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Comparative Anatomical and Histomorphological Study of the Kidney in Chick (Gallus domesticus) and Albino Rat (Rattus norvegicus)

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ABSTRACT

The kidney is the principal osmoregulatory and excretory organ of vertebrates, yet its gross architecture and microscopic organisation differ considerably between classes. The present comparative study examines the anatomical and histomorphological features of the kidney in the domestic chick (Gallus domesticus) and the albino rat (Rattus norvegicus), two commonly used laboratory and biomedical model species belonging to Aves and Mammalia respectively. Gross observations focused on shape, lobation, colour, position and relation to surrounding viscera, while histological observations focused on cortico-medullary organisation, nephron population, glomerular architecture and tubular differentiation. The avian kidney was found to be elongated, trilobed and closely applied to the synsacrum, containing a mixed population of loopless (reptilian-type) and looped (mammalian-type) nephrons, whereas the rat kidney was bean-shaped, unilobed and unipapillate, composed exclusively of looped nephrons arranged into a well-defined cortex, medulla and papilla. These structural differences underlie the markedly greater urine-concentrating capacity of the mammalian kidney compared with the avian kidney. The findings reinforce the value of comparative renal morphology in understanding functional adaptation, phylogeny and the choice of appropriate animal models in physiological and toxicological research.

KEYWORDS
Comparative anatomy, histomorphology, avian kidney, mammalian kidney, nephron, Gallus domesticus, Rattus norvegicus

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Introduction

The kidney is one of the most physiologically versatile organs of the vertebrate body, responsible for filtration of blood, regulation of fluid and electrolyte balance, acid–base homeostasis, and excretion of nitrogenous waste. Although the fundamental filtering unit of the kidney, the nephron, is broadly conserved across vertebrates, its structural elaboration varies greatly among taxa in relation to habitat, diet, and the chemical form in which nitrogenous waste is excreted (Braun, 1998). Comparative anatomical and histological studies of the

kidney across classes are therefore of considerable value, not only for understanding evolutionary adaptation but also for the appropriate selection and interpretation of animal models used in biomedical, pharmacological, and toxicological research.

Birds, being uricotelic, excrete nitrogenous waste mainly as poorly soluble uric acid, which permits substantial water conservation without requiring a fully developed urine-concentrating mechanism (Dantzler, 1989). The avian kidney is unique among vertebrates in possessing two morphologically and functionally distinct nephron populations within a single organ: a majority of short, —reptilian-type‖ nephrons that lack a loop of Henle and are confined to the renal cortex, and a smaller population of —mammalian-type‖ nephrons possessing a loop of Henle, situated in the medullary cones (Braun, 1998; Braun & Dantzler, 1972). This dual nephron population underlies the comparatively modest urine-concentrating ability of birds relative to mammals (Braun & Reimer, 1988).

In contrast, the mammalian kidney, represented in the present study by the albino rat, is a bean-shaped, unipapillate organ in which every nephron possesses a well-developed loop of Henle that dips into the medulla, enabling the generation of a strong medullary osmotic gradient through the countercurrent multiplier system. This arrangement allows mammals to produce urine markedly hypertonic to plasma, a capacity that is central to their ability to survive in water-limited terrestrial environments (Al-Samawy, 2012).

The domestic chick and the albino rat are widely used as experimental animals in physiological, pharmacological, nutritional and toxicological research, including nephrotoxicity studies, and a clear understanding of the baseline comparative renal anatomy and histology of these two species is essential for the correct interpretation of experimentally induced renal changes. Several earlier workers have described the renal morphology of galliform birds (Dhyaa et al., 2014; Mohammed & Reshag, 2020; Mohammed, 2021) and of the albino rat (Al-Samawy, 2012; Fitmawati et al., 2021), but few studies have placed the two species side by side within a single comparative framework. The present paper was therefore undertaken to describe, compare and contrast the gross anatomical and histomorphological features of the kidney of the chick and the albino rat, and to relate these structural differences to their divergent modes of nitrogen excretion and water economy.

