinal lingual groove. High SEM 215 magnification revealed numerous small tubercles in the median area, folds in the peripheral 216 217 area, and various shapes of micro-cells surrounded by micro-grooves on the ventral surface (Fig. 1E-H/DLS, VLS, LN, LG, AF, MC, green stars, and arrowheads). The dorsal surface of 218 219 the caudal portion of the apex was divided into two wide lateral regions by a deep part of the 220 median lingual groove. The dorsal surface exhibited numerous ridge-like papillae with a 221 projected base (at its origin near the groove) and small pointed filiform papillae in the lateral 222 regions (Figs. 2C-D, 3B-J/RPP, HS, SFP). High SEM magnification revealed ridge-like 223 triangular papillae with a pointed apex, dorsal border, and a wide base attached to the dorsal 224 lingual surface, which was surrounded by numerous scales (Figs. 2D and 3D-F/RPP, BS).

225

226 The pyramidal region consisted of two parts: small rostral and large caudal parts. The 227 small rostral part, located rostral to the lingual comb, had numerous rod-like filiform papillae 228 with a projected base, small conical papillae on its lateral regions of the dorsal surface, and numerous ventral rod-like filiform papillae on its lateral border (Figs. 4B-D, 8B-C/RFP, PS, 229 230 SCP, and RFPV). Meanwhile, the lingual comb in the large caudal part had randomly distributed spines, round and elongated tubercles, small filiform papillae, and lingual salivary 231 232 gland openings. Its lateral border had large quadrilateral conical papillae rostrally and large 233 triangular conical papillae with numerous hair-like filiform papillae caudally just at the level of the head and caudal part of the lingual comb (Figs. 5B-F/RFP, PS, RS, RB, RT, ET, 234 235 LCPQ, LCPT, and red arrowheads). High SEM magnification revealed one to three ridges on 236 the dorsal surface of the quadrilateral large conical papillae (Fig. 8B-C/LCPQ, red stars).

238 The pyramidal lingual comb consisted of two halves separated by a shallow lingual groove, as shown in (Figs. 5B-F, 6B-C/PYS, He, Cd, Cr, Rr, and LG). Each half of the comb 239 had two regions that named from caudal to rostral as the followings; the smooth head and 240 241 long thread-like regions that was subdivided into three parts according its appearance; the 242 first smooth caudal part that joined to the pyramidal head, while the middle serrated part had 243 about 14-15 laterally directed triangular processes, but the rostral part was consisted of three laterally serrated tubercles; the large caudal serrated tubercle had 7-8 laterally directed 244 245 processes, the middle serrated one had 5-6 laterally directed processes, and the small ovoid 246 rostral tubercle had only one or two laterally directed processes (Figs. 5B-F, 6B-C, 6F/PYS, He, Cd, Cr, Rr, red, green, blue arrowheads). 247

248

249 The rostral ³/₄ part of the dorsal surface of lingual prominence was divided into parts by a shallow lingual groove, while its caudal ¹/₄ part was devoid of this groove (Figs. 6B-F, 250 251 7B-D/LP, LG). The lingual prominence's lateral surface had a serrated border of 10-12 triangular-pointed processes rostrally and a wedge-shaped structure caudally, as shown in 252 253 (Figs. 6B-F, 7B-D/LP, red stars, LW). The lateral border of the lingual prominence carried 254 the large triangular conical papillae, hair-like filiform papillae, and ventral rod-like filiform 255 papillae rostrally just adjacent to its lateral serrated border (Figs. 6B, 6F, 7B, 8D-E/LCPT, 256 HFP, RFPV, red stars), while caudally, it had numerous small pointed filiform papillae adjacent to the wedged-shape structure (Fig. 10B-E/PFP, LW). High SEM magnifications 257 revealed numerous scales and ridges on conical papillae, with large triangular papillae having 258 259 an accessory wing-like structure (Figs. 7C-D, 8D-E/LS, red stars, AC).

260

The lingual prominence and root were separated by the semilunar caudally curved papillary crest with its caudally oriented mechanically conical papillae, with the complete absence of the giant laterally situated conical papillae. The papillary crest consisted of two transverse papillary rows; the dorsal row had 16–18 large triangular papillae, in which each of the three median papillae carried small accessory papillae with numerous scales, and the ventral row had 14–16 small conical-pointed papillae, in which the median two were fused together (Figs. 7E-G/PC, PCD, red arrowheads, PCV, white *).

268

The short lingual root is bounded by spinated borders on all sides, including the 269 270 papillary crest rostrally, the lateral serrated border laterally, and the dorsal spinated border 271 caudally, which consisted of two halves (right and left) by a narrow median passway, leaving 272 the small smooth semilunar area of the root (Figs. 7E-F, 9C-E/LR, MLR, PC, SB, PB, blue arrowheads). A narrow, smooth median passway of the root was communicated between the 273 274 small, smooth semilunar area of the root and the rostral part of the laryngeal entrance, and it 275 was separated from the medial border of each spinated area bordered by the elevated 276 longitudinal ridge on each side (Fig. 9C-E/green arrowheads).

277

The dorsal spinated border measured 0.4 ± 0.1 cm in width and 0.4 ± 0.02 cm in length for each half, respectively. This border was divided into two halves (right and left) by a median passageway; each half had two papillary rows; the dorsal row had 7-8 small pointed conical papillae, and the ventral row had 6-7 large triangular pointed conical papillae (Fig. 9C-F/SBR, SBP). High magnification revealed numerous small scales on the papillary surface (Fig. 9F/SBR, SBP). The lateral serrated border of the root measured 0.25 ± 0.01 cm in width and 0.4 ± 0.03 cm in length and carried 10–11 pointed triangular papillae on its free lateral border (Fig. 7B, 7E-G/PB). High magnification revealed numerous small scales on this lateral border (Fig. 7G/PB).

