II. Special section.[1]

Monotremata.

Ornithorhynchus anatinus Shaw.

Material. The kidneys of two specimens in alcohol.

Form. In one of the specimens both kidneys measure about 30 × 18 × 12 mm. The pelvis consists of a small flattened cavity. The area cribrosa is oval and lies either on a small crest, that projects into the pelvis, or in the lateral wall of the pelvis (fig. 4 *A*, p. 271). The latter has no processes. The boundary between cortex and medulla is indistinct, as there are many thick medullary rays projecting into the cortex. The cortex is about 4 mm thick, and the medulla 4.5 mm. There is no visible inner zone. After maceration the outer stripe becomes distinct. It is about 1.5—2 mm thick.

The tubules. After maceration the material is very brittle, especially the outer parts of the cortex and the distal tubules. It has, however, been possible to note the following facts. There are a great many cortical nephrons, but no or at any rate very few nephrons with long loops. The capsule and the proximal tubule are of the usual shape. The pars recta is always well developed, even in the deepest nephrons, and it often constitutes as much as half the proximal tubule. The transition into the thin segment occurs at very varying levels. Very few proximal tubules reach the stripe boundary; thus the latter is relatively indistinct even after maceration. There are thin segments in most nephrons, and only in the highest cortical nephrons is it absent, but it is mostly very short. I cannot definitely say if there are loops which turn in the thin segment, as the innermost part of the medulla consists mainly of very tough connective tissue. However, the loops that reach this zone are very few. The thick segment is very markedly differentiated into a thicker and a thinner part, except in the highest nephrons. The distal tubules are relatively thin and without projections. If there are initial collecting tubules, they are very indistinct. The collecting tubules are thin (about 0.020 mm in the cortex and the outer parts of the medulla, less than 0.050 mm in the inner parts of the medulla). As the central

[1] The nomenclature and system of WEBER (1928) have been used when possible.

junctions occur even in the middle and lower parts of the cortex, there is no marked difference between central and peripheral junctions. It is very difficult to examine the peripheral junctions as these are situated in the outer parts of the cortex. It is certain, however, that there are no typical arcades.

Monotremata, survey of the form of the kidney.

The statements on the kidney of *Ornithorhynchus* are rather inconsistent, as are also those on the kidney of *Echidna*. The latter has been thoroughly investigated by ZARNIK (1910). According to ZARNIK there is a distinct pelvis, and also a very low papilla with a shallow concavity, where the area cribrosa is situated. HYRTL (1872), who has investigated the shape of the pelvis, seems to agree with ZARNIK. Both HYRTL and ZARNIK give figures of their findings, and the latter had two fresh kidneys at his disposal; thus his statements have great weight. Accordant statements are given by GERHARDT (1911, 1914) and OWEN (1847 b), too. CUVIER (1840), however, states that there are four papillae, but this seems highly improbable, though it is difficult to imagine how he may have reached such an opinion. The value of his statement is, however, diminished by his obviously erroneous statement that the hedgehog kidney has five papillae. What he meant by papilla is somewhat obscure.

GEGENBAUR (1901) states that there is no papilla, the ureter branching directly without forming a pelvis. As this description is contrary to all other statements and as there are no details given and no drawing, it does not seem to me that it deserves any consideration.

HYRTL (1872) has investigated the form of the pelvis in *Ornithorhynchus*, and his description and figure are in accordance with my findings. The statements of GEGENBAUR (1901) are very divergent in this species also. He is of opinion that the collecting ducts open into the pelvis everywhere, but in addition to this he says there are some larger ducts. He gives a drawing of this species. GERHARDT (1911) is of the same opinion, and in support of it he cites, besides GEGENBAUR, HOME (1801 a and b) and MECKEL (1826). The one paper by HOME "Description of the anatomy of *Ornithorhynchus hystrix*" handles *Echidna*; the other, though it refers to *Ornithorhynchus*, contains nothing about the interior structure of the kidneys. I have not had the opportunity of studying the paper by MECKEL, but OWEN (1847 b) reproduces a drawing of the uro-genital organs of *Ornithorhynchus* according to MECKEL. From this it is evident that MECKEL's findings are quite in agreement with those of HYRTL and myself. OWEN too (op. cit.) describes the kidneys in

accordance with this view, but it is not clear if, in this respect, he only relies on MECKEL, or if — as seems more probable — he has made personal investigations.

In 1914 GERHARDT gave a figure of a section through an *Ornithorhynchus* kidney, but from this it is only clear that the kidney was not well preserved, as he himself mentions. He is aware that it is extremely difficult to form a well-founded opinion on such material, which fact I wish to emphasize.

From the above it seems clear that both the existing forms of *Monotremata* possess simple kidneys, whose pelvis is simple. In *Echidna* there is a low papilla, in *Ornithorhynchus* there is a crest. Both of them have cortical nephrons, and the inner zone of the medulla is but poorly developed. In connection with this the thin segment is short.

Marsupialia.

Sminthopsis murina (Waterh.).

Material. One pair of kidneys in alcohol.

Form. Size: $9 \times 5 \times 4.5$ mm. The papilla is pointed but not very long (fig. 4 *B*, p. 271). After maceration the cortex measures 1.0 mm, the outer zone 1.4 mm and the inner zone 2.4 mm. There is no swelling as compared with alcohol material.

The tubules. BOWMAN's capsule has a very thin, transparent epithelium, but where the proximal tubule begins it is considerably thicker and less transparent (Pl. 1, fig. *2*, *3*). The capsule is most often oval. The proximal tubule begins without any indication of a neck. It is fairly evenly coiled and its surface is relatively smooth. The most proximal part is frequently somewhat thicker, and the most distal part somewhat slenderer, than the rest of the proximal tubule. The pars recta of the high nephrons is long, and the convolutions of the pars convoluta rather irregular. (Pl. 1, fig. *1*.) The pars recta of the deepest nephrons, which are much longer than the others, is short, and the pars convoluta consists of almost straight segments parallel to the cortico-medullary boundary (Pl. 1, fig. *2*). The transition into the thin segment is usually rather sudden, exteriorly also. This transition occurs at slightly different levels, higher in the highest nephrons. The thin segment has a very low, transparent epithelium which is, however, often somewhat higher at the transition to the preceding and the following segment. The thick segment is distinctly differentiated into a thicker part, chiefly restricted to the outer zone, and a thinner and more transparent part in the cortex. The short loops turn in the inner half of the outer zone, normally in the thick

segment (Pl. 1, fig. *1*.) The distal tubule, which begins where the thick segment touches the capsule, is thicker than the distal part of the thick segment. The transition is usually distinct and marked. The contour of the distal tubule is rather even, and the transition to the initial collecting tubule is gradual. The proximal part of the collecting tubules is slightly thicker than the following cortical part, which is usually 15—20 μ thick and fairly transparent. The peripheral junctions are never typical arcades, but occasionally a high nephron may join the collecting tubule below a deep one, so as to reverse the normal order. The central junctions lie in the inner zone, the peripheral ones only in the outer half of the cortex. Three to five nephrons join to form one collecting tubule.

Table 1.[1] *Sminthopsis murina, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	75×60	1100×30	620× 9	1300	850×25	30	17	35	18	7.3
h	68×60	1300×30	400× 8	1150×27	600×28	38	12	33	17	9.6
h	75×69	1350×35	800	1650×30	750×30	30	18	36	16	9.1
m	68×55	1400×34	800	1650×24	550×26	32	18	37	13	12.7
h	83×75	1400	600	1500	680	33	14	36	16	
h	75×56	1430×30								10.2
m	90×65	1450×35	600× 8	1450×26	700×29	35	14	35	16	8.7
h	90×64	1500×30	600× 8	1650×28	800×29	33	13	36	17	7.8
h	75×64	1650×33	530× 7	1430×25	650×28	39	12	34	15	10.1
h	83×65	1650	700	1900						
h	75×60	1650×30	600	1700×24	750×24	35	13	36	16	11.0
d	90×83	1900×37	2300	1800×26	600×27	29	35	27	9	9.4
d	105×75	2600×34	3500× 7	1650×26	850×27	30	41	19	10	11.2
d	105×75	2900×36	3800×10	1550×24	800×24	32	42	17	9	13.3
d	115×82	3300×38	4000×10	1400×25	1000×25	34	41	14	10	13.3
dd	120×85	4900×36	5000×12	1500×25	950×27	40	40	12	8	17.3
Mean	78	1968×33 ±250	1657× 9	1552×26 ±50	738×27					10.8

[1] The abbreviations used in the tables of the Special section are: *h* high nephron, *hc* cortical nephron, *m* middle high nephron, *d* deep nephron, *dd* deepest nephron, *p. t.* proximal tubule, *t. s.* thin segment, *th. s.* thick segment, *d. t.* distal tubule, *Ind.* index (the ratio of the surface equivalents of the proximal tubule and the capsule, cf. p. 262).

Bracketed figures are not measured but estimated; figures calculated from estimated values are also bracketed.

The dimensions of a number of tubules are given in table 1. Among a number of examined loops there are 78 short loops and 24 long ones. The longest measured nephron nearly reached the apex of the papilla. The mean length of the proximal tubules is 2.0 ± 0.25 mm, which figure is probably slightly too high, as the deep nephrons are somewhat too numerous. For the same reason the mean length of the thin segments is overestimated, but this is probably not the case with the means of the thick segments and the distal tubules. A "mean nephron" thus seems to have about this composition: Proximal tubule 33 %, thin segment 28 %, thick segment 26 %, distal tubule 13 %.

Antechinomys laniger (Gould).

Material. The kidneys of a female in alcohol.

Form. Size: 8.5 × 5 × 4 mm. They are of the same form as those of *Sminthopsis*, but the papilla is a little longer (fig. 4 *C*, p. 271). After maceration the cortex measures 1.0 mm, the outer zone 1.5 mm, of which the outer stripe is 0.3 mm, the inner zone 2.9 mm.

The tubules. These are on the whole similar to the tubules of *Sminthopsis*. The epithelium of Bowman's capsule, however, is thin and transparent everywhere. The thick segment is markedly differentiated into a thicker and a thinner part (respectively 35 μ and 20 μ thick). The thick segment is most often slightly more tortuous than in *Sminthopsis*.

Among a number of examined loops there are 55 short loops and 24 long ones. It is obvious that the thin segment is relatively longer in

Table 2. *Antechinomys laniger*, *tubule dimensions in* μ.

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	70× 60	1800×31	800×10	1730×18	700	36	16	34	14	13.3
h	85× 70	1850×32	1050× 8	2050×21	650×30	33	19	37	12	9.9
h	85× 60	2000×31	1000	2100×20	650×26	35	17	37	12	12.2
h	105× 75	2200×38	1000×10	2100×23	750×30	36	17	35	12	10.6
m	105× 85	2200×33	1100× 9	2450×21	750×32	34	17	38	12	8.1
h	100× 60	2300×30	950× 7	2300×22	600×31	37	15	37	10	11.5
m	110× 85	2500×33		2400×20	680					8.8
m	105× 65	2600×34		2600×24	700×33					13.0
dd	165×120	5000×38	(7000)	2200×20	650×25	(34)	(47)	(15)	(4)	9.6
Mean	89	2494×33	9	2214×21	681×30					10.8

Antechinomys than in *Sminthopsis*, as the long loops are more numerous. As this part is somewhat overestimated in *Sminthopsis*, it would seem that the figures given for the "mean nephron" in that species should apply to this species, too.

Didelphys opossum L.

Material. Several pairs of kidneys in alcohol, one of which has been macerated.

Form. The kidney, which has later been macerated, has the following dimensions: 37 × 19 × 18 mm. The papilla is low (fig. 4 *D*, p. 271). The cortex is 3.5—4 mm thick, after maceration about 5 mm. The corresponding values are, for the outer zone, 5 mm and 6 mm, and for the inner zone 8 mm and 11 mm.

The tubules. Even after prolonged maceration it has hardly been possible to tease the medulla, and in the cortex the tubules are very fragile. The results are therefore fragmentary. The capsule is nearly always oval, with a low transparent epithelium. There is no neck. The proximal tubules are mostly of uniform thickness. There are no cortical nephrons. The thick segment is differentiated into a thicker part in the outer zone and a thinner part in the cortex. The contour of the distal tubule is fairly even. Some proximal tubules have been isolated. Their measurements, in μ, are given below.

