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Macroscopic structure of the intestines of the common pheasant (*Phasianus colchicus*)

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Abstract
This article presents a detailed analysis of the intestinal anatomy of the common pheasant (*Phasianus colchicus*), based on a study carried out on 20 females from a specialist breeding farm. After dissection, the intestines were carefully examined taking into account their: length, diameter and weight using a flexible measure, callipers and a laboratory balance. Attention was focused on characteristic anatomical features including the specific function and structure of: duodenum, jejunum and ileum, cecum and rectum. In the discussion, the results of the intestinal structure were compared with data from other bird species, highlighting the influence of diet on the varied morphology of the digestive system. This study, which is a prelude to further, more extensive analyses, provides a basis for the development of knowledge on comparative intestinal anatomy, with recommendations for further research taking into account species and sex diversity.

Running title: Intestines of the common pheasant

Keywords: animal anatomy, bird, intestines, common pheasant

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Introduction

The anatomy of birds, a remarkably diverse group of animals that have been the subject of extensive scientific research for many years, highlights their unique role in biological classification and biodiversity [1]. Birds are distinguished by their distinct morphological and functional characteristics [2] and are classified into altricial and precocial species, setting them apart from other animal groups [3]. These distinctive traits are closely linked to their ability to fly and adapt to a wide range of natural environments [4]. This diversity reflects not only the evolutionary richness and complexity of birds but also their ability to inhabit nearly every environment on Earth—from tropical forests to harsh polar regions [5].

The dietary diversity of birds significantly influences their gastrointestinal anatomy, ranging from plant foods and invertebrates such as insects to vertebrates including fish and rodents. Many bird species adapt their dietary preferences depending on the season, which demonstrates not only their adaptability but also how these changes impact the structure and function of their digestive systems [6,7]. Birds play a fundamental role in trophic networks, not only fulfilling their basic nutritional requirements but also performing key functions in regulating insect populations and dispersing seeds. Through these activities, they contribute significantly to the stability and health of diverse ecosystems [8,9].

This adaptive diversity in birds demonstrates how diet influences the specific structure and function of the intestines. The bird intestine (*intestinum*), a convoluted tube located on the right side of the abdominal cavity, is divided into the small intestine (*intestinum tenue*), which is further subdivided into three sections: the duodenum (*duodenum*), jejunum (*jejunum*), and ileum (*ileum*). The large intestine (*intestinum crassum*) is divided into two ceca (*cecum dextrum et sinistrum*) and the rectum (*rectum*). The length of each segment of the digestive tract varies by species, reflecting the form of ingested food [10,11].

The duodenum, beginning at the pyloric orifice (*ostium pyloricum*) of the stomach, forms the duodenal loop (*ansa duodenalis*), where the descending (*pars descendens*) and ascending (*pars ascendens*) parts encircle the pancreas. In this area, the duodenal papilla (*papilla duodenalis*) is present. The terminal portion of the duodenum transitions into the jejunum at the duodenojejunal flexure (*flexura duodenojejunalis*) near the cranial mesenteric artery (*arteria mesenterica cranialis*). This section is essential for regulating the pH of digestive contents, adjusting it to optimal conditions for pancreatic enzyme activity. The duodenum is also the primary site of nutrient absorption, supported by a large number of intestinal villi (*villi intestinales*) that increase the surface area for absorption [10,11].

The jejunum, the longest segment of the small intestine, forms characteristic jejunal loops (*ansae jejunales*) and an axial loop (*ansa axialis*), with variations depending on the species. In the middle of the jejunum, a *diverticulum vitellinum* can sometimes be observed, a remnant of the active yolk duct present in the embryonic stage. This section is rich in lymphoid tissue, which plays a crucial role in immune defense and forms the papilla of the yolk duct (*papilla ductus vitellini*) in the mucosa. In this region, further enzymatic digestion of food takes place, along with the absorption of nutrients and water [10,11]. The design of the intestinal wall is optimised to maximise the absorptive surface area by increasing the number of microvilli, folds and enterocytes that increase the efficiency of the inner surface area of the mucosa, which also find their analogous use within the duodenum. The intestinal immune system, often referred to as the gut-associated lymphoid tissue or GALT, is fundamental to the systemic immunity of birds, providing the first line of defence against pathogens and other external agents. The ileum *(ileum)* in birds is an exceptionally short segment, with a minimally larger diameter and a significant increase in the terminal segment. Given its characteristic course, a distinction is made between the supraduodenal loop (*ansa supraduodenalis*) and the hyperacusis loop (*ansa cupracecalis*). The large intestine, as a part with a clearly shortened course, is divided into: the caecum and the rectum. In birds, characteristically, the right and left caecum can be distinguished, with each terminal element divided into: base (*base*), body (*corpus*) and apex (*apex*). Depending on the species, there are significant differences in length or even absence of occurrence. Their mucosa is extensive in lymphoid tissue with resident bacterial groups such as: *Firmicutes*, *Bacteroidetes* and *Protobacteria*, contributing to proper digestion and metabolism by participating in the breakdown of nutrients, synthesis of B and K vitamins and production of bactericidal substances (bacteriocins) as a natural immune barrier against pathogens. The bilateral estuary of the caecum *(ostium caeci)* and the estuary of the ileum, which is located in the central part, come together in a specific area. This area is the point where digestion ends and absorption of the last nutrients begins, and it is also the place where undesirable metabolic compounds are diverted for further excretion [10,11].