287

288 The median lingual groove extended along the lingual apex and body, including the 289 nail, except for the caudal ¹/₄ part of the lingual prominence that was devoid of this groove 290 (Figs. 1E, 2C-E, 3B-C, 3G, 4B-E/LG, MG). The groove on the lingual nail and prominence was a shallow groove, but it appears deep on the apex and body (Figs. 1E, 7B, 7F/LG, MG). 291 292 The groove on the apex and rostral part of the body had a triangular shape and is divided into two halves by a single deep median groove of the same width along the apex, while the main 293 294 lingual groove began narrow rostrally and gradually increased in width caudally (Figs. 2C-E, 295 3B-C, 3G, 4B-E/LG, MG). Moreover, this groove appears as a single deep groove between the two parts of the lingual comb (Figs. 5B-F, 6B-C, and 6F/LG). 296

- 297
- 298 <u>3.1. 4. Scanning electron microscopic observations</u>

299 The longest and widest lingual papillary type was the large quadrilateral conical papillary type, while the shortest was the hair-like filiform papillae, and the narrowest was 300 301 the hair-like filiform papillae. In the apex, the ridge-like papillary type had the longest papillae (1.7 \pm 0.53), and the widest was the small pointed filiform papillary type (0.39 \pm 302 303 0.12), as shown in (Table 3). In the lingual body, the large quadrilateral conical papillary type had the longest papillae (2.5 ± 0.78), followed by the ventral rod-like filiform papillae ($2.13 \pm$ 304 305 0.47) and the large triangular conical papillae, while the shortest was the hair-like filiform papillae (0.31 \pm 0.02). The widest type was the large quadrilateral conical papillary type (0.89 306 \pm 0.34), then the large triangular conical papillae (0.51 \pm 0.1), while the narrowest was the 307 308 hair-like filiform papillae (0.032 ± 0.01), as shown in (Table 3). In the papillary crest, the 309 longest and widest papillae were observed on the dorsal papillary row. In the dorsal spinated 310 border of the root, the longest (0.45 ± 0.02) and widest (0.17 ± 0.02) papillae were the large triangular pointed conical papillae of the ventral row (Table 4). 311

312

313 3.2. The laryngeal region

314 <u>3.2. 1. Gross observations</u>

315 The laryngeal region was separated from the lingual root by the dorsal spinated 316 border, and it was bordered laterally by the longitudinal papillary row (Figs. 1A, 7A, 9A-B, 10A/LR, PR, HB). The laryngeal region was divided into two areas: the papillary (pre-glottic) 317 triangular area and the non-papillary (glottic) elevated area (Figs. 1A, 7A, 9A-B, 10A/PTA, 318 NER). The papillary area was bordered by a narrow median smooth passway and a dorsal 319 320 spinated border rostrally, by the non-papillary area caudally, and by its lateral papillary row 321 laterally (Figs. 9B, 10A/PTA, HP, and HPL). The apex of the papillary region was directed rostrally just at a narrow median smooth passway and had numerous papillae that were 322 323 arranged in three rows (Figs. 9A, 10A/PTA, HP, HPM, HPE, and HPL). The non-papillary 324 area is represented by the elevated ovoid laryngeal mound (Mons laryngealis) with a median 325 longitudinal opening called the laryngeal cleft (glottis), bordered by the papillary border. The glottis communicates the pharyngeal cavity to the trachea and continues as a laryngeal fissure
(Figs. 9A, 10A/GO, white and blue arrowheads, and LF). The non-papillary area is
surrounded caudally by diamond-shaped pharyngeal conical papillae, indicating the laryngeal
mound from the esophagus (Figs. 9A, 10A/PP, ES).

- 330
- 331 <u>3.2. 2. Scanning electron microscopic observations</u>

The laryngeal region was bordered laterally by the longitudinally elevated ridge of 332 18-20 small caudally directed papillae (Fig. 10B-C, 10E/HB, green arrowheads). The 333 334 papillary triangular area had three portions: two lateral papillary portions of the caudolaterally directed papillae and the median smooth portion. The lateral papillary portion 335 336 had three slightly oblique longitudinal papillary rows (lateral, middle, and medial), in which the lateral papillary row had 6-7 large, long pointed conical papillae with 4-5 small accessory 337 conical papillae in-between (Fig. 9C-G/HPL, red stars), the middle one had 6-8 conical 338 339 papillae with 6-7 small accessory conical papillae in-between (Fig. 9C-G/HPM, green stars), and the medial row had 4-5 triangular pointed papillae and was located just lateral to the 340 rostral portion of the lateral border of the glottic opening (Fig. 9C-G/HPE, GO). The median 341 342 smooth portion was located just opposite the median passageway of the lingual root rostrally 343 and the rostral beginning of the glottic opening caudally; additionally, this portion had a small number of the laryngeal salivary glands (Fig. 9C-E/MPA, yellow arrowheads). High 344 345 magnification revealed numerous small scales on the papillary surface (Fig. 9G/HS).

346

347 The non-papillary area had an elevated ovoid laryngeal mound with its median glottis (Figs. 9C, 10B/NER, LM, GO, LF). This area was bordered by the medial papillary row of 348 349 the non-papillary area at its rostral portion and caudally by the diamond-shape pharyngeal papillae with numerous caudally directed mechanical conical papillae (Figs. 9C-D, 10B/NER, 350 HPE, PP). The larvngeal mound was divided into two plates (right and left) by the median 351 352 longitudinal glottic opening that was bordered by a slightly elevated papillary border of 10-353 12 caudomedially directed conical papillae; these papillae began small rostrally and increased 354 in size caudally (Fig. 10B-C, 10E/LM, GO, GB, blue arrowheads). The glottis was continued caudally as a laryngeal fissure that was bordered by 2-4 small papillae on each side (Fig. 355 356 10B-C, 10E/LF, white arrowheads) at its rostral portion before beginning the pharyngeal papillae, while the rest of the fissure was bordered by the longitudinal pharyngeal papillary 357 row of the large caudally directed conical papillae (Fig. 10E-F/GPL). High magnification 358 359 revealed that each plate of the laryngeal mound was devoid of any papillae with a small 360 number of laryngeal salivary gland openings (Fig. 10C–D/red arrowheads).