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
m	295×200	13500	(16.0)	*d*	280×200	15000×67	17.9
h	310×195	14700×71	17.3	*h*	300×210	15800×76	17.4
h	260×205	15000×63	17.7	*h*	300×200	16500×74	20.4

Macropus giganteus (Zimm.).

Material. One kidney in alcohol.

Form. The dimensions are 82 × 52 × 28 mm. There is a low papilla (Fig 4 *L*). The cortex is 8 mm thick, the outer zone 9 mm, the inner zone 17 mm.

The tubules. After maceration the tubules are very brittle and have shrunk about 10 %. There are no cortical nephrons. The capsule and the proximal tubule present nothing uncommon. The collecting tubules, sometimes at any rate, begin with arcades. It has been possible to prepare only two proximal tubules.

	Capsule	Prox. tubule	Ind.
m	270×190	12000×47	11.0
h	220×220	13000×45	12.1

Marsupialia, survey of the form of the kidney.

All examined *Polyprotodontia* have simple kidneys with a papilla. The latter is long and pointed in *Philander*, *Sminthopsis* and *Antechinomys*, moderately long in *Perameles* and *Dasyurus viverrinus* (Shaw) (fig. 4 *E*, cf. also GERHARDT 1914). In *Didelphys opossum* L. and *Sarcophilus satanicus* Thom. the papilla is low and crest-like (fig. 4 *F*). OWEN (1847 a) has found grooves containing blood-vessels on the surface of the kidneys of *Dasyurus viverrinus* (Shaw) and *D. macrourus* Geoff. [= *D. maculatus* (Kerr.)]. Like GERHARDT (1914), I have not been able to find them in *D. viverrinus*, but my material, like that of GERHARDT, is not very well preserved. In *Sarcophilus satanicus* Thom., however, there are distinct grooves. They are relatively deep and divide the kidney surface into several fields (fig. 4 *G*, *H*). Though the kidney thus seems lobated exteriorly, neither the cortex nor the medulla is divided, but the former forms ridges on its inner surface, corresponding to the grooves. Except in *Sarcophilus* the cortico-medullary boundary is even, and, in well-preserved kidneys, marked. The area cribrosa is small and rounded, or oblong, as in *Didelphys* and *Sarcophilus*.

In the *Diprotodontia* there is generally a distinct papilla, also. In *Acrobates pygmaeus* (Shaw) (fig. 4 *I*) it is long and pointed, and somewhat less so in *Petaurus breviceps* Waterh., *Phascolarctus cinereus* (Goldf.), and *Phalangista vulpina* (Meyer) (fig. 4 *K*). In *Macropus giganteus* I have found a very low papilla (fig. 4 *L*), but GERHARDT (1914) states that all kangaroos examined by him possess very large papillae (*Macropus giganteus*, *Halmaturus thetidis* Less., *Thylogale eugenii* Desm.). Judging from Pl. I, fig. 6 (op. cit.) it seems that *Thylogale* has a very low papilla, but from the section of *Macropus* (Pl. I, fig. 7 a) it is evident that GERHARDT's specimen had a more pointed papilla than mine. It is difficult to say whether this is due to individual or perhaps racial differences (GERHARDT's specimen belonged to the smaller race *melanops*), or possibly to differences of age. The last possibility is perhaps the most probable, as the joint thickness of cortex and medulla is the same in both specimens, though mine is much larger (cf. p. 393).

In *Phascolomys wombat* Perron & Lessueur (HYRTL 1872), *Ph. latifrons* Owen (GERHARDT 1914) and *Ph. mitchelli* Owen there is no papilla, but the area cribrosa lies on a narrow crest (fig. 4 *M*).

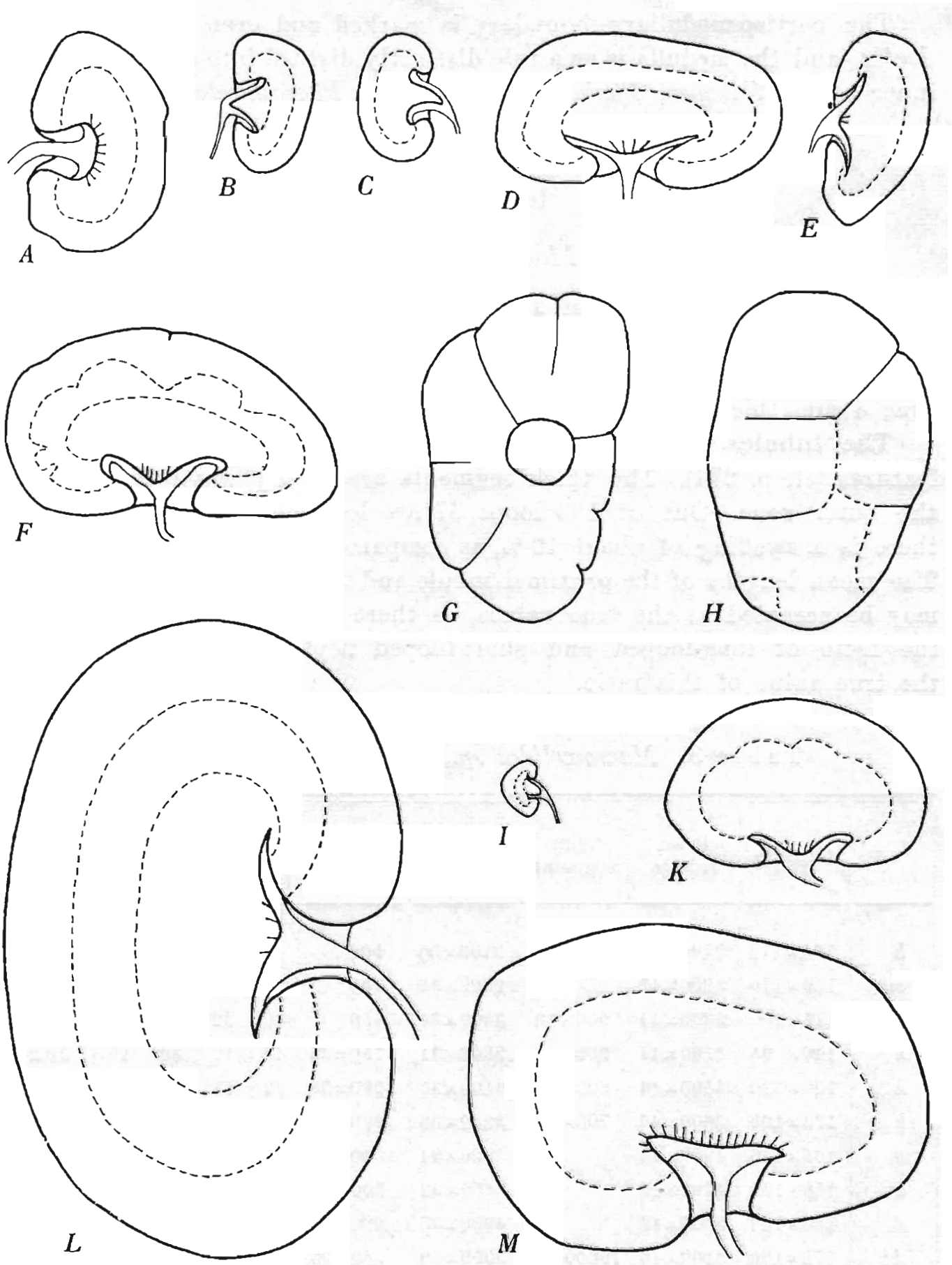

Fig. 4. Kidneys of *Monotremata* and *Marsupialia*. *A Ornithorhynchus anatinus* Shaw. *B Sminthopsis murina* (Waterh.) 2 ×. *C Antechinomys laniger* (Gould) 2 ×. *D Didelphys opossum* L. *E Dasyurus viverrinus* (Shaw). *F, G, H Sarcophilus satanicus* Thom. (*G* ventral, *H* dorsal view). *I Acrobates pygmaeus* (Shaw). *K Phalangista vulpina* (Meyer). *L Macropus giganteus* (Zimm.). *M Phascolomys mitchelli* Owen.

The cortico-medullary boundary is marked and even in the *Diprotodontia*, and the medulla is as a rule distinctly divided into an outer and an inner zone (*Macropus*, *Phalangista*, *Acrobates*, *Phascolarctus*).

Insectivora.

Macroscelides sp.

Material. The kidneys of a specimen in alcohol.

Form. Dimensions 10 × 7 × 5 mm. The long pointed papilla projects into the ureter (fig. 5 *C*, p. 282). Cortex 1.4 mm, outer zone 2.6 mm, inner zone 4 mm thick.

The tubules. These agree with those of the shrews in all essential features (cf. p. 274). The thick segments are mostly wavily tortuous in the outer zone. Out of 109 loops 37 are long ones. After maceration there is a swelling of about 10 %, as compared with the alcohol material. The mean lengths of the proximal tubule and the thick segment in table 3 may be accepted as the true values, as there is no marked deviation of the ratio of long-looped and short-looped nephrons as compared with the true value of this ratio.

Table 3. *Macroscelides sp., tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	130×115	3100×41		3100×36	900					8.5
m	150×110	3200×42		2900×33	750					8.1
h	115×100	3300×44	950×12	3300×34	650	40	12	40	8	12.6
h	140× 95	3300×41	900	2800×31	750×35	43	12	36	10	10.2
h	120×120	3500×43	900×11	3100×35	900×38	42	11	37	11	10.5
h	175×100	3600×45	700×15	3200×38	900×34	43	8	38	11	9.3
m	165×135	4200×45		3900×34	1000×36					8.5
m	150×150	4300×46		3600×32	700×38					8.8
d	150×150	5400×47		4200×35	900×38					11.3
dd	175×150	8100×46	(10000)	3000×30	950×36	(36)	(45)	(14)	(4)	14.2
Mean	135	4200×44 ±490	13	3310×34 ±140	840×36					10.2

Erinaceus europaeus L.

Material. The kidneys of a male.

Form. The weight of one kidney 3.0 gm, its dimensions 24 × 15 × 14 mm. The thickness of the cortex about 2.4 mm, of the outer zone 2.3 mm (outer stripe about 0.4 mm), and of the inner zone 5.6 mm. The pelvis has marked processes, and the papilla is pointed. (fig. 5 *D*, p. 282).

The tubules. The capsule is of the usual shape and structure. Often there is a slight indication of a neck. Occasionally the capsule lies peripheral to the convolute of the proximal tubule, even in the highest nephrons. This means that some of the capsules are situated immediately beneath the surface of the kidney, and there is no marked cortex corticis.

Normally, the short loops turn in the thick segment at various levels; the loops of the highest nephrons turn about 0.6 mm above the zone boundary. The thick segment is differentiated into a thicker and a thinner part. The distal tubule also consists of two parts. The first of these is considerably thicker than the thick segment, and its epithelium contains a great number of small refractive droplets, so that this segment is relatively opaque. The distal tubule then diminishes and becomes more transparent; thus the second part has the structure normally characterizing this segment. The transition is gradual, as is the transition into the initial collecting tubule, which has as usual a low transparent epithelium.

Table 4. *Erinaceus europaeus, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p.t.	t.s.	th.s.	d.t.	
d		4900								
h	142×113	4950×49								15.1
h	135×130	5150×47								13.8
h				4500×25	1500×42					
h	135×120	5200×50	1650	4350	1500×39	41	13	34	12	16.0
h	140×120	5600×48	1550×10	4450×28	2200×36	41	11	32	16	16.0
m	170×150	5700×52	2800× 9	4450×30	1730×40	39	19	30	12	11.6
m	165×120	5850×50	1850×10	4280×26	2180×38	41	13	30	15	14.8
d		6000								
d		6100×49								
d		6980×50		2500×31						
Mean	137	5643×49 ±200	10	4105×28 ±140	1822×39					14.6

The collecting tubules are thin, and have the same appearance as the preceding segment. The peripheral junctions are mostly direct, but sometimes there are small arcades, or the initial collecting tubules unite in pairs (cf. fig. 11 nr *12*, p. 319). The initial collecting tubules are generally long when they join the collecting tubules directly, but short when the nephrons join arcades, in which case they may be absent altogether.