2. Materials and Methods

This comparative account is based on gross anatomical dissection and light-microscopic histological examination of kidneys obtained from clinically healthy adult domestic chicks (Gallus domesticus) and adult albino rats (Rattus norvegicus), supported by correlation with previously published anatomical and histological descriptions of the avian and mammalian kidney (Bacha & Bacha, 2012; Braun & Dantzler, 1972; Al-Samawy, 2012; Dhyaa et al., 2014). For gross study, the kidneys were exposed in situ by careful dissection of the dorsal body wall to observe their position, relations, shape, colour, lobation and capsular covering, following which the organs were removed, weighed, and their external morphology recorded and photographed. For histological study, kidney samples from both species were fixed in 10% neutral buffered formalin for 24–48 hours, dehydrated through an ascending series of ethanol, cleared in xylene, and embedded in paraffin wax. Sections of 5–6 µm thickness were cut using a rotary microtome, mounted on glass slides, and stained with routine Haematoxylin and Eosin (H&E) for general histoarchitecture, following standard histological protocols (Bacha & Bacha, 2012; Fitmawati et al., 2021). Stained sections were examined under a light microscope at low and high magnification to study the cortico-medullary organisation, glomerular structure, and the proximal and distal tubular segments, and representative fields were photomicrographed for comparative description.

3. Gross Anatomical Observations

3.1. Kidney of the Chick

The kidneys of the chick are paired, elongated, dark

reddish-brown organs situated retroperitoneally within deep depressions of the synsacrum, to which they are closely applied along their entire dorsal surface. Each kidney is conventionally divided into three lobes — cranial, middle and caudal — of which the caudal lobe is typically the largest, a pattern also reported for domestic fowl by Dhyaa et al. (2014) in their comparative study of the harrier, chicken and mallard duck. Unlike the mammalian kidney, the avian kidney lacks a discrete renal pelvis and a single ureteric funnel; instead, numerous primary and secondary branches of the ureter directly drain the collecting duct system of each lobe. The avian kidney does not present a smooth, encapsulated bean shape but rather a lobulated, closely adherent surface intimately moulded to the bony pelvic girdle, an arrangement that reflects the absence of a well-developed perirenal fat capsule and loose connective tissue seen in mammals (Nabipour et al., 2009).

3.2. Kidney of the Albino Rat

The kidneys of the albino rat are paired, bean-shaped, reddish-brown organs located retroperitoneally in the dorsal abdominal cavity, one on either side of the vertebral column, with the right kidney positioned slightly cranial to the left. Each kidney is invested by a thin, smooth, transparent fibrous capsule that can be readily stripped from the underlying parenchyma, external to which lies a variable amount of perirenal adipose tissue. Unlike the chick kidney, the rat kidney is unilobar and unipapillate: a single renal papilla projects into a funnel-shaped renal pelvis that continues as the ureter, a simple mammalian pattern also described by Al-Samawy (2012) in the albino rat. On longitudinal section, the kidney clearly shows an outer, granular cortex and an inner, striated medulla converging upon the single papilla, a gross organisation fundamentally different from the lobulated, pelvis-less avian kidney.