361

The diamond-shaped pharyngeal papillae were arranged in 7 or 8 overlapped transverse rows and one longitudinal papillary row of the caudally directed mechanical papillae (Fig. 10E-F/PP). The rostral row had 8–9 longest triangular-pointed papillae (Fig. 10E–F/GPT), and then decreased gradually on the rest of the transverse papillary rows to 2-3 small papillae on the most caudal (last) row (Fig. 10E–F/SP, SP1–7). The longitudinal papillary row had 5–6 long, pointed papillae (Fig. 10E–F/GPL). High magnification revealed numerous small scales on the papillary surface (Fig. 10F).

370 <u>3.2. 3. Scanning electron microscopic Morphometric analysis of the tongue</u>

In the lateral papillary portion of the triangular laryngeal area, the longest and widest papillary type is the large pointed conical papillae that formed the lateral longitudinal row, then the triangular pointed papillae that formed the medial longitudinal row, and the shortest and narrowest ones are the small accessory papillae that formed the middle longitudinal row, and then the small accessory papillae that formed the lateral longitudinal row (Table 5).

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377 4. Discussion

378 This study represents the first gross and SEM depictions of the tongue and laryngeal entrance of the migratory Eurasian teal, with unique insight into its filter feeding apparatus 379 and the influence of dietary habits, readily available nutrient components, and environmental, 380 migratory, and climatic factors on their morphological adaptation. The morphological 381 knowledge of the tongue and laryngeal entrance of ducks, particularly A. crecca, is limited, 382 383 with only a few recent articles providing insights into the tongue and the laryngeal mound in some duck species (Abumandour et al., 2019; Skieresz-Szewczyk & Jackowiak, 2016; 384 385 Skieresz-Szewczyk et al., 2014; Skieresz-Szewczyk et al., 2014); however, the oropharyngeal 386 cavity roof is completely described in A. crecca by (Alruhaimi et al., 2024).

388 The tongue plays a crucial role in collecting, filtration, processing, and movement of the food particles towards the esophagus, as described in food intake feeding behavior in 389 avian species. These different lingual functions reflect the lingual appearance and 390 391 ultrastructural features (Erdogan & Iwasaki, 2014). There is a species-specific characteristic 392 of the lingual appearance that has adapted to specific feeding habits and the types of available 393 food particles (Erdogan & Iwasaki, 2014). Our description of an elongated, wide tongue with 394 a free apex and a strong lingual frenulum fixation to the oropharyngeal cavity floor is similar 395 to those described in all waterbirds, including the domestic duck and goose (Iwasaki et al., 396 1997; Jackowiak et al., 2011; Skieresz-Szewczyk & Jackowiak, 2016; Skieresz-Szewczyk et 397 al., 2014), and the omnivorous Garganey (Abumandour et al., 2019). Avian species have 398 elongated, narrow tongues for carnivorous behaviors (Abumandour & El-Bakary, 2017b; 399 Emura et al., 2008a), herbivorous behaviors (Abumandour, 2018; Abumandour & El-Bakary, 400 2019b), and migratory behaviors of the coots (Abumandour & El-Bakary, 2017a), while 401 triangular tongues are used for herbivorous behaviors in Galliformes, Passerines, and 402 Columbiformes (Abumandour & El-Bakary, 2019a; Abumandour, El-Bakary, et al., 2021; Abumandour & Kandyel, 2020; Dehkordi et al., 2010; El-Mansi et al., 2021). Some birds 403 404 exhibit different tongue shapes, such as the oval tongue in Middendorf's bean goose (Iwasaki et al., 1997), the brush-like tongue in the hummingbirds (Rico-Guevara & Rubega, 2011), the 405 mushroom tongue in the cormorants (Jackowiak et al., 2006), a toothpick tongue in the 406 Japanese pygmy woodpecker (Emura et al., 2009), and the needle-shaped tongue in the Little 407 408 Egret and heron (Emura, 2009). The longer tongue than the lower jaw is seen in the 409 woodpecker (Emura et al., 2009), while there are two cases of short according to its 410 adaptations; the short primitive nonfunctional tongue is seen in hoopoes and ratites (Abumandour & Gewaily, 2019a; Crole & Soley, 2010b; Jackowiak & Ludwig, 2008b; 411 Santos et al., 2011), and the short functionally movable tongue is seen in Egyptian nightjars 412 413 (El-Mansi et al., 2020) and the Eurasian collared dove (El-Mansi et al., 2021).

415 The lingual apex is closely linked to avian dietary habits and is responsible for various functions in various feeding techniques, including food collection and manipulation 416 (Abumandour, Farrag, et al., 2021; Bassuoni et al., 2022; El-Mansi et al., 2021; Erdogan & 417 418 Iwasaki, 2014; Gewaily & Abumandour, 2020). Our description of the spatula-like nail of the 419 lingual apex of Anas crecca is similar to those described in most water birds, including ducks and geese (Abumandour et al., 2019; Jackowiak et al., 2021; Jackowiak et al., 2011; Marzban 420 421 Abbasabadi & Sayrafi, 2018; Skieresz-Szewczyk & Jackowiak, 2016), but is absent in some 422 waterbird species like the coot and moorhen (Abumandour & El-Bakary, 2017a; Bassuoni et al., 2022). Previous data revealed some anatomical adaptations of the apex, including 423 424 numerous rostrally directed acicular processes on the rostral and lateral borders of the rounded apex of moorhens, coots, Japanese pygmy woodpeckers, and magpies (Abumandour 425 & El-Bakary, 2017; Bassuoni et al., 2022; Emura et al., 2009; Erdogan et al., 2012), while, 426 427 the ratites have a smooth apex (Jackowiak & Ludwig, 2008a; Santos et al., 2011), but Egyptian nightjars have a blunt apex (El-Mansi et al., 2020), whilst the Eurasian Collared 428 429 Dove tongue has a spear-like apex (El-Mansi et al., 2021). However, the nutcracker's apex 430 has two dagger-like processes for catching, raising, and putting seeds on the median lingual 431 groove (Jackowiak et al., 2010). The bifid apex is found in carnivorous birds like the little tern, owl, peregrine falcon, and kestrel (Emura & Chen, 2008; EMURA et al., 2008b; 432 Iwasaki, 1992) and some herbivorous birds like the red jungle fowl and magpie (Erdogan et 433 434 al., 2012; Kadhim et al., 2011), while the pointed apex is found in the chicken and the zebra finch (Dehkordi et al., 2010; Iwasaki & Kobayashi, 1986). 435