The large intestine is divided into the colon *(caecum)* and the rectum *(rectum)*, which eventually expands significantly and transitions into the cloaca *(cloaca)*, a sac-like expansion divided by the cloacal septum into dorsal and ventral parts. The mucosal folds divide this area into three sections: the coprodeum, which connects with the colon; the urodeum, where the ureter and either the vas deferens or left oviduct open; and the posterior part of the cloaca *(proctodeum)*, containing the bursa of Fabricius *(bursa Fabricii)*. It is important to note that anatomical differences or variations may arise depending on the systematic classification of birds [10,11].

The aim of this study includes a precise analysis and morphological characterization of bird intestines, with an emphasis on the anatomical structure of specific intestinal segments, in the context of their significance for digestive processes.

Material and methods

The study was conducted on 20 female common pheasants of varying ages. The research material consisted of carcasses from pheasants originating from a specialized ornamental poultry breeding facility. The material was obtained post-mortem, and therefore, approval from the ethics committee was not required.

Some of the material was frozen immediately after collection and stored until later dissection, while the remaining carcasses were stored in a 10% aqueous formaldehyde solution.

All the carcasses were in very good condition, which allowed detailed examinations and analyses to be carried out.

The abdominal shells were cut into each individual. The intestines were then removed starting from the pyloric outlet ending at the cloaca. The intestines were cut, cleaned and irrigated with tap water and then dried with paper towels. After prior preparation of the slides, measurements were taken in several different ways.

Estuaries were measured using callipers to the nearest 0.01 mm, intestinal lengths were measured with a flexible tape measure to the nearest 1 mm