After maceration there is a swelling of slightly more than 10 %. The long loops constitute 39 ± 4.3 % of the total number. Taking into account the swelling, the mean length of the proximal tubules is 5.0 mm. It would seem that one of the deepest nephrons ought to have the following dimensions: Proximal tubule 6.3 mm, 27 %, thin segment 12 mm, 52 %, thick segment 2.3 mm, 10 %, distal tubule 2.4 mm, 10 %. It must, however, be taken into consideration that the proximal tubule is undoubtedly underestimated, as no special search has been made for the longest tubules.

Sorex araneus L.

Material. Several specimens have been examined with regard to the form, weight, and dimensions of their kidneys. A more thorough investigation after maceration has been made of a young male (born the year of its capture) and a female (more than a year old).

Form. The kidneys are covered by the peritoneum dorsally as well as ventrally, and are thus relatively loosely fastened to the dorsal abdominal wall. They are of the common bean shape (fig. 5 *A*, p. 282). The papilla is distinct but does not project very much into the pelvis. The latter has processes. In young individuals (total weight 6—8 gm) the total kidney weight is most often 0.13—0.15 gm, and the dimensions of a kidney about 7 × 5 × 3.5 mm. In older animals (body weight 10—14 gm) the kidney weight is 0.18—0.35 gm with measurements up to 9×6×4 mm. The cortex is about 0.9 mm in the former, and up to 1.2 mm in the latter. The corresponding values of the outer zone are, 1.0 and 1.1, and of the inner zone, 1.5—2.0 and about 2.0.

The tubules. Bowman's capsule has a thin, transparent epithelium. The proximal tubule is usually only slightly coiled, especially in the high nephrons. The bends are gentle and smooth. The last segment is, normally, more transparent. The thin segment has the usual low epithelium and the thick segment is, at least in the higher nephrons, differentiated into a thicker and a thinner part. The short loops turn in the thick segment at different levels in the inner stripe of the outer zone. The loops of the highest nephrons turn about 0.3 mm from the zone boundary. The outer stripe is sharply demarcated microscopically. The distal

tubule is markedly thicker than the last part of the thick segment, and its contour is even, without any projections. The transition to the initial collecting tubule is gradual. The latter is thinner and more transparent. The peripheral junctions are, normally, direct ones, and the first central junctions occur in the most peripheral part of the inner zone. The collecting tubules are rather thin, even in the central parts of the medulla.

Table 5 a refers to an old female, kidney weight 0.35 gm. The percentage of long loops is 12 ± 2.3.

As the low nephrons are somewhat too numerous, the mean length of the proximal tubule will be lower than that given in the table, about 2.2 mm. The mean length of the thin segment is estimated at 0.9 mm, that of the thick segment at 1.7 mm and that of the distal tubule at 0.64 mm.

Table 5 a. *Sorex araneus, old female, tubule dimensions in* μ.

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	75×60	1850×40	550×8	1600×22	630×32	40	12	35	14	16.4
h	60×60	2050×38	530×8	1730×22	650×30	41	11	35	13	21.6
h	82×64	2060×40	640×9	1850×22						15.7
h	75×60	2150×41	650×9	1800×21	600×31	41	13	35	12	19.6
h	83×56	2180×40	520×8	1600×21	670×32	44	10	32	13	18.8
m	90×68	2200×41	750×9	1950×24	620×31	40	14	35	11	14.7
d	83×76	2250×38	2400×7	1450×22	600×30	34	36	22	9	13.6
m	86×70	2330×40	1800×8	1780×23	630×30	36	28	27	10	15.5
d	90×75	2500×41	2600×9	1280×24	700×36	35	37	18	10	15.2
m	97×78	2600×42	2450×9	1800×22	600×31	35	33	24	8	14.4
d	90×68	2800×40	3000×8	1430	600×35	36	38	18	8	18.3
d	90×63	2800×41	3300×9	1330×24	680×35	35	41	16	8	20.2
d	108×75	2850×41	2700×8	1680×21	675×31	36	34	21	9	14.4
d	105×65	3300×43	3600	1650×23	840×36	35	38	18	9	20.8
d	94×75	3450×42	3500×9	1200×26	825×34	38	39	13	9	20.6
d			4000×8	1580×26	900×34					
dd	94×86	4880×39								23.5
dd		(5000)	(4800)	(1100)	(1000)	(42)	(40)	(9)	(8)	
Mean	78	2640×40	8	1607×23	676×32					17.7

Table 5 b. *Sorex araneus, young male, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
h	68×61	1350×31	10.2	*m*	75×63	1740×34	12.5
h	70×60	1510×32	11.5	*m*	83×74	1880×34	10.4
h	72×64	1530×32	10.6	*d*	86×75	1950×35	10.6
h	75×53	1540×31	12.0	*m*	79×57	2020×31	13.9
m	80×57	1730×32	12.1	*d*	96×84	2940×34	12.4

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	71×56	1390×32	370×6	1430	525×23	37	10	38	14	11.2
h	68×53	1500×31	350×5	1350×20	670×23	39	9	35	17	12.9
h	75×66	1580×33	450×5	1440×21	530×24	40	11	36	13	10.5
m		1870×32	1850×6	1170×21	750×24	33	33	21	13	
d	95×84	2330×33		920×23	840×30					9.6
dd		(3000)	(4200)	(1000)	(1000)	(31)	(46)	(11)	(11)	
Mean	71	1791×32.5 ±110	6	1262×21	25					11.5

Table 5 b refers to a young male. The ratio of long and short loops is 13: 42. The mean length of the proximal tubule may be estimated at 1.6 mm.

Sorex minutus L.

Material. The kidneys of an old male.

Form. The agreement with *S. araneus* is very close. Kidney weight 0.075 gm. Dimensions: 5.5 × 3.5 × 3 and 5 × 3.5 × 3.5 mm. Cortex 0.6 mm thick, outer zone 0.8 mm, inner zone 1.1 mm.

The tubules. The tubules, also, agree in essentials with those of *S. araneus* (Pl. 3, fig. *1*). The proximal tubules are still less tortuous than those of *S. araneus*, but the loops and distal tubules show no deviations from the corresponding parts of the common shrew. The peripheral junctions of the collecting tubules are nearly always direct. In the deepest nephrons the initial collecting tubule often joins a collecting tubule in the medulla, even in the inner zone, where, normally, there are only central junctions. Such an initial collecting tubule may well be looked upon as a collecting tubule with only one nephron, and the

Table 6. *Sorex minutus, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
h	45×40	820×24	10.9	*h*	55×45	900		*m*	48×44	1000	
h	38×37	820×25	14.6	*h*	45×40	900×26	13.0	*m*	56×52	1050×28	10.1
h	60×38	825×27	9.8	*h*	57×48	940		*m*	56×50	1150×26	10.7
h	45×40	840×26	12.1	*m*	55×38	950×26	11.8	*m*	68×45	1200×26	10.2
h	54×35	860×25	11.4	*m*	52×40	960		*d*	68×48	1275×27	10.5
h	52×35	880×27	13.1	*h*	50×42	970×24	11.1	*d*	68×50	1350×25	9.9
m	62×34	900×26	11.1	*m*	56×32	1000×26	14.5	*d*	72×52	1500×27	10.8

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
a[1]	56×45	1070×24	310×4	830×18	460×20	40	12	31	17	
a	49×36	1100×23	320×5	850×18	380×19	42	12	32	14	
a	54×42	1130×23	285×4	810×17	450×19	42	11	30	17	
a	52×39	1140×24	260×4	790×18	450×20	43	10	30	17	
a	47×39	1180×24	340×4	850×21						
a	56×40	1350×29	375×4	900×19	600×22	42	12	28	19	
h	53×40	860×26	340	850						10.5
h	48×40	950×26	320×5	800	300	40	14	34	13	12.9
m	55×35	1020×27	340×6	880×14	350×18	39	13	34	14	14.3
d	50×45	1100×27	550×6	1050×17	350×22	36	18	34	11	13.2
dd		(1800)	(2600)	(900)	(800)	(30)	(43)	(15)	(13)	
Mean[1]	48	1001×26 ±35	6	895×16	333×20					11.7

differences between central and peripheral junctions becomes less distinct in this species.

Table 6 includes nephrons that have been mounted in Canada balsam after staining with borax carmine.[1] The percentage of long loops is 16 ± 3.1.

[1] The nephrons mounted in Canada balsam are distinguished with *a* and are not included in the mean.

Table 7. *Neomys fodiens, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t	
h	58×58	1100×27								8.8
h	50×48	1150×25	640×4	1150	320×24	35	20	35	10	12.0
h	64×53	1150×26	300	900×15	375	42	11	33	14	8.8
h	72×52	1280×28								9.6
h	72×42	1280×27	340×5	1000×18	640×23	39	10	31	20	11.4
h	68×68	1300×29	450×5	1200×16	430×25	38	13	36	13	8.2
h	72×48	1300×26	360×4	1150×19	480×22	40	11	35	14	9.8
h	90×50	1350	350	1100	350	40	10	33	17	
h	58×55	1350×28	400×5	1100×20	550×23	40	12	32	16	11.8
m	68×64	1350×29	700	1150						9.0
h	60×45	1400×26	350×5	1100×18	480×22	42	11	33	14	13.5
m	74×64	1430×29	680×5	1050×19						8.8
m	88×50	1450×28	500	1200×18	650×23	38	13	32	17	9.2
h	85×50	1450×26	400	1100×18	620×22	41	11	33	17	8.9
h	85×50	1450	500	1200	650	38	13	32	17	
h	72×56	1450×27	400	1300×20	600×22	39	11	35	15	9.7
h	70×70	1450	350	1200	650	40	10	33	17	
m	68×62	1500×30	640×6	1150×18	400×28	41	17	31	11	10.7
h	80×65	1500×27	475×5	1300×18	750×22	37	12	32	19	7.8
m	85×65	1500	1000	1300	600	34	23	30	13	
d	80×56	1500×26	2000	650×19	800×23	30	40	13	17	8.7
h	68×60	1500×29	550×5	1250×19	480×25	40	15	33	12	10.7
m	72×64	1600×29								10.1
h	88×55	1600								
m	83×65	1600×30	1650×6	1130×19	450×24	32	33	23	12	8.9
h	68×60	1600×28	580×6	1230×17	450×24	41	15	32	12	11.0
h	80×58	1600×30	410×5	1280×18	800×24	39	10	31	20	10.3
m	64×64	1680×29								11.9
h	88×55	1680×30								10.4
d	88×56	1700×31	1500×6	1000×20	480×24	36	32	21	11	10.7
m	90×65	1700×30	1500×6	1200×18	550×22	34	30	24	12	8.7
d	80×75	1730×29	1900×8	600×18	600×19	36	39	12	13	8.4
m	80×64	1750								
m	100×71	1750×30	2270×7	1300×13	540×20	30	39	22	9	7.4
m	82×75	1750×29	1350	1200						8.3

Table 7 (Cont.)

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
d	72×68	1760×30	1700×5	1100×22	400×26	35	34	22	8	10.8
d	80×50	1760×31								13.6
d	85×70	1760×28	1800×6	1100×20	480×24	34	35	21	10	8.3
m	90×72	1760×30	1600×7	1300×20	700×23	33	30	24	13	8.1
d	79×71	1800×29	2000×6	1130×18	450×27	33	37	21	9	9.3
d	88×65	1800×29	1800×6	1040×19	600×24	34	34	20	12	9.1
m	80×70	1850×30	1700	1250	320	36	33	24	6	9.9
m	80×72	1850								
d	85×80	1900×31	2100×6	1100×18	600×23	33	37	19	11	8.7
m	104×80	2000×29	2300×6	1300×16	800×24	31	36	20	13	7.0
d	112×72	2000×30	2300×7	1050×18	650×23	33	38	18	11	7.4
d	100×95	2000×31	2100×7	1200×18	550×25	34	36	21	9	6.5
d	80×60	2000×31	2000×5	1100×20	400×23	36	36	20	7	12.9
d	88×84	2000×30								8.1
d	84×75	2050×30	2000×7	1050×19	500×26	37	36	19	8	9.8
d	96×60	2100×30	2800×6	960×18	800×24	32	42	14	12	10.9
d	75×65	2150×30	2200×8	900×20	380×24	38	39	16	7	13.2
d		2200×30	2900×7	1000×21						
d	104×96	2480×32								7.9
d	95×80	3050×32		900×19	500×26					12.8
d	105×90	3100×30	3500×8	960×19	800×24	37	42	11	10	9.8
dd		(3300)	(4000)	(900)	(800)	(37)	(44)	(10)	(9)	
Mean	72	1702×29	6	1105×19	552×24					9.66

Neomys fodiens Schreb.