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437 Our study revealed that the lingual feeding filtering apparatus is classified as lateral and dorsal papillary apparatus, in which the lateral apparatus has numerous mechanically 438 439 conical papillae, including long and hair-like filiform papillae, which filter food particles 440 from water streams during ejection, while the dorsal apparatus has ridged-like and rod-like 441 papillae, along with small papillae of the papillary crest and spinated border of the root, 442 which move food particles with water to the lateral sides of the prominence. Our study revealed that the feeding filtering apparatus has eight papillary types: ridge-like, small 443 pointed, rod-like, small conical, large quadrilateral, large triangular, small triangular, and 444 445 hair-like filiform papillae. Meanwhile, the domestic duck's feeding filtering apparatus consists of three papillary types: small conical and filiform papillae on the rostral part of the 446 447 body, large conical papillae on the caudal part of the body, and conical papillae on the lingual prominence (Skieresz-Szewczyk & Jackowiak, 2016), while Abumandour et al. (2019) 448 revealed three papillary types: hair-like papillae on the lateral tip surface, rostral, and middle 449 parts of the body; small conical papillae on the lateral surface of the rostral and middle parts 450 and prominence; and large conical papillae on the lateral surface of the caudal part of the 451 452 body and prominence in the Garganey. Previous studies have described numerous hair-like 453 filiform papillae on the lateral border of the lingual prominence in the Garganey, domestic duck, and geese tongues (Abumandour et al., 2019; Iwasaki et al., 1997; Jackowiak et al., 454 2011; Skieresz-Szewczyk & Jackowiak, 2014). 455

457 Our description of the papillary distribution included that the two lateral apical regions (except the nail) has numerous ridge-like and small pointed filiform papillae on their 458 459 lateral surfaces, and the rostral part of the pyramidal region (before the lingual comb) has numerous rod-like filiform, small conical, and ventral rod-like filiform papillae on its lateral 460 461 surfaces, while the large part of the pyramidal region has a lingual comb, randomly spines, 462 round and elongated tubercles, the numerous small filiform papillae on its dorsal surface, and its lateral surface carried numerous large quadrilateral conical papillae rostrally and large 463 464 triangular conical papillae with numerous hair-like filiform papillae caudally just at the level 465 of the head and caudal part of the lingual comb. Furthermore, the lingual prominence's dorsal surface has a lateral serrated border on its rostral part of the lateral portion, while its caudal 466 part carries a wedge-shape structure, and the lateral surface of the prominence carries large 467 triangular conical, hair-like, and ventral rod-like filiform papillae at its rostral part, while its 468 caudal part has numerous small pointed filiform papillae. Also, the lingual root has numerous 469 470 spinated borders from all sides: the papillary crest rostrally, the lateral serrated border laterally, and caudally by the dorsal spinated border, which is divided into two halves (right 471 472 and left).

474 The Anseriformes have slight variations in the appearance of their lingual groove on 475 their dorsal surface. Our results show that the rostral ³/₄ part of the lingual prominence has a 476 shallow median groove, but the caudal ¹/₄ part is devoid of this groove, similar to domestic 477 ducks (Skieresz-Szewczyk & Jackowiak, 2016). The lingual prominence in Garganey and domestic goose has a median groove along its dorsal surface (Abumandour et al., 2019; 478 479 Jackowiak et al., 2011), while in domestic goose, it only appears on the median portion 480 (Skieresz-Szewczyk et al., 2021). Our study reveals that the lingual groove begins and ends 481 as a shallow groove, but it appears as a triangular groove on the apex and rostral part of the body with a central deep groove, and it appears as a single deep groove at the lingual comb. 482 483 Meanwhile, the groove extends along the dorsal surface of the apex and body, where it is 484 deep in the rostral $\frac{2}{3}$ and shallow in the caudal $\frac{1}{3}$ of the tongue on the lingual prominence in 485 Garganey and coot (Abumandour et al., 2019; Abumandour & El-Bakary, 2017a). However, 486 it is a shallow groove on the body and the lingual prominence in domestic ducks (Skieresz-487 Szewczyk & Jackowiak, 2016), whereas it is only on the dorsal surface of the body in the domestic goose (Jackowiak et al., 2011), only on the rostral part of the body without the apex 488 489 and prominence in the Middendorff's bean goose (Iwasaki et al., 1997), only on the apex and 490 body in the Eurasian Collared Dove (El-Mansi et al., 2021), and only on the apex in the 491 Egyptian nightjar (El-Mansi et al., 2020). The groove is absent in certain birds with varying feeding habits, such as the penguin, Rhea americana, and Egyptian laughing dove 492 493 (Abumandour & El-Bakary, 2019b; Kobayashi et al., 1998; Santos et al., 2011).