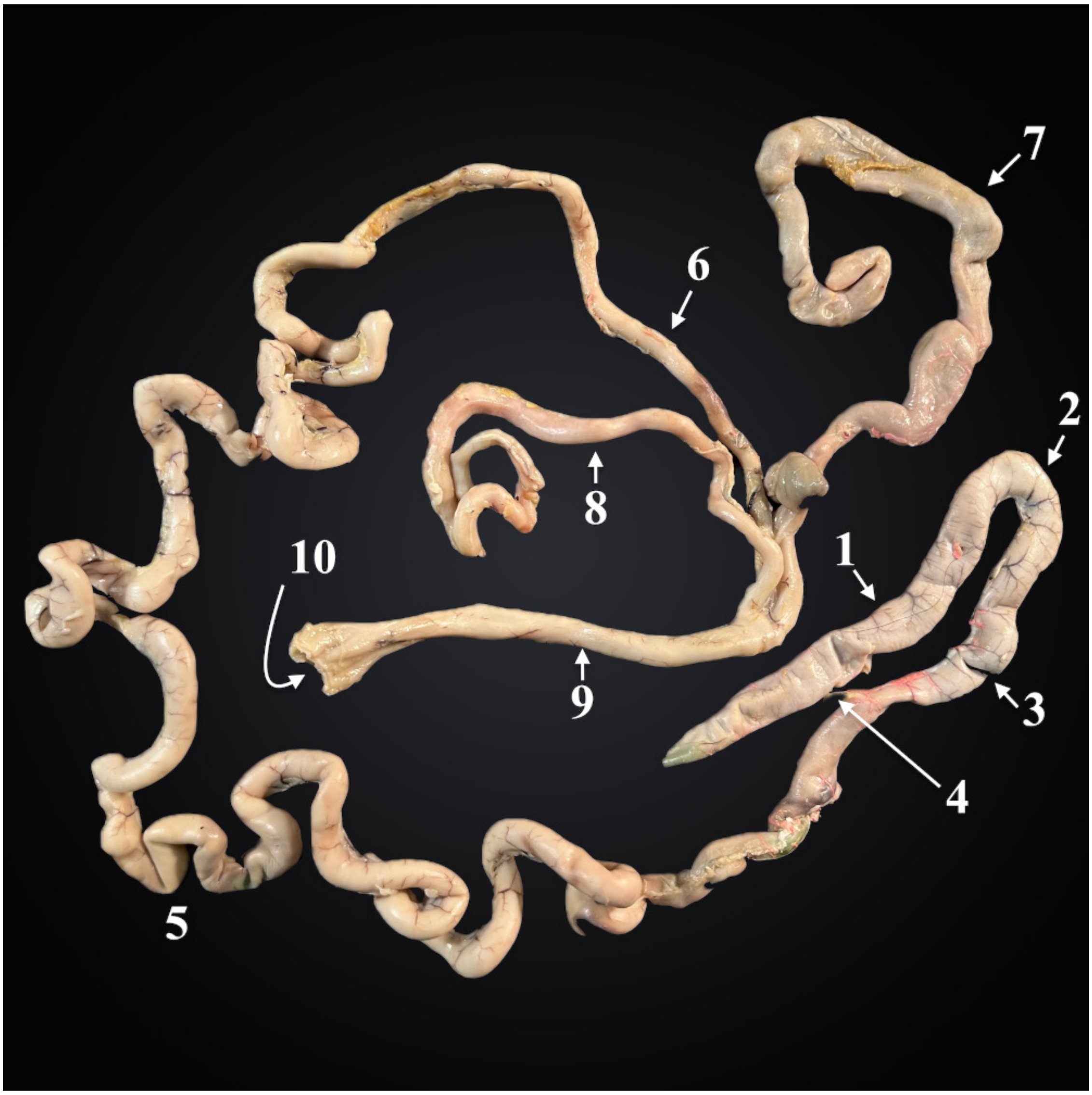

FIGURE 1 Pheasant intestines. 1 – descending part of duodenum. 2 – duodenal loop. 3 – ascending part of duodenum. 4 – pancreatic ducts. 5 – jejunum. 6 – ileum. 7 – right cecum. 8 – left cecum. 9 – large intestine. 10 – cloaca

TABLE 1 Evaluation of the length of segments and the number of intestinal loops in the digestive tract

MEASUREMENT	VALUE MIN.	VALUE MAX.	AVERAGE	MEDIAN
Duodenum length (mm)	144.00	325.00	208.08	234.500
Length of jejunum and ileum (mm)	640.00	865.00	779.25	752.500
Length of left cecum (mm)	143.00	252.00	191.36	197.500
Length of right cecum (mm)	151.00	290.00	213.64	220.500
Length of rectum and steak (mm)	71.00	124.00	89.86	97.500
Length of the descending part of the duodenum (mm)	52.00	94.00	68.38	73.000
Length of the ascending part of duodenum (mm)	61.00	114.00	88.54	87.500
Number of intestinal loops	20.00	27.00	22.17	23.500

and weight measurements were taken using a laboratory balance to the nearest 0.01 g.

An analysis of the length of individual bowel fragments was carried out, including the length of the descending and ascending part of the duodenum, the combined length of the jejunum and iliac ileum, the length of the left and right cecum, and the length of the colon and rectum. The number of small bowel loops was counted. The diameters of structures such as the duodeno-cheek outlet, the iliac-caecal outlet, the right cecal outlet, the left cecal outlet and the diameter of the cloaca were measured. After the material was cleaned of fat, connective tissue, contents and other unwanted tissues that are not part of the intestine, the weight of the individual intestinal fragments, i.e. the duodenum, jejunum and ileum, the weight of the right and left cecum separately, and the weight of the colon including the rectum, were measured. The material was analysed '*in situ*' and '*ex situ*' taking into account anatomical structures found in other birds. Images were taken with an iPhone 13 mini (Apple, Cupertino, CA, USA) and then graphically processed in Preview Version 11.0 editing software (1056.2.4), Copyright© 2002-2023 Apple Inc. (Apple, Cupertino, CA, USA).