Material. The kidneys of a young male (body weight 8.8 gm).

Form. The kidneys are of the same form as those of *Sorex araneus*. Their weight is 0.19 gm. The dimensions of the right kidney are 6.5 × 5 × 3.8 mm. The cortex measures 0.7 mm, the outer zone 0.9, the inner zone 1.6 mm.

The tubules. These agree very closely with those of *S. araneus*. 21 ± 3.2 % of the loops are long. The mean length of the proximal tubules is about 1.5 mm (mean of high nephrons 1.4 ± 0.035 mm, of nephrons with long loops 1.9 ± 0.04 mm). The means of the other segments are: Thin segment 0.8 mm, thick segment 1.15 mm, distal tubule 0.55 mm.

Pachyura etrusca Savi.

Material. The kidneys of a specimen in alcohol.

Form. Exteriorly, the kidneys are of the same shape as those of the other shrews, but the dimensions are, of course, smaller: 4.3 × 2.8 × 2.3 mm. The papilla, however, is relatively much longer in this species, and projects into the beginning of the ureter (fig. 5 *B*, p. 282). The cortex is 0.5 mm thick, the outer zone 0.75 mm, the inner zone 1.3 mm.

The tubules. I have not been able to detect any differences as compared with *Sorex minutus*.

91 short and 20 long loops have been counted.

The tabulated nephrons (except the deepest one) are all prepared from the same small piece, and may be considered representative of the average composition of the kidney.

Table 8. *Pachyura etrusca, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	49×40	830×26	290×7	800×20	350×19	37	13	35	15	11.0
h	45×40	870×23	270×7	840×18	350×20	37	12	36	15	11.1
h	53×38	900×26	450×5	860×20	350×20	35	18	34	14	11.6
h	50×45	940×25	320×6	900×19	380×20	37	13	35	15	10.4
h	44×39	950×23	430×5	880×20	400×18	36	16	33	15	12.7
h	50×41	970×25	370×6	950×19	380×20	36	14	36	14	11.8
m	54×50	1200×27	600×7	1070×19	450×19	36	18	32	14	12.0
m	52×50	1250×26	500×7	1100×20	410×20	38	15	34	13	12.5
m	49×48	1450×29	1900×8	1200×19	370×20	29	39	24	8	17.9
d	64×45	1580×30	2400×6	1200×19	470×19	28	42	21	8	17.6
dd	71×60	3050×31	(3000)	1150×20	600×19	(39)	(38)	(15)	(8)	22.2
Mean[1]	47	1094×26 ±83	753×6 ±240	980×19 ±48	391×20					12.9

Desmana moschata Pall.

Material. One pair of kidneys in alcohol.

Form. Dimensions: 16 × 11 × 7.5 mm. Cortex 2.2 mm thick, outer zone 2.3 mm, inner zone 2.0 mm. The small area cribrosa is situated on

[1] Not including the deepest nephron.

a small, short crest, which projects a little way into the pelvis (fig. 5 *F*, p. 282), which has processess.

The tubules. The proximal tubules pass into the thin segment at slightly different levels, the highest at the cortico-medullary boundary. The thin segment is short in the highest nephrons, and the loops of the latter turn only a short distance central to the stripe boundary. There are a few long loops, but their frequency has not been estimated. They probably form about 5 % of the total number. The thick segment is differentiated into a thicker and a thinner part.

Hyrtl (1872) states that *Desmana* has a distinct papilla.

Table 9. *Desmana moschata, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
h	75×63	2650×24	11.1	*h*	75×70	3150×23	13.8
h	75×70	2800×23	12.3	*m*	80×75	3200×25	13.3
m	70×65	2800×22	13.5	*h*	82×70	3400×23	13.6
h	75×60	3000×24	16.0	*d*	80×80	3600×24	13.5
m	78×70	3100×23	13.1	*d*	100×85	4100×23	11.1
				Mean	75	3180×23 ±140	13.4

Insectivora, survey of the form of the kidney.

All insectivores hitherto investigated have simple kidneys. Nearly all of them display a distinct, usually pointed papilla. This is true of *Tupaia* (fig. 5 *E*), *Ptilocercus* (Le Gros Clark 1926), *Macroscelides*, *Centetes* (Dobson 1882, Gerhardt 1914), *Gymnura* (Dobson), *Erinaceus* (Gerhardt 1914, Hyrtl 1872, cf. also Cuvier 1840), *Sorex*, *Neomys*, *Pachyura*, *Talpa* (Gerhardt 1914). *Desmana*, cf. above.

In all kidneys investigated in this respect the pelvis has distinct processes, and the medulla is differentiated into an outer and an inner zone.

Chiroptera.

Pteropus edulis Geoffr.

Material. One pair of kidneys in alcohol.

Form. Dimensions: 20 × 13 × 11 mm. The kidneys are bean-shaped and the pelvis has distinct processes; there is a small pointed papilla (fig. 5 *G*, p. 282). The boundary between cortex and medulla is somewhat indistinct, as there are a great number of relatively thick medullary

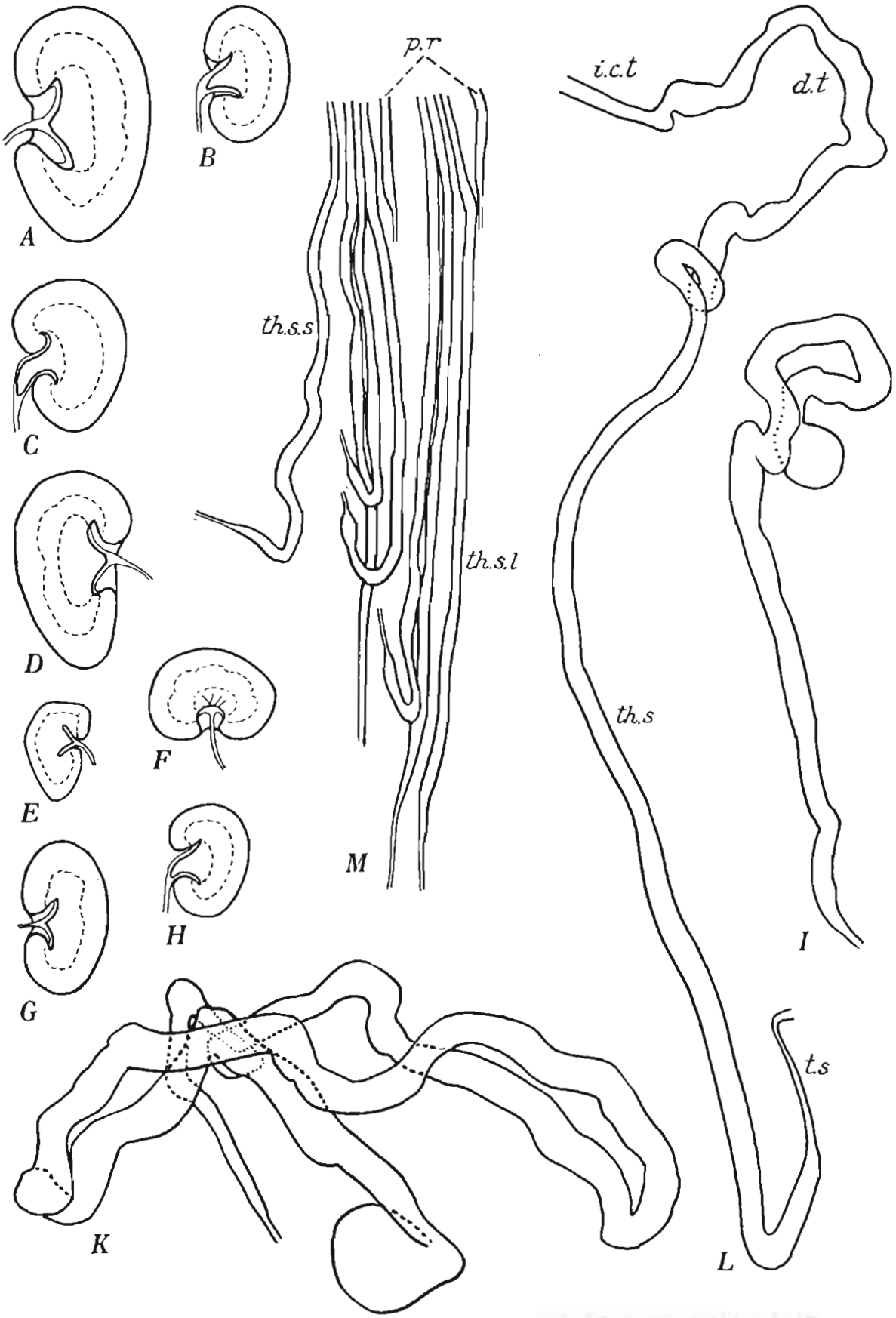

Fig. 5. Kidneys and tubules of *Insectivora* and *Chiroptera*. *A Sorex araneus* L. 4 ×. *B Pachyura etrusca* Savi. 4 ×. *C Macroscelides sp.* 2 ×. *D Erinaceus europaeus* L. *E Tupaia sp.* *F Desmana moschata* L. *G Pteropus edulis* Geoffr. *H Vespertilio murinus* L. 2 ×. *I, K, L, M Pipistrellus nilssoni* Keys. & Blasius. *I* high proximal tubule. *K* deep proximal tubule. *L* distal part of nephron. *d.t* distal tubule, *i.c.t* initial collecting tubule, *th.s* thick segment, *t.s* thin segment. *M* portion of the outer zone. *p.r* pars recta, *th.s.l* thick segment of long loop, *th.s.s* thick segment of short loop. *I, K, L* 100 ×, *M* about 70 ×.

rays projecting into the cortex. The latter is about 2.7 mm thick, and the medulla, which is not divided into zones, is about 5.3 mm thick, including the outer stripe, which is about 2 mm.

The tubules. There are a great many cortical nephrons; on the other hand there are no typical long loops. The proximal tubules all have well-developed partes rectae that end at very different levels, from the inner boundary of the outer stripe to the outer zones of the cortex. In exceptional cases the thin segment may be absent, but most cortical nephrons have thin segments. All examined loops turn within the thick segment, but it is possible that the deepest nephrons are an exception to this rule. Fragments of very low loops showed the bend at the transition between thin and thick segment, or occasionally within the thin segment. The thick segment is differentiated into a thicker and a thinner part. This differentiation is very distinct in deep neprons, but is often absent in the cortical nephrons. There is seldom an initial collecting tubule. The collecting tubules are typical arcades and are usually joined by a fairly large number of nephrons. They are also extraordinarily thick, about 0.1 mm even in the cortex.

It may be added that a kidney of *Pteropus medius* Temm. shows the same structure, but the cortex is a little thicker as compared with the medulla.

Table 10. *Pteropus edulis*, *tubule dimensions in* μ.

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
hc	85× 65	1950×34	0	675×17	750×30	58	0	20	22	12.0
h	82× 75	2600×35	200× 6	950×17	700×24	58	4	21	16	14.8
h	90× 70	2900×34								15.7
m	100× 90	3500×42	550×11	2200×20	600×32	51	8	32	9	16.3
m	105× 90	3900×40	500× 8	1800×20						16.5
d	145×125	4900×52	2700×10	4800×23	1200×45	36	20	35	9	14.1
d	135×115	5200×50	2500×10	4500×26	1100×40	39	19	34	8	16.7
dd	160×130	5500×56	3500×10	5500×25	1100×42	35	22	35	7	14.8
Mean	104	3806×43	1421× 9	2918×21	908×36					15.1

Pipistrellus nilssoni Keys. & Blasius.

Material. The kidneys of a young specimen.

Form. The weight of the kidneys is 0.12 gm and their dimensions are $7 \times 5 \times 3.5$ mm. The papilla is pointed and the pelvis has distinct

Table 11. *Pipistrellus nilssoni*, *tubule dimensions in* μ.