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The rectangular lingual prominence, with its papillary crest and its role as typical lingual structure in the filter feeding technique, has been described in our study as well as on the tongue of *Anseriformes*, including domestic and wild duck (Abumandour et al., 2019; Skieresz-Szewczyk & Jackowiak, 2016; Skieresz-Szewczyk et al., 2014) and domestic geese (Jackowiak et al., 2011; King & McLelland, 1984). The lingual prominence functions as a "fat cushion" that absorbs forces from eating and transporting food by placing it against the 501 palate (Jackowiak et al., 2011; Kooloos et al., 1989) and pressing on the lingual glands to secrete mucus (Jackowiak et al., 2011; Kooloos et al., 1989). Our study confirms the role of 502 lingual prominence and root in the feeding filter apparatus by observing the arrangement of 503 504 various papillary types, in which the rostral part of the lateral portion of the prominence has a 505 serrated border of 10-12 small triangular pointed processes, while its caudal part has a wedge-shaped structure; additionally, its lateral surface carries large triangular pointed 506 507 processes. Moreover, the short lingual root is completely bordered by numerous spinated 508 borders: the papillary crest rostrally, the lateral serrated border laterally, and the dorsal 509 spinated border caudally.

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The papillary crest, a fundamental part of lingual structures in most birds of the 511 different nutritional mechanisms (Abumandour & Kandyel, 2020; Abumandour, Farrag, et 512 al., 2021; El-Mansi et al., 2020; El-Mansi et al., 2021; Iwasaki et al., 1997; Marzban 513 Abbasabadi & Sayrafi, 2018; Skieresz-Szewczyk & Jackowiak, 2016), is absent in some 514 birds like the penguin, Japanese pygmy woodpecker, and Rhea Americana (Emura et al., 515 2009; Kobayashi et al., 1998; Santos et al., 2011). We agree with the former data that the 516 papillary crest plays a crucial role in preventing food particles from rostral escape and 517 518 directing them towards the esophagus (Abumandour & El-Bakary, 2019a; Abumandour & El-519 Bakary, 2017a; Abumandour & El-Bakary, 2017b; El-Mansi et al., 2021; Jackowiak et al., 2011). The study reveals minor variations in the crest among avian species, including shape, 520 number of papillary rows, and direction. Our study describes two transverse papillary rows: 521 522 the dorsal row of 16–18 large triangular papillae and the ventral row of 14–16 small papillae. Papillary crest formation from two transverse papillary rows is common in Anseriformes like 523 524 domestic ducks (Skieresz-Szewczyk & Jackowiak, 2016) and some avian species like kestrels, owls, and sparrows (Abumandour, 2018; Abumandour & El-Bakary, 2017b), while 525 one transverse papillary row is found in coots, quails, and Eurasian collared doves 526 527 (Abumandour & El-Bakary, 2017a; Abumandour, Farrag, et al., 2021; El-Mansi et al., 2021). 528 The V-crest is the most common crest shape in birds, including sparrows, Hobby, and 529 Northern Pintail (Abumandour, 2018; Abumandour, 2014; El Bakary, 2015), while, the W-530 crest is observed in the hoopoe (El-Bakary, 2011), but the U-crest in the cattle egret and Egyptian nightjar (Al-Ahmady Al-Zahaby, 2016; El-Mansi et al., 2020). Our findings 531 revealed the characteristic short root in the Anatoidea, in which it is divided into two halves 532 533 (right and left) by a narrow median passway, leaving a small smooth semilunar area, as in Garganey and domestic ducks (Abumandour et al., 2019; Skieresz-Szewczyk & Jackowiak, 534 535 2016). The lingual root of the coot has four portions: round, triangular, semilunar, and depressed (Abumandour & El-Bakary, 2017a), while the root is classified into two portions: 536 the rostral V-portion and caudal wide portion in the sparrow (Abumandour, 2018). 537 538 Meanwhile, the root of the kestrel was formed from one portion of a U-shape (Abumandour 539 & El-Bakary, 2017b) and a V-shape in the Hume's tawny owl.

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The laryngeal entrance is neglected in previously published articles on all <u>Anatoidea</u>, except that described in garganey (Abumandour et al., 2019) and also in other avian species (Abumandour & El-Bakary, 2019a; Abumandour, 2014; El-Mansi et al., 2020; El-Mansi et al., 2021). Our study gave a specific classification of the laryngeal region into the papillary (pre-glottic) triangular and the non-papillary (glottic) elevated areas, similar to that described in Garganey (Abumandour et al., 2019). Our study provides a fantastic subdivision of the papillary area into the lateral papillary portion with a small number of sphenopalatine salivary glands and the median smooth portion with three slightly oblique papillary rows that have not previously been described in any avian species. Meanwhile, the papillary area of the Garganey has numerous randomly distributed caudally and caudolaterally oriented small conical papillae and a median non-papillary longitudinal ridge (Abumandour et al., 2019).