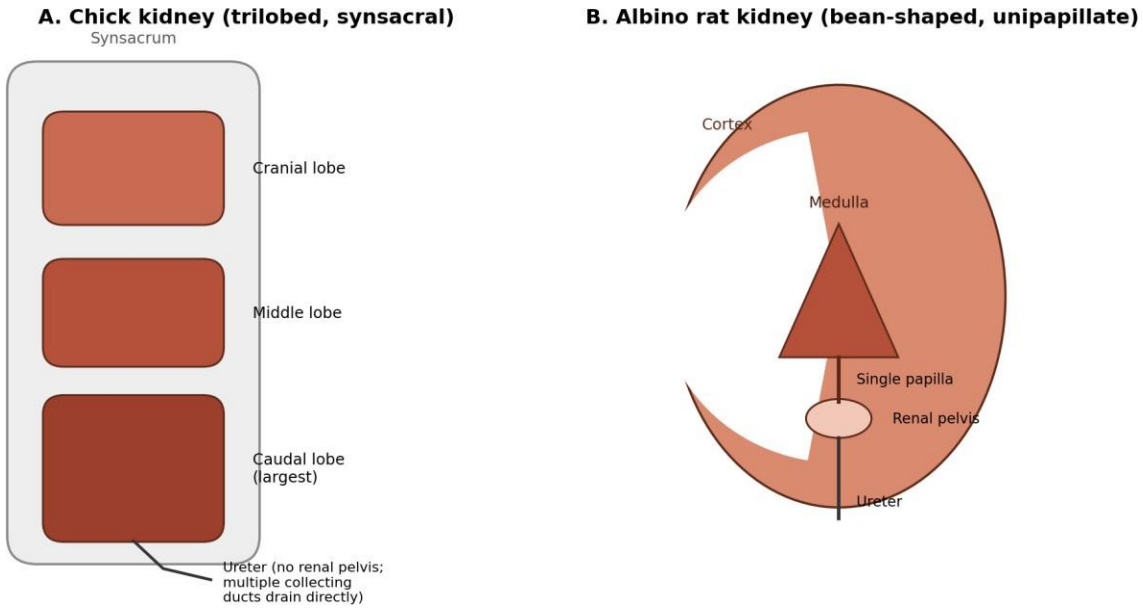

Figure 1.

Schematic comparison of gross renal architecture. (A) The chick kidney is elongated and trilobed (cranial, middle, caudal lobes), closely applied to the synsacrum, and lacks a discrete renal pelvis. (B) The albino rat kidney is bean-shaped and unipapillate, with a distinct cortex, medullary pyramid, renal pelvis and ureter.

(Original schematic prepared by the authors based on descriptions in Dhyaa et al., 2014; Nabipour et al., 2009; and Al-Samawy, 2012.)

Table 1. Comparative summary of gross anatomical features of the kidney in the chick (Gallus domesticus) and the albino rat (Rattus norvegicus), based on the present observations and cited literature.

Feature	Chick (Gallus domesticus)	Albino rat (Rattus norvegicus)
Shape	Elongated, flattened, trilobed	Bean-shaped, smooth, unilobar
Number of lobes	Three (cranial, middle, caudal)	None (single undivided mass)
Relation to skeleton	Embedded within synsacral depressions	Free in retroperitoneal space, only loosely fixed by fat
Capsule	Thin, closely adherent, poorly defined	Thin, smooth, transparent, easily stripped
Renal pelvis	Absent; multiple primary/secondary ureteric branches	Present; single funnel-shaped pelvis
Papilla	Absent (multiple medullary cones)	Single renal papilla
Colour	Dark reddish-brown	Reddish-brown
Largest lobe/region	Caudal lobe	Not applicable (unilobar)
Key source(s)	Dhyaa *et al.* (2014); Nabipour *et al.* (2009)	Al-Samawy (2012)

4. Histomorphological Observations

4.1. Histology of the Chick Kidney

Microscopically, the avian kidney is organised into cortical and medullary components arranged around central medullary cones, rather than as a continuous cortex and medulla as in mammals. The cortex is composed predominantly of numerous small, superficially placed nephrons — the —reptilian-type‖ nephrons — each consisting of a small glomerulus with a simple, single capillary loop, a Bowman's capsule, and a proximal and distal tubule that connects directly to a collecting duct without an intervening loop of Henle (Braun & Dantzler, 1972; Braun, 1998). A second, less numerous population of larger nephrons, the —mammalian-type‖ nephrons, arise deeper in the cortex and possess a short loop of Henle that descends into the medullary cone before ascending to join the distal tubule, closely resembling the corresponding structures of the mammalian nephron (Braun & Reimer, 1988). The medullary cones themselves are composed of the descending and ascending limbs of the looped nephrons together with collecting ducts, arranged in a countercurrent fashion, and are considerably less elaborate than the mammalian medulla. Histochemical and histomorphometric studies of the developing and adult chicken kidney have confirmed that the basic nephron components — glomerulus, Bowman's capsule, proximal convoluted tubule and distal convoluted tubule—are already recognisable from late embryonic stages onward, with a progressive increase in tubular diameter and differentiation after hatching (Mohammed, 2021). Renal corpuscles are generally smaller and more numerous per unit area of cortex in the chick than in the rat, consistent with the smaller, less elaborately vascularised avian glomerulus described by Gregg and Wideman (1990) in the domestic fowl.