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h		1070	350	1250	530	33	11	39	17	
h	100× 80	1100×30		1400×27	650×29					4.1
h		1200×32		1390×24	700					
h	87× 77	1200×31	650×12	1450×28	550×30	31	17	38	14	5.6
m	102× 86	1250×28	750×10	1400×26	650×31	31	19	35	16	3.4
m	92× 74	1300×30	1100× 8	1300×21	550×23	31	26	31	13	5.7
m	107× 83	1500×32	750×10	1500×29	900×30	32	16	32	19	5.4
h		1550×34	750× 9	1600×28	1000×30	32	15	33	20	
h		1600×31	700× 8	1500×29	800×29	35	15	33	17	
m	120× 93	1600×45	2100× 9	1700×27	750×32	26	34	28	12	6.5
m	140× 80	2000×36		1850×30	800×33					6.4
d	130×130	2800×45		1700×33	1000×28					7.5
d	140×110	2800×37								6.7
d	120×115	3300×35								8.4
d	156×137	4000×44								8.2
dd	160×140	4550×48	(6000)	1490×30	(1000)	(35)	(46)	(12)	(8)	9.8
Mean	111	2051×36 ±270	9	1502×28 ±48	740×30					6.5

processes. The demarcation of the cortex is distinct, and the thickness of the layers is: Cortex 0.85 mm, outer zone 1.3 mm, inner zone 2.8 mm. After maceration an inner and an outer stripe can be seen, the latter about 0.15 mm thick.

The tubules. At times the epithelium of the capsule is more opaque at the beginning of the proximal tubule. There is no neck. The proximal tubules are in the main evenly bent with very few loops (fig. 5 *I*, p. 282), but the central proximal tubules, which are relatively very long, consist of some long loops parallel to the cortico-medullary boundary, and a very short pars recta (fig. 5 *K*). The last part of the proximal tubule is mostly somewhat thinner and less transparent than the main part. The short loops turn within the thick segment, which is differentiated into a thicker and a slightly thinner part (fig. 5 *L*), except in the deepest nephrons. The short loops turn at varying levels (fig. 5 *M*). Normally, the distal tubule has a smooth surface. The initial collecting tubule is occasionally absent. In most cases three or four nephrons join each

collecting tubule in the cortex and the junctions are, normally, direct. The first central junction is most often situated at the zone boundary.

The long loops constitute 25 ± 3.1 % of the total number. The mean length of the tabulated proximal tubules is almost certainly too high, as there are relatively too many deep nephrons measured. The mean length of the proximal tubules of nephrons with short loops is 1.39 mm, and of such as are connected with long loops 2.96 mm. Thus the true mean ought to be about 1.8 mm. The means of the table may be accepted as mean lengths for the thick segments and distal tubules.

Vespertilio murinus L.

Material. The kidneys of a young female and one pair of kidneys in alcohol.

Form. The form is much the same as in *Pipistrellus*, but the papilla is somewhat longer and projects into the ureter (fig. 5 *H*, p. 282). Weight of the fresh kidneys 0.11 gm, dimensions of the same: $7 \times 4.5 \times 3.5$ mm; of one kidney in alcohol $7.2 \times 4.9 \times 4.6$ mm. Cortex 0.9 mm, outer zone 1.3 mm, inner zone 2.9 mm thick in the latter kidney.

The tubules. The agreement with the tubules of *Pipistrellus* is very close. However, the epithelium of the capsule is always low and transparent. It is not possible, as in *Pipistrellus*, to distinguish any structurally different parts of the proximal tubule.

The mean of table 12 a (from a fresh kidney) may be accepted as the mean length of the proximal tubules, since the relation between long and short loops is about the same as in the kidney. In the fresh specimen the long loops constitute 27 ± 3.8 % of the total number and in the alcohol specimen the percentage of long loops is 36 ± 3.9.

In the alcohol specimen 8 further proximal tubules have been measured in addition to the tubules tabulated in table 12 b, as also 17 thick segments. The mean length of the proximal tubules is 1.77 ± 0.05 mm and that of the thick segments 1.85 ± 0.04 mm. The mean length of the distal tubules is about 0.8 mm. The thin segment is 0.6—0.9 mm long in short-looped nephrons, and in long-looped nephrons it is 1—9 mm, on an average probably about 3 mm in the latter. Thus, the mean length of the thin segment may be estimated at about 1.5 mm.

Chiroptera, survey of the form of the kidney.

The kidneys of all *Chiroptera* hitherto examined are simple, with smooth surfaces. As far as I know the following authors have contributed to our knowledge of this subject: Hyrtl (1872) (*Pteropus kerau-*

Table 12 a. *Vespertilio murinus, tubule dimensions in μ.*

Capsule	Prox. tubule	Ind.	Capsule	Prox. tubule	Ind.	Capsule	Prox. tubule	Ind.
106×66	1320×33	6.2	106×82	1600×40	7.4	133× 74	1850×40	7.5
105×75	1400×35	6.2	96×82	1700×37	8.0	114× 90	1860×37	6.7
109×85	1400×35	5.3	102×80	1700×36	7.5	123× 98	1890×40	6.3
105×70	1400×34	6.5	132×80	1700×45	7.2	130× 80	2010×40	7.7
100×69	1460×38	8.0	106×83	1700×33	6.4	110× 83	2100×40	7.2
88×85	1530×38	7.8	95×72	1800×37	9.7	145×115	2350×46	6.5
95×82	1580×31	6.3	119×90	1800×40	6.7	167×138	3300×48	6.9
101×82	1600×40	7.7						

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	90×70	1380×29	600× 7	1380×20	600×19	35	15	35	15	6.4
h	93×70	1400×30	440× 8	1370×21	750	35	11	35	19	6.5
h	104×88	1600×38	520× 7	1580×19	790×23	36	12	35	18	6.6
h	103×90	1750×30	700×10	1600	750	36	15	33	16	5.7
m	158×85	1930×39	1430×10	1910×25	670×25	32	24	32	11	5.6
d	160×98	2250×39	1600× 7	1700×22	900×19	35	25	26	14	5.6
dd		(3500)	(5500)	(1200)	(1000)	(32)	(50)	(11)	(9)	
Mean	99	1763×37 ±75	8	1590×21	743×22					6.9

Table 12 b. *Vespertilio murinus, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
h	95×65	1430×30	6.9	*h*	98×60	1650×38	10.7
m	95×70	1520×36	9.7	*m*	90×90	1800×40	8.9
m	90×75	1560×35	8.1	*d*	105×75	1880×40	9.5
h	90×75	1580×33	7.7	*d*	110×85	2100×45	10.1
h	80×75	1600×32	8.5	*d*	95×90	2150×41	10.3
				Mean	85	1727×37	9.0

denii Quoy & Gaim., *P. edwardsii* Dobs.), GERHARDT (1914) (*Pteropus edulis* Geoffr.), INOUYE (1931) (*Pteropus pselaphon* Sav.), and especially ROBIN (1881), who examined 46 species from all groups of this order.

The papilla is not very long in the *Megachiroptera*, but in several *Microchiroptera* it is very long and projects into the ureter. According to ROBIN this is especially the case in *Emballonura nigrescens* Gray, and to a less degree in some other forms.

In the *Microchiroptera* which I have examined, the medulla is divided into inner zone and outer zone, but this is not the case in the two species of *Pteropus*. It seems probable that the few examined species are representative of their suborders in this respect.

Xenarthra and Pholidota.

Survey of the form of the kidney.

The kidneys of *Dasypus villosus* Desm. (GERHARDT 1914) and *Dasypus sexcinctus* L. (fig. 6 *A*) have a distinct papilla, more prominent in the former species. The area cribrosa is small, situated on the apex of the papilla. *Dasypus novemcinctus* L. (HYRTL 1872) also has a papilla, and the pelvis has processes.

Bradypus tridactylus L. (HYRTL 1872, GERHARDT 1914) and *Choloepus didactylus* L. (HYRTL 1872) have a simple pelvis without processes. This is also the case in a kidney of a *Bradypus sp.*, which I have examined. The papilla is crest-like and the area cribrosa oblong (fig. 6 *B*).

In *Myrmecophaga* (HYRTL 1872) and *Cyclopes* the pelvis has processes. In the latter there is a distinct papilla (fig. 6 *C*).

Manis javanica Desm. has round, flattened kidneys with a small, obtuse papilla (fig. 6 *D*).

RAPP (1852) states that all "*Edentata*" have simple, smooth kidneys.

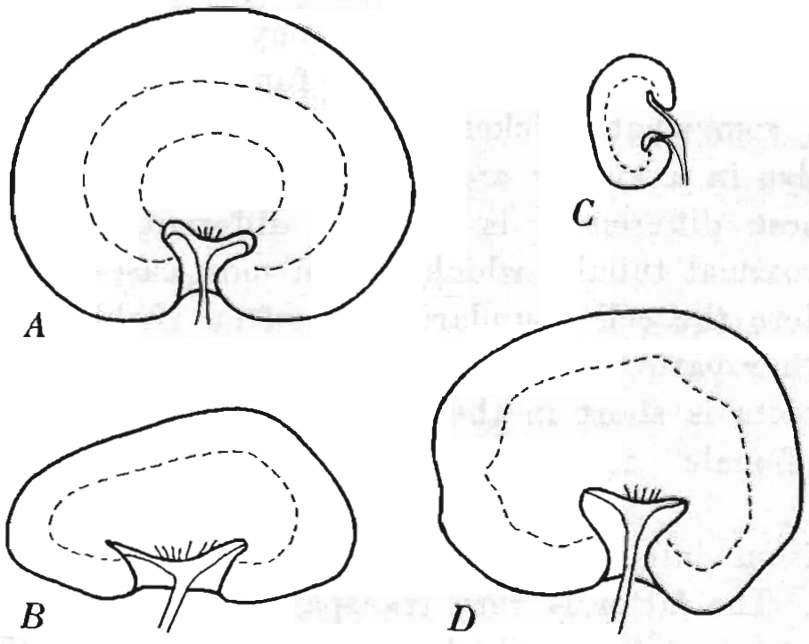

Fig. 6. Kidneys of *A Dasypus sexcinctus* L., *B Bradypus sp.*, *C Cyclopes didactylus* L., *D Manis javanica* Desm.

Rodentia.

Oryctolagus cuniculus (L.).

Material. Several kidneys of the domesticated form. Several of the specimens belonged to the same family (Swedish white country breed).

Form. Dimensions:

	Weight, one kidney, gm	Dimensions, mm	Thickness of		
			cortex, mm	out. z. mm	inn. z. mm
Young, 7 days old	0.58	14.5× 9 × 8.5	2.0	5.5	
Young, 3 weeks	4.1	27 ×17 ×16	2.5	2.0	9
Young, 8 weeks	6.8	31 ×23 ×18.5	3.3	2.9	10
Young, 2 months	7.2	32 ×24 ×15	3.2	3.0	10
Male, 6 months	9.0	35 ×24.5×18.5	4.8	4.3	9
Male, 8 months	10.5		4.5	4.3	9
Male, 10 months	11	36.5×26.5×21	5	5	9.5
Old female	17	44 ×34 ×25	5.5	5.5	10

These specimens form a series from the same family.

The cortico-medullary boundary is distinct, like the zone boundary, except in very young specimens, where the latter is not visible to the naked eye. In most cases the stripe boundary also is visible. The pelvis has processes and the papilla is well developed, with the small area cribrosa on its apex (fig. 7 *A*, p. 295).

The tubules. The capsule is, normally, almost round, and somewhat irregular. In some kidneys almost every nephron has a distinct neck, but in others no trace of a neck is to be found. The proximal tubule in most cases is somewhat thicker in its distal part, but sometimes all proximal tubules in a kidney are thickest in the middle part. More constant than these differences is a slight differentiation of the terminal part of the proximal tubule, which has in most cases a more transparent epithelium. Here the cell boundaries are often visible, which is not the case in the other parts.

The pars recta is short in the deepest nephrons, but always distinct. In the "Old female" it is very tortuous, like all parts of the nephron (Pl. 1, fig. *4*).

The transition into the thin segment sometimes occurs at slightly varying levels. The latter is very transparent.

The thick segment has a thicker and a thinner part. This differentiation is very marked in the high nephrons, where the thin part is long,

very thin, and transparent. In the deepest nephrons the thinner part is short and resembles the thicker part much more. The short loops normally turn in the inner part of the outer zone only. An exception to this is the "Male, 6 months" which has some cortical nephrons and where some loops turn in the outer stripe. The short loops most often turn where the thin segment passes into the thick segment.