552

553 Our findings show that the elevated laryngeal mound with its median glottic opening and two non-papillary glandular plates is bordered caudally by the pharyngeal papillae, 554 555 similar to those previously described in the pigeon, moorhen, Egyptian nightiar, and Eurasian Collared Dove (Abumandour, El-Bakary, et al., 2021; Bassuoni et al., 2022; El-Mansi et al., 556 557 2020; El-Mansi et al., 2021). Minor variations exist in the mound and its glottic opening appearance among various avian species. Our findings reveal the ovoid mound being similar 558 to the mound of the moorhen (Bassuoni et al., 2022) and hobby (Abumandour, 2014), the 559 circular, conspicuous, and fleshy mound found in the Eurasian collared dove (El-Mansi et al., 560 561 2021), and the rectangular mound in quail (Abumandour, Farrag, et al., 2021), while the 562 triangular mound is the most famous among avian species (Abumandour, 2018; Abumandour, 2014; Abumandour & El-Bakary, 2017a; Abumandour & El-Bakary, 2017b; 563 El-Mansi et al., 2020; Erdogan & Alan, 2012). Moreover, our findings reveal an ovoid, wide 564 glottic opening with a papillary border of 10–12 conical papillae, extending as a laryngeal 565 566 fissure with 2-4 papillae on each side, bordered by a longitudinal pharyngeal papillary row of large conical papillae. The ovoid opening is also described in the hoopoe and Eurasian 567 collared dove (Abumandour & Gewaily, 2019b; El-Mansi et al., 2021), the elongated opening 568 found in the Garganey (Abumandour et al., 2019), the elliptical glottic opening observed in 569 the moorhen (Bassuoni et al., 2022), and the elongated triangular shape seen in the coot 570 571 (Abumandour & El-Bakary, 2017). Our descried papillary border surrounding the glottic 572 opening has been reported in some birds, including the Garganey, quail, Egyptian laughing 573 dove, and sparrow (Abumandour, 2018; Abumandour et al., 2019; Abumandour & El-Bakary, 2019b; Abumandour, Farrag, et al., 2021; El-Mansi et al., 2021), while the non-574 575 papillary border is found in some avian species, including the moorhen, the Egyptian nightjar, and hobby (Abumandour, 2014; Bassuoni et al., 2022; El-Mansi et al., 2020), but there are 576 577 papillae surrounding the caudal portion of the glottic opening only, as in the Eurasian coot 578 (Abumandour & El-Bakary, 2017).

579

580 Our study provides that the fantastic diamond-shape pharyngeal papillae are arranged in 7-8 transverse papillary rows and one longitudinal papillary row of the caudally directed 581 mechanical conical papillae. The diamond-shaped pharyngeal papillae are also described in 582 583 the Garganey (Abumandour et al., 2019), while the heart-shaped pharyngeal papillae are in the coot (Abumandour & El-Bakary, 2017a). Meanwhile, the pharyngeal papillae are 584 585 observed as one transverse papillary row in some birds (Abumandour & Gewaily, 2019b; Mahdy, 2020), but the two transverse papillary rows are found in the Egyptian nightjar (El-586 Mansi et al., 2020) and the magpie and raven (Erdogan & Alan, 2012), while the three 587 588 semilunar papillary rows are found in the common moorhen (Bassuoni et al., 2022).

589 Meanwhile, the pharyngeal papillae disappeared completely in ratites (Crole & Soley, 590 2010a). Our work confirmed what has previously been reported about the important role of 591 these pharyngeal papillae in the caudal direction of the caught and filtrated nutrient materials 592 toward the esophagus (Abumandour, 2018; Abumandour & El-Bakary, 2019b; Abumandour 593 & El-Bakary, 2017a).

594

595 **5. Conclusion**

596 Our study is the first morphological effort to characterize the tongue and laryngeal 597 mound adaptations with their species-specific feeding behaviors, to identify the feeding 598 filtering technique in A. crecca. The feeding apparatus is formed by the lateral and dorsal 599 papillary systems. The lateral papillary system had conical papillae with numerous long 600 filiform and hair-like filiform papillae to constitute the food filtration apparatus, while the dorsal papillary system had ridged-like and rod-like papillae in addition to the small papillae 601 602 of the papillary crest and spinated border of the root to help in moving the food particles with water to the lateral sides of the prominence. The papillary laryngeal area had two lateral 603 papillary portions of the caudolaterally directed papillae and the median smooth portion. 604 605 Consequently, tongue and laryngeal mound ultrastructure exhibits anatomical adaptations for 606 efficiently filtering feeding mechanisms.

607608 Declarations

609 Ethics approval and consent to participate

610 This study was carried out according to the Institutional Animal Care and Use 611 Committee (IACUC) protocols of Laboratory Animals, Faculty of Veterinary Medicine, 612 Alexandria University (Approval No.: 11/3/2023/231). All methods were performed in 613 accordance with relevant guidelines and regulations by the Basel Declaration and the 614 International Council for Laboratory Animal Science (ICLAS). The anatomical nomenclature 615 was applied according to *Nomina Anatomica Avium* (1993)

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617 **Consent for publication:** Not applicable.

619 Availability of data and materials:

620 The datasets used and/or analyzed during the current study are available from the 621 corresponding author on reasonable request. The manuscript contains all data supporting the 622 reported results.

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627

624 **Competing interests:**

625 None of the authors has any financial or personal relationships that could 626 inappropriately influence or bias the content of the paper.

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886 Tables:

Table 1. Length and width of the different parts of the tongue of the Eurasian teal (*Anas crecca*)

Parts of the oropharyngeal cavity floor				
Length of the rostral part of the lower beak that does not occupy by the				
	tongue			
	Length	Rostral free part	2.8 ± 0.33	
		(Till beginning of lingual frenulum)		
		Caudal fixed part	1.4 ± 0.23	
		Tongue	4.2 ± 0.56	
		Lingual nail	0.4 ± 0.02	
		Apex	1.4 ± 0.32	
		Body	2.4 ± 0.76	
_		Root	0.4 ± 0.12	
Tongue		Lingual nail	0.6 ± 0.10	
		Apex	0.8 ± 0.34	
	Width	Body	$0.85 \pm$	
			0.32	
		Root	0.6 ± 0.21	
	Thickness	Lingual nail	0.2 ± 0.01	
		Apex	0.3 ± 0.03	
		Body	0.5 ± 0.1	
		Root	$0.42 \pm$	
			0.11	
Papillary crest		1.4 ± 0.32		
Median lingual groove		3.2 ± 0.76		
Lateral serrated		0.25 ±		
border of the root		0.01		
		0.4 ± 0.03		
Each half of the		0.4 ± 0.1		
dorsal spinated border of the root		0.3 ± 0.02		