Results

The intestines of the pheasant (**Fig. 1**) give the impression of being highly looped and difficult to separate. The intestines themselves begin with the duodenum which has a 'horseshoe' shape characteristic of birds. The length of the descending part of the duodenum averaged 68.38 mm, while the ascending part measured 88.54 mm, respectively. The total length of the duodenum varied between 144 and 325 mm – 208.08 mm on average (**Tab. 1**). The diameter of the duodenal lumen measured at the duodeno-cheek flexure averaged 4.62 mm. The long jejunum begins next, followed by the jejunum. The jejunum is characterised by numerous loops that ranged from 20 to 27, with an average of 22. Most individuals were characterised by loops numbering 21. In the present study, the presence of yolk diverticulum was not found in any individual. The jejunum, together with the ileum, was a long section of intestine averaging 779.25 mm. The highest value recorded was 865 mm and the lowest 640 mm. The lumen of the iliac bowel was measured near the transition to the large bowel. It averaged 1.75 mm. It is directly adjacent to the caecal orifices, which are 2.15 mm and 1.77 mm for the right and left cae-

TABLE 2 Analysis of morphometric parameters of the gastrointestinal tract

MEASUREMENT	VALUE MIN.	VALUE MAX.	AVERAGE	MEDIAN
Diameter of ileal outlet into the large intestine (mm)	2.77	7.39	4.62	5.080
Bowel outlet diameter hip into the large intestine (mm)	1.03	3.19	1.75	2.110
Diameter of left cecum outlet (mm)	0.82	3.40	1.77	2.110
Diameter of right cecum outlet (mm)	0.91	4.03	2.15	2.470
Cloaca diameter (mm)	8.26	13.05	10.12	10.655

FIGURE 2 The cecum in longitudinal section

cum, respectively (**Tab. 2**). Preparing the large intestine, at the very beginning we can observe a tee-shaped structure, with the mouths of the caecum on the sides and the mouth of the iliac intestine in the centre, which together form the large intestine. The length of the caecum averaged 213.64 mm and 191.36 mm for the right and left caecum respectively. The cecum in longitudinal section had square-like structures on the mucosa (**Fig. 2**).

The length of the large bowel including the rectum averaged 89.86 mm. In addition, the diameter of the cloaca was measured, which was 10.12 mm. The total length of the intestines without the caecum averaged 1077.18 mm, while with the caecum it reached 1482.18 mm.

The organs were then weighed, which amounted to 6.1 g for the duodenum; 13.16 g for the jejunum and ileum; 4.72 g for the left caecum; 5.78 g for the right caecum; and 20.23 g for the large intestine including the rectum (**Tab. 3**). In total, the whole intestines weighed 49.99 g.

In accordance with the results presented above, the percentage of the different intestinal segments was calculated (**Tab. 4**). The length ratio of the small intestine to the large intestine was 1.995, while the weight ratio was 0.63.

Discussion

So far, no studies have focused exclusively on the anatomy of the pheasant's intestines. However, recent research, such as that by Skowroński et al. [12], has explored aspects of vascularization, offering valuable insights into the blood supply and its role in supporting intestinal function. These findings contribute significantly to our understanding of the pheasant's digestive system, laying a foundation for future anatomical studies.

The small intestine and large intestine of the common pheasant resemble the arrangement also found in domestic fowl such as the domestic hen *(Gallus gallus domesticus)*, domestic goose *(Anser domesticus)*, rock pigeon *(Columba livia)*, and birds of the duck family (Anatidae) [11].

The shape of the duodenum resembled the letter 'U', which is characteristic of birds. It consisted of two parts: a descending and an ascending part, connected by a loop of duodenum. However, it is worth noting that there are birds whose duodenum has a different, unusual shape. For example, the duodenum of the Cape penguin *(Spheniscus demersus)* is highly undulating, which deviates from the characteristic shape for the bird cluster. In addition, some species, such as the white-fronted goby *(Morus bassanus)*, which is a large seabird, have a folded duodenum, while birds of the pigeon family (Columbidae), are characterised by the complete absence of a duodenal loop [10]. The diameter of the duodenum is reported to be 8 mm in the hen, 12-16 mm in the goose, 4-11 mm in the duck, and 5-12 mm in the pigeon, respectively, by Kobryń and Kobryńczuk [11]. For the present study in the pheasant, the diameter of the duodenum was found to average 4.62 mm. Turning to the jejunum, the same authors report that it forms about 10 loops in the domestic hen and between 5 and 8 in the goose and duck. In our study in the common pheasant, the median number of loops was 21. The yolk diverticulum was not observed and the jejunum showed no particular