In some specimens the first part of the distal tubule shows the same structure as the thinner part of the thick segment (Pl. 3, fig. *2*), but normally there is no intercalated segment. In the latter case the transition into the distal tubule is very marked. The contour of the distal tubule is even in the younger individuals, but in the older ones it has often some small projections, which make the contour irregular.

The highest nephrons generally have initial collecting tubules, but in nephrons joining arcades they are, as a rule, absent.

The collecting tubules are normally arcades with a small peripheral branch (fig. 7 *B*, p. 295). The ascending part of the arcade never lies in the medullary rays, where the descending part is always situated. This has been confirmed in each of several kidneys examined in respect of this. This is also true of other kidneys possessing well-developed arcades.

When distal tubules join the ascending part of the arcade, the structure of the arcade, immediately above the junction, may often be apparently identical with that of the distal tubule. Such segments may then alternate with segments of the structure typical of the collecting tubules. The collecting tubules are slender, especially in the cortex and the outer zone (25—35 μ). The central junctions occur in the inner zone, but sometimes also in the inner parts of the outer zone.

The dimensions of some nephrons are tabulated in table 13.

The mean dimensions of the proximal tubules of some other kidneys are:

Young, kidney weight	5.75 gm	8.5×0.047	mm,	index	17
Young, kidney weight	7.25 »	8.9×0.053	»	»	16
Young		9.1×0.052	»	»	19
Young, kidney weight	9.15 »	10.2	»	»	19
Young, kidney weight	12 »	9	»	»	15

These rabbits belong to various races, and the means have been calculated from 9—28 tubules.

The long loops have been counted in the following specimens: "Young, 2 months old" 44 ± 3.6 %, "Male, 6 months" 44 ± 4.4 %, "Male, 8 months" 43 ± 3.4 %, "Male, 10 months" 48 ± 2.7 %, "Female, 10 months" 46 ± 4.2 %.

The mean lengths of the segments have been estimated in the two last-mentioned specimens, which may be considered full-grown. The figures are, respectively: Proximal tubule 16.2 ± 0.40 and 16.7 ± 0.29 mm, thin

Table 13 a. *Rabbit, young, 7 days old, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.
h	83× 60	1280×27	6.9
h	95× 68	1650×31	7.9
m	95× 84	2180×36	9.8
d	111×100	2800×40	10.1
d	128× 98	3000×38	9.1
d	130×105	3150×39	9.0
d	120×113	3150×41	9.5
d	160×120	3450×43	7.7
d	158×112	3700×45	9.4
d		4150×41	
Mean[1]	97	2641×37 ±210	10.2

Table 13 b. *Rabbit, young, 4 weeks old, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.
m	115× 80	4500×38	18.6
h	120× 90	4650×39	16.8
h	100× 90	4800×40	21.3
h		5250×38	
m	130× 85	5300×40	19.2
m	105×100	5400×37	19.0
d	130×120	5400×42	14.5
d	120×115	6250×41	18.6
Mean	107	5194×39 ±200	18.3

Table 13 c. *Rabbit, young, 2 months old, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.
m	150× 98	7200×45	22.0
m	138×101	7400×46	24.4
d	130×130	7500×48	21.3
m	135×105	7800×45	24.8
h		7900×41	
d	150×135	8250×47	19.1
d	125×125	8500×47	25.6
d	120×120	9150×46	29.2
Mean	126	7963×46 ±240	23.8

Table 13 d. *Rabbit, male, 6 months old, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.
h	165×143	7500×53	16.8
h	190×150	8300×60	17.5
m	220×180	12500×60	18.9
d		15800×59	
Mean[1]	183	11891×59 ±800	20.6

segment 3.6 and 5 mm, thick segment 7.1 ± 0.18 and 7.5 ± 0.26 mm, distal tubule 1.7 and 2 mm. The percentages are 56, 13, 25 and 6 in the male, and 54, 16, 24 and 6 in the female. The figure for each segment is the mean of 13 to 26 data, except for the thin segment. In calculating the length of this the method described on p. 262 has been employed. For this purpose a bundle of 130 long loops has been examined in the male, in the female a bundle containing 57 long loops.

[1] Including the data of table 13 i.

Table 13 e. *Rabbit, male, 8 months old, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.
m	205×180	12400×64	21.5
m		12500×59	
d		12800×62	
m		13000×62	
h		13200×61	
m	220×180	13500×60	20.5
d		13600×65	
h		13800×58	
h		14900×63	
h		15000×60	
Mean		13470×61 ±260	21.0

Table 13 f. *Rabbit, female, 10 months old, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.
m	210×180	14800×54	21.1
d	195×180	15800×55	24.8
d	265×210	17500×53	16.7
d	240×210	17800×58	20.5
h	225×185	18000×57	24.6
Mean[1]	200	16767×55	23.0

Table 13 g. *Rabbit, male, 10 months old, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.
m	225×190	15000×56	19.6
m	165×145	15000×62	38.9
d	225×175	15000	
h	190×150	15600×63	34.5
m	240×195	16500×60	21.2
m	203×165	17300	
h	240×185	18000×68	27.9
h	225×175	18000×75	34.3
h	210×185	18800	
Mean[1]	190	16177×64 ±400	30.0

Table 13 h. *Rabbit, old female, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.
h	225×225	23800×62	29.1
h	315×225	24000×62	21.0
m	225×220	25900×56	29.3
d	250×210	26300×58	29.1
m	280×205	27600×60	28.9
m	325×270	30000×64	21.9
Mean[1]	248	25971×60 ±900	26.1

The ratio of the mean lengths of the proximal tubule and the thick segment is in the "Young, 2 months old" 1.60, in "Male, 10 months" 2.25, in "Female, 10 months" 2.23, and in an about 1-year-old rabbit of mixed breed it is 2.07.

The relative volumes of cortex, outer zone and inner zone have been estimated in "Male, 8 months". The cortex forms 75 % of the total volume, the outer zone 21 % and the inner zone 4.5 % (cf. HOLLATZ 1922).

The rabbit kidney has been investigated repeatedly, and there is a number of descriptions of its shape and structure. These usually agree

[1] Including the data of table 13 i.

Table 13 i. *Rabbit, young 7 days old* (1), *male 6 months* (2), *male 10 months* (3), *female 10 months* (4), *old female* (5), *tubule dimensions in* μ.

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
(1) *h*	78× 59	1500×28	450× 7	1130×15	370×19	43	13	33	11	9.1
h	90× 56	1890×34	770	1500×18	450	41	17	33	10	12.8
m	90× 70	2100×38	1500	2200×19	750×25	33	23	33	11	13.3
m	84× 73	2480×37	2550×11	2050×18	460×27	33	34	27	6	15.0
d	98× 86	2780×38	3100×10	2030×20	900×25	32	35	23	10	12.5
d	95× 95	3000×38		1880×20	550×30					10.3
dd		(4200)	(8000)	(1800)	(800)	(28)	(54)	(12)	(5)	
(2) *hc*	195×120	9400×54	0	3700×22	850×45	67	0	27	6	21.7
d	225×170	11600×58		4500×35	975×44					17.6
m	215×190	11700×57		4600×32	1200					16.3
d	230×160	12400×60		3600×34	1300×42					20.2
m	220×150	13500×62		4350×32	1200×45					25.4
h	180×165	13800×62	2100×14	6750×37	1280×41	58	9	28	5	28.8
h	205×195	14300×63	1900	6380×37	1650×43	59	8	26	7	22.5
dd		(12500)	(21000)	(3600)	(1300)	(33)	(55)	(9)	(3)	
(3) *h*	190×150	14800×64	2200×10	7300×28	1900×40	56	8	28	7	33.2
h	195×160	15200×62	2500×10	8400×30	1800×38	54	9	30	6	30.2
h	175×165	15300×63	3000×11	7900×30	2000×41	54	11	28	7	33.4
d	230×190	15800×65		4800×26	1800×36					23.5
dd		(16000)	(21000)	(4500)	(2000)	(37)	(48)	(10)	(5)	
(4) *m*	205×175	15400×54		6000×29	1500×40					23.1
h	190×165	16500×53	1950	7500	2200	59	7	27	8	22.8
h	225×180	16500×56	2200×15	8000×26	2600×38	56	8	27	9	27.9
h	225×180	18600×55	1900×10	8700×28	2600×40	58	6	27	8	25.3
dd		(17800)	(20000)	(4200)	(2600)	(40)	(45)	(9)	(6)	
(5) *h*	260×240	24200×60	2700×18	12000×32	3000	58	6	29	7	23.3
dd		(27000)	(23000)	(6000)	(2500)	(46)	(39)	(10)	(4)	

with my findings. The dimensions of the kidney and the thickness of the cortex, however, are often stated to be lower than is normal in my material (KRAUSE 1921, JAFFÉ 1931, MARSCHNER 1937). This may be due to racial differences, but more probably these writers have examined young rabbits only. From the data given above it is evident that MARSCHNER's statement (op. cit. p. 365) that rabbit kidneys may be distinguished from other kidneys by their thin cortex, is not correct.

The microscopical structure has been investigated by PETER (1909) and HUBER (1911) in particular. My findings agree qualitatively with their descriptions, but the measurements given by them, especially by PETER, are much smaller than mine made on mature specimens. PETER, however, used the kidneys of a young rabbit, only 2 months old (op. cit. p. 70). It also seems clear that his material had shrunk considerably, as is normal after maceration with the relatively weak acid he used. There can be no doubt that the figures for the length and thickness of the proximal tubule, given by PETER, are very much lower than those normally existing in a mature rabbit. This, of course, had little weight with PETER, who was more interested in the structure than in the dimensions of the tubules. It is, however, much to be regretted that these figures have been generally accepted as representative of the rabbit kidney (PÜTTER 1926, MARSHALL 1934, CONWAY 1937). The measurements given by HUBER are in closer agreement with mine, though somewhat low. The ratio of the lengths of the proximal tubule and the whole nephron is also too small, as calculated from PETER's figures.

KOLLMANN (1864) and PYE (1875) give some details of the microscopical structure, and in a paper on pathological changes in the rabbit kidney, STRONG (1940) depicts a complete, isolated, normal nephron.

Sciurus vulgaris L.

Material. The kidneys of an old male.

Form. The weight of the kidneys is 1.70 gm and the dimensions 16.5 × 11 × 8.5 mm. Papilla relatively long and pointed (fig. 7 *C*, p. 295), pelvis with processes. The cortico-medullary boundary is distinct and even. Cortex 1.8 mm, outer zone 2.6 mm and inner zone 3.8 mm thick. The outer stripe is marked and thick.

Tubules. The epithelium of the capsule is high and opaque at the transition into the proximal tubule. There is no neck, and the proximal tubule is tortuously convoluted. The distal third of the proximal tubule is differentiated into two segments. The first of these is less transparent than the preceding two-thirds of the proximal tubule, the second part, on the other hand, is lighter and more transparent than these. This last segment is often somewhat slenderer than the proximal tubule on an average.

The short loops are about as numerous as the long (24: 18). The short loops always turn in the thick segment. The difference between the thicker and the thinner part of the thick segment is small in the high nephrons also. The collecting tubules often join already in the inner part of the cortex.

UTSUGI (1931 a) has investigated the tubules of the squirrel kidney. The paper is written in Japanese, and the abstract is short and in some respects obscure; a comparison is thus impossible.

Table 14. *Sciurus vulgaris, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
h	125×120	6000×52	20.8	*h*	140×155	7000×56	18.1
h		6400×49		*h*	135×150	7100×53	18.6
	150×113	6800×48	19.3	*h*	135×135	7200×55	21.7
m	150×120	6900×50	19.2		160×120	7500×50	19.5

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
	135×116	6250	1100	3500	1050	53	9	29	9	
h	150×120	6500×50	1000×6	3200×20	900×35	56	9	28	8	18.1
h	150×120	6900×42	1150×8	3900×26	1150×39	53	9	30	9	16.1
	150×130	6900×46		3300×27	1000×34					16.3
h	135×113	7100×53	1300×8	3700×24	1200×35	53	10	28	9	16.3
m	155×113	7200×52								21.4
d	158×135	7800×54		3100	1050					19.7
dd		(8000)	(9500)	(2500)	(1200)	(38)	(45)	(12)	(6)	
Mean	135	6903×51 ±120	7	3450×24	1058×36					18.9

Castor fiber L.