4.2. Histology of the Rat Kidney

In marked contrast, the rat kidney displays the typical uniform mammalian architecture, with a clearly demarcated outer cortex and inner medulla converging on a single papilla. Every nephron in the rat kidney possesses a loop of Henle, and there is no loopless nephron population comparable to that of birds. The renal corpuscle, comprising the glomerulus and its surrounding Bowman's capsule, is relatively large and tuft-like, formed by a complex, highly branched capillary network rather than the single capillary loop of the avian reptilian-type nephron. The proximal convoluted tubule is lined by tall, simple cuboidal to low columnar epithelium bearing a prominent brush border of microvilli, and occupies the greater part of the cortical labyrinth, while the distal convoluted tubule is lined by shorter cuboidal cells lacking a conspicuous brush border and stains comparatively paler with eosin (Al-

Samawy, 2012). The medulla is composed of parallel bundles of thin and thick limbs of the loop of Henle and collecting ducts, arranged into distinct medullary rays that converge toward the papilla, an organisation that provides the structural basis for the mammalian countercurrent multiplier system. Comparative histochemical work on the kidneys of several mammalian species, including Rattus norvegicus, has shown that these general histological features — a well-vascularised glomerulus, brush-bordered proximal tubule and looped nephron — are consistently conserved across omnivorous, carnivorous and herbivorous mammals, reflecting a shared evolutionary strategy for efficient water conservation (Al-Samawy, 2012).

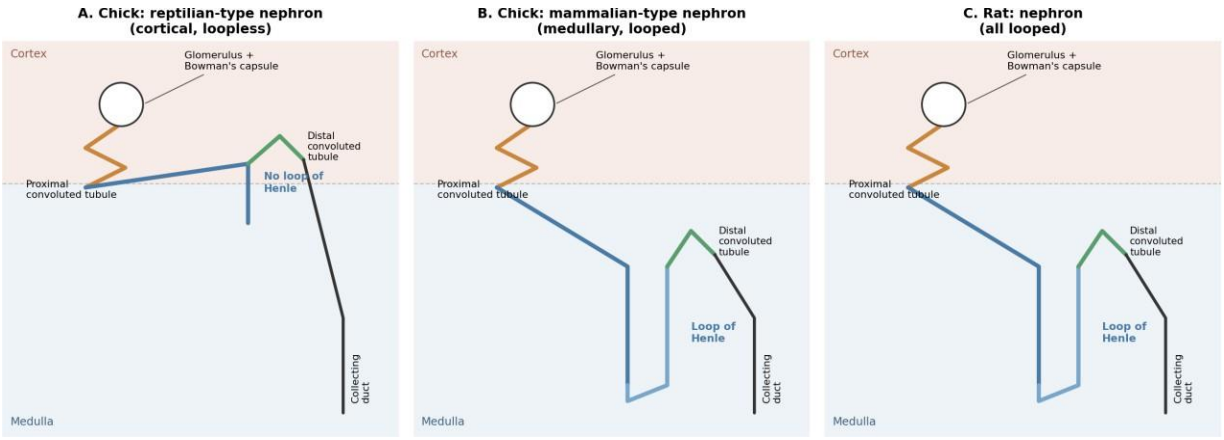

Figure 2.

Schematic comparison of nephron histoarchitecture. (A) Chick reptilian-type nephron: confined to the cortex, glomerulus with a simple capillary loop, proximal and distal tubules connecting directly to a collecting duct with no loop of Henle. (B) Chick mammalian-type nephron: arises deeper in the cortex and possesses a short loop of Henle descending into the medullary cone. (C) Rat nephron: every nephron possesses a fully developed loop of Henle descending into the medulla. (Original schematic prepared by the authors based on Braun & Dantzler, 1972; Braun & Reimer, 1988; and Al-Samawy, 2012.)

Table 2. Comparative summary of histomorphological (nephron-level) features of the kidney in the chick and the albino rat, based on the present observations and cited literature.