Table 2. Length and width of the different parts of the laryngeal region of the Eurasian teal (Anas crecca)

tear (Thus creecu)			
Parts of the	Parts of the laryngeal region		
Length of Pharyngeal cavity	ength of Pharyngeal cavity		1.3 ± 0.23
Papillary (pre-glottic) triangula	ir area		0.4 ± 0.1
	Length		0.9 ± 0.12
Non-papillary glottic elevated		Rostral part	0.45 ± 0.12
area (Laryngeal mound)	Width	Middle part	0.61 ± 0.24
		Caudal part	0.3 ± 0.11
	Equatorial diameter Axial diameter Length		2.8 ± 0.54
			1.52 ± 0.64
			0.5 ± 0.1
Glottis Width		0.2 ± 0.01	

895	Table 3. Average Length and width of the lingual papillae on the different parts of the
896	tongue of the Eurasian teal (Anas crecca)

Lingual	Papillary type	Average	Average
regions		length (µm)	width (µm)
	Ridge-like papillae	1.7 ± 0.53	0.28 ± 0.1
Apex	Small pointed filiform papillae	1.4 ± 0.32	0.39 ± 0.12
	Rod-like filiform papillae	1.25 ± 0.32	0.26 ± 0.01
	Ventral rod-like filiform papillae	2.13 ± 0.47	0.27 ± 0.01
	Small filiform papillae	0.46 ± 0.1	0.04 ± 0.01
	Large quadrilateral conical papillae	2.5 ± 0.78	0.89 ± 0.34
	Large triangular conical papillae	1.563 ± 0.42	0.51 ± 0.1
Body	Hair-like filiform papillae	0.31 ± 0.02	0.032 ± 0.01
	Small pointed filiform papillae of the	0.41 ± 0.01	0.17 ± 0.01
	caudal part of the lateral border		

Eurasian tear (Anus Creccu)				
Papillary type		Papillary Number	Average length	Average width (um)
			μm)	(fun)
Donillow crost	Papillae of the dorsal row	16–18	0.71 ± 0.08	0.2 ± 0.01
rapmary crest	Papillae of ventral row	14–16	0.55 ± 0.06	0.17 ± 0.01
	Small pointed conical	7-8	0.31 ± 0.01	0.05 ± 0.001
Dorsal spinated	papillae of the dorsal row			
border of the root	Large triangular pointed	6-7	0.45 ± 0.02	0.17 ± 0.02
	conical papillae of the			
	ventral row			
Lateral serrated	Triangular papillae	10–11	0.3 ± 0.02	0.15 ± 0.01
border of root				
Lateral serrated				
border of rostral	Small triangular-pointed	10-11	0.09 ± 0.01	0.05 ± 0.01
part of the				
prominence				

Table 4. Length and width of the papillary border and crest of the tongue of the
Eurasian teal (Anas crecca)

the Eurasian teal (Anas crecca)					
			Papillary	Average	Average
Papillary type			Number	length	width (µm)
				(µm)	
Papillary border	Conical	papillae	10–12	0.25 ± 0.01	0.07 ± 0.001
of the glottis					
			16–18	0.4 ± 0.1	0.23 ± 0.02
			14–16	0.26 ± 0.07	0.09 ± 0.01
	7 or 8	Conical	12–14	0.25 ± 0.06	0.06 ± 0.02
Diamond-shaped	transverse	papillae	10–8	0.19 ± 0.01	0.05 ± 0.01
pharyngeal	rows		8–6	0.2 ± 0.01	0.04 ± 0.01
papillae			8–6	0.27 ± 0.08	0.03 ± 0.02
			4-6	0.2 ± 0.09	0.03 ± 0.01
	One	Long,			
	longitudinal	pointed	5–6	0.64 ± 0.15	0.18 ± 0.02
	row	papillae			

Table 5. Length and width of the papillary border and crest of the laryngeal region of the Eurasian teal (*Anas crecca*)

907 Figures



Figure 1. Gross (A-D) and SEM (E-H) images of the floor of the oropharyngeal cavity of 909 Anas crecca showing the external serrated surface (SLR) of lateral lower mandibular ramus 910 911 (LRB), sublingual space (SLS), rostral short smooth space (SDR), lingual frenulum (LF), 912 tongue (TO) with apex (LA) of ridged papillae (HP), tip (LT), nail (LN), transverse groove 913 (TG), body (LB) of lingual comb, small (SCP) and large (SCP) conical papillae had a rostral 914 pyramidal part (BP) and caudal lingual prominence (LP), root (LR) with its papillary crest (PC), large papillae (red arrowhead), serrated border (SB) with median space (blue 915 916 arrowheads). The pharyngeal region (PR) had papillary triangular (PTA) and non-papillary 917 elevated regions (NER) that had a mound (LM), glottis (GO), and pharyngeal papillae (PP). The medial groove (LG), lingual comb (PYS) had a head (He) and column of caudal (Cd), 918 919 middle (Cr), and rostral (Rr) parts. The lingual nail (LN) had a dorsal surface (DLS) of 920 numerous small tubercles (green stars) and a ventral surface of numerous micro-cells of 921 different shapes (MC) that were surrounded by micro-grooves (green arrowheads), and 922 Esophagus (ES).





Figure 2. Gross (A) and SEM (B-E) images of the tongue of *Anas crecca* showing the apex (LA), nail (LN), transverse groove (TG), and folds (AF). The tip (LT) carried ridge-like papillae (RPP) of the projected base (HS) and small filiform papillae (SFP). The median groove (LG), deep median groove (MG), and body (LB) carried small (SCP) and large (SCP) conical papillae. The prominence (LP) and the lingual comb (PYS) with its head (He) and column of caudal (Cd), middle (Cr), and rostral (Rr) parts.