Material. The kidneys of four specimens in alcohol.

Form. One of the kidneys has the dimensions 60 × 36 × 21 mm. There are two papillae, only slightly projecting into the pelvis (fig. 7 *D*). The collecting ducts are very large distally, and form almost all of the apices of the papillae. The cortex is about 7 mm thick, the medulla is 14 mm. The former contains thick medullary rays, and the latter is not divided into zones. The kidneys of two of the other specimens agree in essentials with this description, but the third has only one papilla.

The tubules. The above-described kidney has been macerated. There are cortical nephrons, and the kidney seems to be devoid of long loops. There is always a pars recta, though it may be tortuous, like the main part of the proximal tubule. The transition into the thin segment occurs

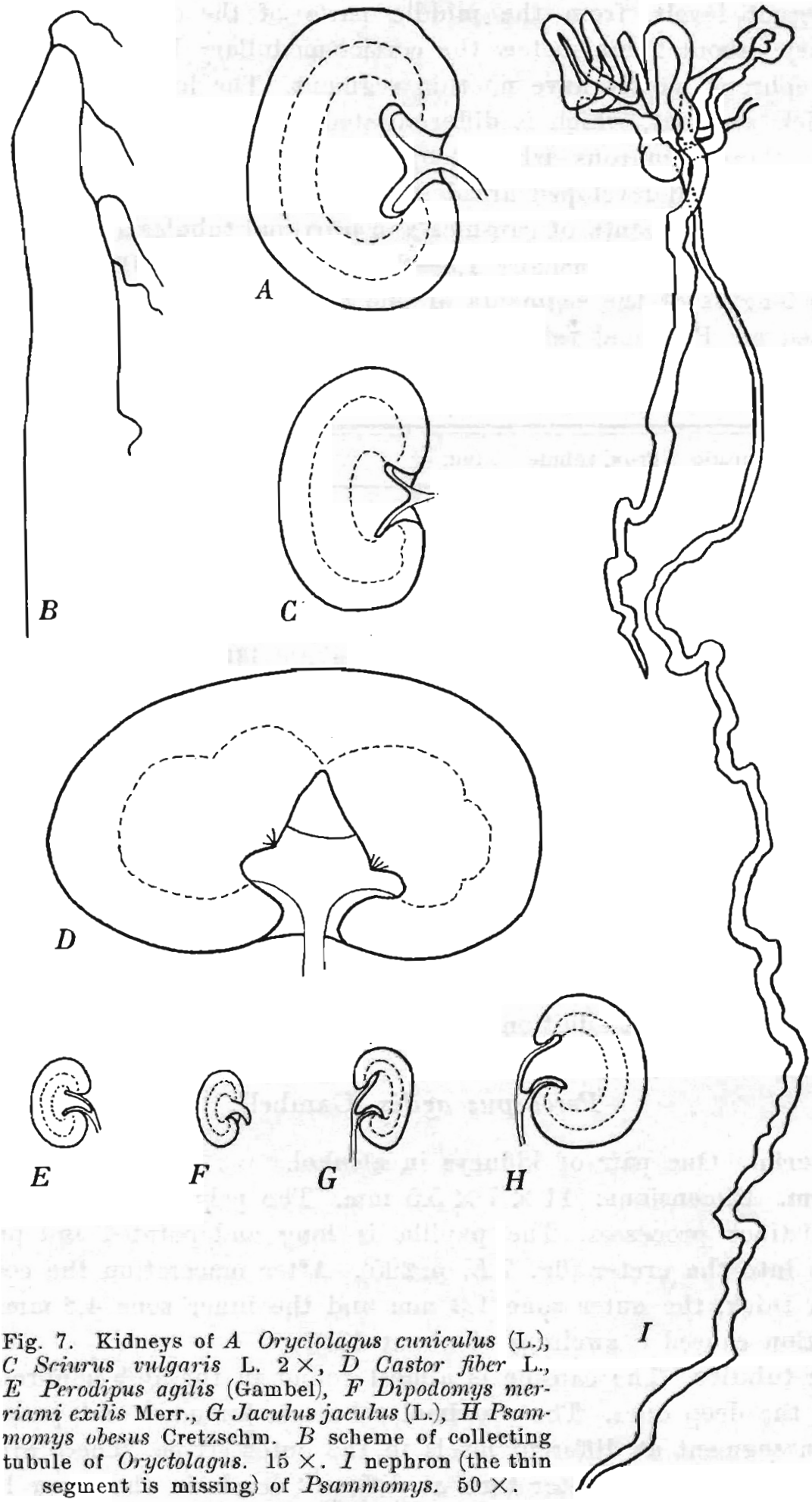

Fig. 7. Kidneys of *A Oryctolagus cuniculus* (L.), *C Sciurus vulgaris* L. 2 ×, *D Castor fiber* L., *E Perodipus agilis* (Gambel), *F Dipodomys merriami exilis* Merr., *G Jaculus jaculus* (L.), *H Psammomys obesus* Cretzschm. *B* scheme of collecting tubule of *Oryctolagus*. 15 ×. *I* nephron (the thin segment is missing) of *Psammomys*. 50 ×.

at different levels, from the middle parts of the cortex to the stripe boundary, about 2 mm below the cortico-medullary boundary. The cortical nephrons mostly have no thin segment. The loops always turn in the thick segment, which is differentiated into a thicker and a thinner part in those nephrons whose loops enter the medulla. The collecting tubules have well-developed arcades.

Some measurements of capsules and proximal tubules are given below. The distal tubules are usually 1.5—2.0 mm long and 0.035 mm thick.

The lengths of the segments of one of the deepest nephrons may be estimated at: Proximal tubule 13 mm, 41 %, thin segment 7 mm, 22 %, thick segment 10 mm, 31 %, distal tubule 2 mm, 6 %.

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
hc	94× 83	5600×41	29.4	*h*	173×120	10100×48	23.4
hc	120× 98	5800×42	20.7	*d*	175×115	11000×51	27.9
m	160×135	9800×52	23.6	*d*	165×135	13100×49	28.8
				Mean	131	9200×47	25.6

GERHARDT (1914) states that *Castor* has several tubi maximi, but no pelvis. He has, however, not been able to examine his material thoroughly, as the kidney belonged to the exhibition material of a museum. Probably as a result of this the description is somewhat obscure, and in the drawing (op. cit. Pl. I, fig. 19) nothing resembling tubi maximi is to be seen. The spaces visible there are certainly blood-vessels. It seems most probable that the section has not cut into the pelvis at all, but is lateral to it. There is no need to believe that the beaver kidney might show tubi maximi in addition to the two forms described above.

Perodipus agilis (Gambel).

Material. One pair of kidneys in alcohol.

Form. Dimensions: 11 × 7 × 5.5 mm. The pelvis is relatively large with distinct processes. The papilla is long and pointed and projects slightly into the ureter (fig. 7 *E*, p. 295). After maceration the cortex is 1.7 mm thick, the outer zone 1.9 mm and the inner zone 4.8 mm. The maceration caused a swelling of about 13 %.

The tubules. The capsule is almost round in the high nephrons, but oval in the deep ones. The proximal tubule is tortuous and passes into the thin segment at different levels in the outer stripe. There are long and short loops. The latter turn at different levels in the inner half of

the outer zone, and they turn within the thick segment. The latter always consists of a thicker and thinner part. There are often short arcades. The collecting tubules are relatively thin.

In addition to the tubules tabulated 13 more thick segments have been measured. The mean length of the thick segment is 2.9 ± 0.04 mm. A further 10 distal tubules have also been measured, and the mean length of this segment is about 0.8 mm.

Table 15. *Perodipus agilis, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
h	80×75	3100×36	18.6	*h*	100× 85	3700×34	14.8
h	90×80	3200×34	15.1	*m*	100× 90	4300×36	17.2
m	85×80	3400×36	18.0	*m*	105× 90	4400×38	17.7
h	100×70	3600×37	19.0	*d*	140×110	5700×38	14.1
m	105×75	3600×34	15.5	*d*	135×135	6700×38	14.0

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	83× 75	3200×34	1250×10	2850×24	800×25	40	15	35	10	17.5
h	85× 75	3350×36	1400× 8	2950×25	650×28	40	17	35	8	18.9
h	100× 75	3400×37	1350×12	2800×24	900×29	40	16	33	11	16.8
m	105× 75	3500×35	1400×10	3000×23	900×28	40	16	34	10	15.6
d	120× 95	4500×38		3200×27	900×30					15.0
d	130×115	5200×40		3000×25	750×30					13.9
Mean	96	4053×36 ±250	10	25	28					16.4

Dipodomys merriami exilis Merr.

Material. One pair of kidneys in alcohol.

Form. The kidneys agree in essentials with those of *Perodipus* (fig. 7 *F*, p. 295). The dimensions are 9 × 5 × 4.5 mm, and the joint depth of cortex and medulla 6 mm. After maceration the cortex is 0.75 mm thick, the outer zone 0.9 mm and the inner zone 2.9 mm.

The tubules. I have not been able to find any differences as compared with the tubules of *Perodipus*.

The dimensions of some nephrons are given in table 16. The shrinkage was about 25 % of the alcohol material. 54 short and 20 long loops

have been counted. Including 14 more proximal tubules the mean length of the proximal tubule is 1.8 ± 0.1 mm. The mean length of the thin segment of 18 long loops is 2.5 mm. The mean length of the thin segment of the short loops is 0.7 mm. The mean length of this segment, with both short and long loops included, would thus be about 1.2 mm. The mean length of the thick segment (18 measurements) is 1.4 ± 0.02 mm, and the mean length of the distal tubule about 0.35 mm. The proximal tubule constitutes about 38 % of the total tubule length in the kidney, the thin segment 25 %, the thick segment 29 %, the distal tubule 7 %.

Table 16. *Dipodomys merriami exilis, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	45×40	1500×15	700× 5	1300×12	300×15	39	18	34	8	12.5
h	45×45	1600	700	1350	350	40	18	34	8	(12.6)
h		1900×17	1800×10	1450	400	34	32	26	7	
m	55×50	2100	2500	1400	375	33	39	22	6	(15.3)
d	68×45	2250×20		1350	300					14.7
m	75×45	2400×19	2800× 8	1500×16	400×14	34	39	21	6	13.5
d	70×45	2500×21	3300× 6	1500×14	350×15	33	43	20	5	16.7
d	75×60	3600×19	5400× 8	1350×13	370×15	34	50	13	4	15.2
d	90×65	4100×20								14.0
dd	100×50	4300×19	(6500)	(1350)	(500)	(34)	(51)	(11)	(4)	16.3
Mean	59	19	7	14	15					14.7

Jaculus jaculus (L.).

Material. The kidneys of an old female, captured at Omdurman, in alcohol.

Form. The kidneys are of the common bean-shape. The papilla is long and projects into the ureter (fig. 7 *G*, p. 295). The cortex is 1.4 mm thick, the outer zone 2.1 mm, the inner zone 5.3 mm. Dimensions $12 \times 7 \times 6$ mm.

The tubules. The capsule is often oval, especially in the deep nephrons. The pars recta is always well developed and the pars convoluta is always distinct also, though it is unusually short in the high nephrons. The loops of the high nephrons turn as much as 1 mm above the zone boundary. There is very little difference between the thicker and the thinner part of the thick segment, with regard to both thickness and

structure. The thick segments are mostly wavily tortuous. The short loops often turn in the thick segment. Since the transition into the thick segment occurs at varying levels in the long loops it is often very difficult to decide if a loop is long or short. About a third of about 150 loops were certainly short, and as many long, but the remaining 50 loops could not be classified with certainty. The distal tubule and the initial collecting tubule show nothing unusual. The collecting tubules are thin and often have arcades.

Some nephrons have been measured and their dimensions are given in table 17. The longest of these nephrons nearly approaches the maximum length in this kidney, and there is certainly not more than one such nephron in hundreds. It must therefore be excluded in calculating the means. Proximal tubules with the lengths 3.6, 3.9, 4.0, 4.1, 4.2, 4.4, 5.3 mm have been measured in addition. The mean length of the proximal tubule is 4.5 ± 0.23 mm. Seven more thick segments have lengths varying from 3.5 to 4.3 mm. The mean length of this segment is (the longest nephron still excluded) 3.9 ± 0.04 mm.