Feature	Chick (*Gallus domesticus*)	Albino rat (*Rattus norvegicus*)
Nephron population	Heterogeneous: reptilian-type (loopless, majority) and mammalian-type (looped, minority)	Homogeneous: all nephrons possess a loop of Henle
Location of nephrons	Reptilian-type in cortex; mammalian-type extend into medullary cones	Proximal/distal segments in cortex; loop of Henle in medulla
Glomerular capillary tuft	Simple, single capillary loop; comparatively small	Complex, highly branched capillary network; larger corpuscle
Loop of Henle	Present only in mammalian-type nephrons	Present in every nephron
Feature	Chick (Gallus domesticus)	Albino rat (Rattus norvegicus)
Nephron population	Heterogeneous: reptilian-type (loopless, majority) and mammalian-type (looped, minority)	Homogeneous: all nephrons possess a loop of Henle
Location of nephrons	Reptilian-type in cortex; mammalian-type extend into medullary cones	Proximal/distal segments in cortex; loop of Henle in medulla
Glomerular capillary tuft	Simple, single capillary loop; comparatively small	Complex, highly branched capillary network; larger corpuscle
Loop of Henle	Present only in mammalian-type nephrons	Present in every nephron

5. Discussion

The comparative findings of the present study clearly demonstrate that, although the chick and the albino rat kidney share the same fundamental filtering unit — the nephron, composed of a glomerulus, Bowman's capsule and a tubular system — the two organs differ substantially in gross architecture, lobation, and internal organisation. Grossly, the lobulated, pelvis-less, synsacrum-embedded chick kidney contrasts sharply with the smooth, encapsulated, unipapillate, pelvis-bearing rat kidney, differences that reflect the divergent skeletal relations and excretory duct systems of birds and mammals (Nabipour et al., 2009; Al-Samawy, 2012).

Histologically, the most functionally significant distinction is the heterogeneous nephron population of the avian kidney, comprising a majority of loopless, reptilian-type nephrons together with a minority of looped, mammalian-type nephrons, compared with the homogeneous, uniformly looped nephron population of the rat kidney (Braun & Dantzler, 1972; Braun, 1998). This structural difference has direct functional consequences: because only the mammalian-type nephrons of the avian kidney contribute to the medullary countercurrent multiplier, and because these constitute only a minority of the total nephron population, birds are able to concentrate their urine only modestly relative to mammals, in which every nephron participates in the concentrating mechanism (Braun & Reimer, 1988; Dantzler, 1989). Uric acid excretion in birds further reduces the physiological requirement for powerful urine concentration, since uric acid can be excreted as a semi-solid precipitate with comparatively little accompanying water loss, whereas the urea-excreting rat depends heavily on an efficient countercurrent system to conserve water (Dantzler, 1989).

These comparative structural and functional differences have practical relevance for experimental biology. Because the chick kidney combines features that are, in part, structurally simpler (loopless cortical nephrons) and, in part, comparable to the mammalian pattern (looped medullary nephrons), it has proved a useful natural model for studying the differential function of looped versus loopless nephrons within a single organ (Braun & Dantzler, 1972). The rat kidney, by contrast, remains one of the most extensively used and best-characterised mammalian models for nephrotoxicity, pharmacokinetic and renal pathology studies, precisely because its histological organisation closely parallels that of the human kidney (Fitmawati et al., 2021; Al-Samawy, 2012). Recognition of these baseline anatomical and histological differences is therefore essential before extrapolating renal toxicological or physiological findings between avian and mammalian experimental models.

6. Conclusion

The present comparative study confirms that the kidney of the chick (Gallus domesticus) and that of the albinorat (Rattus norvegicus) differ substantially in both gross anatomy and histomorphology, despite sharing the nephron as their common structural and functional unit. The chick kidney is elongated, trilobed, pelvis-less and embedded within the synsacrum, and is histologically characterised by a dual population of loopless (reptilian-type) and looped (mammalian-type) nephrons. The rat kidney, in contrast, is bean-shaped, unipapillate and possesses a distinct renal pelvis, and is histologically uniform, with every nephron possessing a fully developed loop of Henle. These structural differences underlie the markedly greater urine-concentrating capacity of the mammalian kidney and reflect the divergent excretory strategies — uricotelism in birds versus ureotelism in mammals — that have evolved in these two vertebrate classes. A sound understanding of these comparative features is of value to veterinary anatomists, comparative physiologists, and researchers employing avian and rodent models in biomedical and toxicological research.

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