931 Figure 3. Gross (A and H) of the lower mandibular beak and SEM (B-G and I-J) images 932 of the apex (LA) of Anas crecca show that the nail (LN), transverse groove (TG), tip (LT), 933 ridge-like papillae (RPP) of the projected base (HS), small filiform papillae (SFP), scales 934 (BS), lingual groove (LG), deep groove (MG), body (LB), papillary crest (PC), small (SCP) 935 and large (SCP) conical papillae, small filiform papillae (SFP), lingual prominence (LP), 936 ventral lingual surface (VLS), lingual frenulum (LF), sublingual space (SLS), the external 937 serrated surface (SLR) of the lateral lower mandibular ramus (LRB), and dorsal beak surface 938 (SDR). The lingual comb (PYS) had a head (He) and column of caudal (Cd), middle (Cr), 939 and rostral (Rr) parts.



941 Figure 4. Gross (A) of the tongue and SEM of the lingual body (B-F) images of *Anas* 942 *crecca* showing apex (LA), tip (LT), nail (LN), transverse groove (TG), numerous ridge-like 943 papillae (HP), body (LB), a rostral pyramidal part (BP) with rod-like filiform papillae (RFP), 944 a projected base (PS), and small conical papillae (SCP), while the lingual prominence (LP) 945 with large conical papillae (LCP). The lingual groove (LG), deep groove (MG), and lingual 946 comb (PYS) had heads (He) and columns of caudal (Cd), middle (Cr), and rostral (Rr) parts.





948 Figure 5. Gross (A) of the tongue and SEM of the lingual body (B-F) images of Anas crecca show the apex (LA), tip (LT), nail (LN), transverse groove (TG), ridge-like papillae 949 950 (HP), body (LB), a rostral pyramidal part (BP) with small conical papillae (SCP) and small 951 filiform papillae (SFP) with its base (PS), large quadrilateral conical papillae (LCPQ), 952 randomly distributed spines (RS), and round tubercles (RB) at its rostral part, and large 953 triangular conical papillae (LCPT) with hair-like filiform papillae (HFP). The prominence 954 (LP), groove (LG), and the lingual comb (PYS) with its head (He) and column of caudal part 955 (Cd), middle part (Cr), and rostral (Rr) part are three portions (blue, green, and red 956 arrowheads).



957

Figure 6. Gross (A) of the tongue and SEM of the lingual body (B-F) images of Anas 958 crecca showing the body (LB), rostral pyramidal part (BP) with large triangular conical 959 papillae (LCPT), and hair-like filiform papillae (HFP). The prominence (LP) with its serrated 960 961 rostral portion (red stars) had large triangular conical papillae (LCPT) with hair-like filiform papillae (HFP), round tubercles (RT), elevated tubercles (ET), salivary gland openings (red 962 963 arrowheads) at its posterior part, the groove (LG), papillary crest (PC), and root (LR), and the 964 and the lingual comb (PYS) with its head (He) and column of caudal (Cd), middle (Cr), and 965 rostral (Rr) parts.





967 Figure 7. Gross (A) and SEM (B-F) images of the lingual body of *Anas crecca* showing 968 the body (LB), lingual groove (LG), lingual comb (PYS), lingual prominence (LP), papillary 969 crest (PC) with its dorsal (PCD) that had small accessory papillae (red arrowheads) and 970 ventral papillary row (PCV) with its median large ones (white star), large triangular conical 971 papillae (LCPT) with hair-like filiform papillae (HFP), pointed filiform papillae (PFP) and 972 wing (LW). The root (LR) has a median smooth part (MLR), a serrated border (SB), and a 973 pointed lateral border (PB).





Figure 8. Gross (A) and SEM (B-E) images of the lateral lingual surface of *Anas crecca* showing the apex (LA), nail (LN), ridge-like papillae (RPP), and small filiform papillae (SFP). The body (LB) had a rostral pyramidal part (BP) with small conical papillae (SCP) and rod-like filiform papillae (RFP), while the prominence (LP) had ventral rod-like filiform papillae (RFPV), large quadrilateral (LCPQ) and triangular (LCPT) conical papillae, hair-like processes (HFP) with a median ridge (red stars), accessory fan-like structure (AC), and round tubercles (RT). The lingual root (LR) has a papillary crest (PC).



982

983 Figure 9. Gross (A) and SEM (B-F) images of the tongue of Anas crecca showing the body (LB), groove (LG), comb (PYS), prominence (LP), and the papillary crest (PC) with its 984 985 large median papillae (red arrowheads). The root (LR) has a spinated border (SB) with its 986 rostral (SBR) and posterior papillary row (SBR), a narrow passage (blue arrowheads), and a 987 processed border (PB). P The pharyngeal region (PR) had a papillary triangular part (PTA) 988 with their papillae (HP) that were arranged in three papillary rows: lateral (HPL) with 989 accessory papillae (red star), middle (HPM) with accessory papillae (green star), and medial 990 (HPE) row with papillary scales (HS), while the non-papillary elevated part (NER) had a 991 laryngeal mound (LM), glottic opening (GO), pharyngeal papillae (PP), and esophagus (ES).



993 Figure 10. Gross (A) and SEM (B-F) images of the laryngeal entrance of Anas crecca 994 showing the root (LR), papillary crest (PC), spinated border (SB), narrow passage (blue 995 arrowheads), and processed border (PB). Pharyngeal region (PR) had papillary triangular part 996 (PTA) with their papillae (HP) that were arranged in three papillary rows: lateral (HPL), 997 middle (HPM), and medial (HPE) rows with papillary scales (HS), while the non-papillary 998 elevated part (NER) had their laryngeal mound (LM) with laryngeal gland openings (red 999 arrowheads) and was surrounded by longitudinal laryngeal border (HB) with their spines (green arrowheads), glottic opening (GO) with its papillary border (GB), spines (blue 1000 1001 arrowheads), and laryngeal cleft (LF). Pharyngeal papillae (PP) are arranged in seven rows: 1002 the rostral slightly oblique transverse row (GPT), the median longitudinal row (GPL), the six 1003 transverse rows (SP 1-6), and the esophagus (ES).