TABLE 3 Mass parameters of selected intestinal segments

MEASUREMENT	VALUE MIN.	VALUE MAX.	AVERAGE	MEDIAN
Duodenal weight (g)	3.79	9.83	6.10	6.810
Weight of jejunum and ileum (g)	9.21	19.60	13.16	14.405
Weight of left cecum (g)	3.19	7.31	4.72	5.250
Weight of right cecum (g)	3.81	8.50	5.78	6.155
Weight of colon (g)	1.70	4.38	2.32	3.040

TABLE 4 Percentage contribution of individual intestinal segments

SHARE PERCENTAGE	DUODENUM	JEJUNUM AND ILEUM	LEFT CAECUM	RIGHT CAECUM	COLON AND RECTUM
Length	14%	52,5%	12,9%	14,5%	6,1%
Mass	12,2%	26,3%	9,4%	11,6%	40,5%

TABLE 5 Length of individual intestinal segments in domestic birds [11] [mm] compared to the common pheasant (own research)

STRUCTURE	HEN	GOOSE	DUCK	PIGEON	PHEASANT
Duodenum	220-350	400-490	220-380	120-220	144-243
Jejunum and ileum	980-1380	1700-2130	1000-1580	530-840	640-865
Cecum	120-250	220-340	100-200	2-7	142-290
Rectum and steak	80-110	160-220	80-130	30-40	71-124
Overall length	1520-2340	2700-3520	1500-2500	720-1250	1148-1856

morphological changes. It represented only a short fragment leading to the large intestine.

The large intestine of the pheasant consists of two caeca and a rectum. The shape and size of the cecum in birds are highly variable. The cecum of the pheasant is a closed at the end of the tubular structures similar to those seen in domestic poultry [13,14]. The average length of the caeca in the pheasant in our study was 191.36 mm for the left and 213.64 mm for the right caeca (**Tab. 5**). Most bird species have two caeca, and the lengths of the right and left caeca are approximately equal. The average length of caeca is 150-250 mm in domestic hens, 20-50 mm in pigeons, 220-340 mm in ducks and 100-200 mm in geese. In each of the pheasant individuals studied, the left caecum was shorter than the right caecum. The variability of caeca is well described in a study by McLelland [15]. The author presents several dozen types of caeca, dividing them into simple caeca and saccular caeca. Despite the comprehensiveness of the study, it lacks the common pheasant which underlines the validity of the present study. It does, however, confirm that usually the right cecum shows greater length. It should be noted that there is a numerous group of birds that are characterised by the absence of caeca or their presence in a vestigial form. An example of birds possessing a single caecum is the heron, among others [16,17]. The flagship example of an order of birds for which the complete absence of a caecum is characteristic is the parrots (Psittaciformes), although caeca are absent in representatives of as many as seven orders, as reported in Handbook of avian anatomy [10]. Some report that the development of the caecum in birds is linked to their dietary preferences. The diversity and high specialisation of birds' diets lead to significant differences in anatomy between different species. Most likely, the average length of the caecum is significantly greater in herbivorous birds than in those that feed on animal foods [18].

The caeca of pheasants have two separate mouths which occur in most birds, but differ from those of ostriches (Struthioniformes), in which the caeca merge into one common mouth [11].

Further, the contents are moved to the colon which is also referred to as the rectum in many publications. In birds, no division is used due to the inability to anatomically and histologically distinguish the structures [16,19,20]. In most domestic birds including the pheasant, the rectum is flat. However, in ostrich and other birds of the order Struthioniformes, such as emu and kiwi, it is noted that the outer surface of the rectum has a sac-like form [20-22].

Conclusions

In the present study, the intestines of the common pheasant were found to have an anatomical structure similar to other bird species. The following were found to be present: duodenum, jejunum, ileum, cecum and rectum. The duodenum has a characteristic 'U' shape. A yolk diverticulum was not found in the study. The jejunum was the longest section of the entire digestive system. The presence of two cecum were found – a left and a right. The right caecum was significantly longer than the left. The present study is a preliminary one and the results obtained need to be verified through studies conducted on a wider group of animals, including the male gender aspect. Nevertheless, it provides a foundation for further development of knowledge on normal and comparative animal anatomy.

Ethical approval

The conducted research is not related to either human or animal use.

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Conflict of interest statement

The authors declare no conflict of interest.

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