Table 17. *Jaculus jaculus, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
m	85× 70	3300×30		3200×22	750×28					16.6
h	75× 75	3600×32	1800×9	3700×23	650×27	37	18	38	7	20.5
h	95× 65	4000×35		3700×25	1000×30					22.7
d	150×105	5500×36		3600	950					12.6
dd	165×135	11000×42	(13000)	2700×23	1000×32	(40)	(46)	(10)	(4)	20.7
Mean	102	35		23	29					18.6

Microtus agrestis (L.).

Material. The kidneys of two mature specimens, a female and a male.

Form. In the female the dimensions are $12 \times 7.5 \times 5$ mm, and the weight of the kidneys is 0.48 gm. The cortex is 2 mm thick, the outer zone 2.3 mm, and the inner zone 2.3 mm. The outer stripe occupies 1.1 mm of the outer zone.

In the male the corresponding values are: $15 \times 8 \times 6$ mm, cortex 2.1, outer zone 2.8, of which the outer stripe occupies 1.4 mm, inner zone 2.4 mm. The shape of the papilla is shown in fig. 8 *A*. The pelvis has processes.

The tubules. The nephrons have long or short loops, or they are confined to the cortex. In the male the latter had loops which reached the cortico-medullary boundary, and even penetrated slightly into the outer zone. There is often a distinct neck, especially in the deepest nephrons. The thin segment is usually absent in the cortical nephrons, and is very short in the high short loops (cf. fig. 8 *B*). The transition into it occurs at varying levels, from the cortico-medullary boundary to the

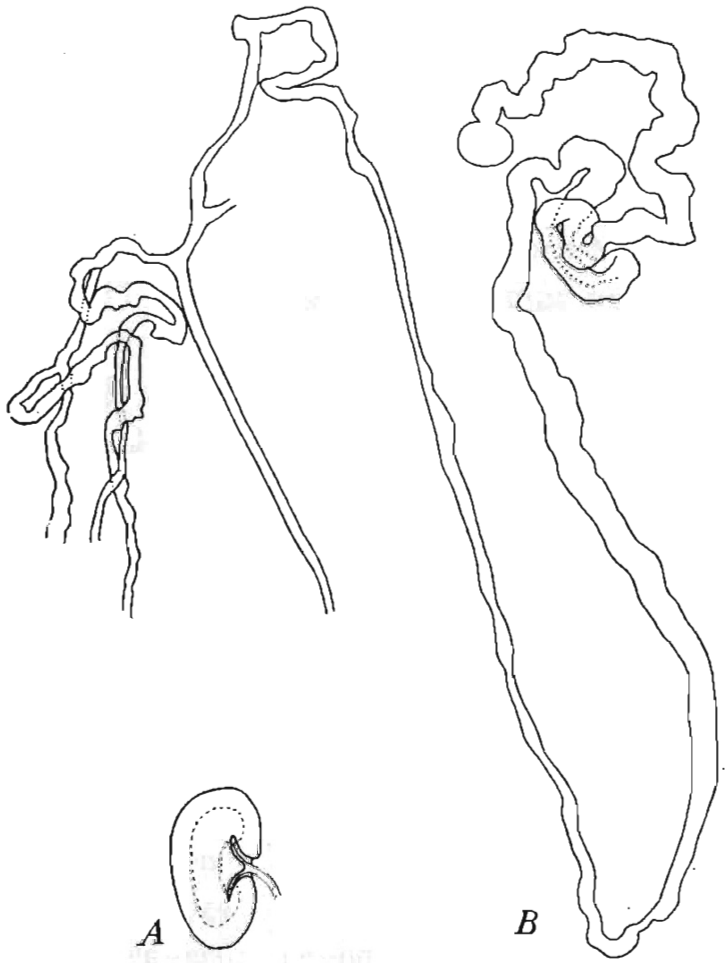

Fig. 8. *A* Kidney of *Microtus agrestis* L. *B* High nephron of *Evotomys glareolus* Schreb. 50 ×.

stripe boundary. The transition into the thick segment occurs in the high short loops already in the outer stripe. In the female the thick segments of the cortical nephrons are not differentiated into a thicker and a thinner part, but in the male all nephrons show a differentiation of this kind. The short loops always turn within the thick segment. The collecting tubules sometimes have arcades, and normally 4 or 5 nephrons join each collecting tubule. The first central junctions may occur in the central parts of the cortex, but usually they are found in the outer zone.

In the male there is a swelling of about 10 % after maceration. In the female there are 16 cortical nephrons out of 160 nephrons examined, and 23 have long loops. In the male 120 nephrons have been

Table 18 a. *Microtus agrestis, female, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
h	138×115	3900×31	7.6	*m*	162×130	4600×31	6.8
m	140×110	4000×35	9.1	*m*	158×120	4700×35	8.7
h	120×120	4000×34	9.4	*d*	145×135	4900×38	9.5
m	143×135	4100×36	7.6	*m*	150×135	4900×32	7.7
m	158×135	4600×37	8.0	*d*	145×140	6000×36	10.6

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
hc	113× 98	2200	0	1000×26	500	59	0	27	14	
hc	113×105	2300×30	0	1100×26	500×38	59	0	28	13	5.8
h	135×110	2900×30	75× 7	1600×22	600×38	56	1.5	31	12	5.9
hc	129×110	2950×29	0	1400×26	700×34	58	0	28	14	6.0
h	120×100	3000×31	75×10	1700×24	600	56	1.4	32	12	7.8
h	143×110	3200×30	80× 8	1800×22	600×40	56	1.4	32	11	6.1
h	120×120	3300×31	50× 6	1650×23	640×38	59	1.0	29	11	7.1
m	130×115	3600×32	300	2000×23	700×38	55	5	30	11	7.7
h	120×120	3700×31	40×20	1600×26						8.0
m	135×120	3900×32			825×31					7.7
d	165×130	4700×38		2225×26	800×32					8.3
d	150×150	5600×36		2200×30	800×40					9.0
dd	165×165	6600×37	(5400)	2400×26	(900)	(43)	(35)	(15)	(6)	9.0
Mean	131	4072×33 ±230	10	1723×25	660×37					7.9

examined in this respect. 15 are cortical nephrons; 95 loops are short, and 10 long. The mean lengths of the segments are difficult to estimate, since the variations are very great. In the female the mean length of the proximal tubule is about 4.1 mm. The thin segment is 0—1 mm long in the high nephrons, and the average value is probably about 0.4 mm. In the long loops the length varies from 1.3 to 5 mm, and since the longest loops are very few, the average is probably not over 2 mm. The average length of the thin segments of all nephrons is then about 0.6 mm. Correspondingly, the length of the thick segment is estimated at 1.8 mm, and the length of the distal tubule at about 0.7 mm. The proximal tubule should thus occupy 56 % of the total tu-

Table 18 b. *Microtus agrestis, male, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
hc	100×100	3700×51	0	1900×27	650×40	59	0	30	10	18.9
h	115×100	3800×52	230×20	2500×26	600×40	53	3	35	8	17.1
h		4050×50	350×15	2600×24	675×44	53	5	34	9	
d	110× 95	4200×53	1100×15	3200×29	800×42	45	12	34	9	21.3
m	115×100	4600×49	780×13	3000×31	850×37	50	8	33	9	19.6
d	130×100	4800×55		3200×28	900×41					20.3
m	110× 90	4900×52	540×12	3300×30	750×43	52	6	35	8	25.7
d	135×115	5200×55	1300×10	3250×34	750×45	50	12	31	7	18.4
d	120×100	5400		3000×30	800×38					
Mean	108	4517×52	14	2883×29	753×41					20.2

bule length, the thin segment 8 %, the thick segment 25 % and the distal tubule 10 %. Though the uncertainty of these figures is great, they may have some value for comparison purposes. In the male the thick segment is plainly somewhat longer than in the female.

Table 19. *Evotomys glareolus, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
hc		2800×38	0	1100×16	700×24	61	0	24	15	
hc	96×88	3100×41								15.0
hc	96×60	3100×38	0							20.5
h	88×72	3100×40	20× 8	1100×20	650×25	64	0.4	23	13	19.6
h	88×65	3100×41	250× 7	1600×16	700×23	55	4	28	12	22.2
h	90×75	3300×40	20×10	1400×20	720×24	61	0.4	26	13	19.6
hc	96×72	3400×39	0	1100×15	700×26	65	0	21	13	19.2
m	96×70	3400×40								20.2
d	120×80	3600×41								15.4
d	96×80	4000×40								20.8
Mean	85	3290×40 ±110	8	1260×17	694×24					19.2

Evotomys glareolus Schreb.

Material. The kidneys of a mature female have been macerated.

Form. The kidneys agree in shape with those of *Microtus*. Weight 0.32 gm.

The tubules. The tubules agree in essentials with those of *Microtus* (fig. 8 *B*, p. 300). The thick segment of the cortical nephrons is not differentiated into thicker and thinner parts, and their loops reach the cortico-medullary boundary.

Arvicola terrestris (L.).

The kidneys of this species also agree qualitatively with those of *Microtus agrestis*, as regards both shape and microscopical structure.

Epimys rattus (L.).

Material. The kidneys of an old female of the common white rat.

Form. Dimensions 19.5 × 13 × 10 mm. Weight 2.9 gm. The papilla is pointed (fig. 9 *A*, p. 307) and the pelvis has processes. The cortex is distinctly and evenly demarcated, 2.9 mm thick, the outer zone 2.6 mm, the inner zone 5.4 mm.

The tubules. The capsule is round or oval. There is no neck. The proximal tubule is very tortuous, with many bends (Pl. 1, fig. 5). The

Table 20. *Epimys rattus, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
d	195×145	9000×51		4900×28	900×43					16.2
m	180×135	9000×52		5100×26	1300×41					19.3
m	180×135	9500×50		5000×29	1600×38					19.5
h	180×165	9800×48		5700						15.8
h	180×140	9800×49		5800×26	1400×39					19.1
h	185×125	10100×53		6000×25	1600×38					23.1
h	180×160	10200×47	1700×15	6000×26	1500×39	53	9	31	8	16.6
h	180×135	10300×50	2000×14	5300×26	1400×40	54	11	28	7	21.2
m	155×150	10600×49		5200×25	1350×44					22.3
dd	205×165	12000×54	(12000)	4900×29	1600×40	(39)	(39)	(16)	(5)	19.2
Mean	164	10030×50 ±270	15	5390×27 ±140	1406×40					19.2

terminal part of the proximal tubule is, normally, distinctly thicker than the rest of this segment, but tapering towards the transition into the thin segment. The proximal tubule has often small protuberances. The thick segment is as a rule relatively tortuous in its thicker part. The latter is indistinctly differentiated from the thinner part. The distal tubule is strongly and irregularly looped, and its surface often shows small projections. The initial collecting tubule is often absent. The collecting tubules are most often formed by the junction of 6 nephrons and, normally, have a small arcade, and some direct junctions. The long loops constitute 28 ± 4.5 % of the total number.

The kidneys of the white rat have been examined with maceration methods by UTSUGI (1931 b), and by WALKER and OLIVER (1941). I have had access to UTSUGI's paper in abstract only. The abstract is very short and does not permit any discussion of the inconsistencies between UTSUGI's description and mine.

WALKER and OLIVER have isolated a number of the highest nephrons of rat kidneys (and guinea-pig kidneys). They give the dimensions of some nephrons. These agree relatively well with my measurements, but on the whole the thin segment is shorter and the distal tubule is longer in their material.

Mus musculus L.

Material. The kidneys of several specimens have been examined, some of them after maceration.

Form. The kidneys differ from those of *Mus flavicollis* and *sylvaticus* only in the shape of the papilla, which is distinctly longer and more pointed in this species (fig. 9 *B*, p. 307). It normally projects into the beginning of the ureter. The kidney weight ranges from 0.20 to 0.35 gm in mature specimens. In the most minutely examined specimen it is 0.23 gm, and the dimensions 9 × 5.5 × 4.5 mm. The cortex is 1.3 mm thick, the outer zone 1.2 mm and the inner zone 3.7 mm.

The tubules. The tubules agree closely with those of *M. flavicollis* and *sylvaticus* (cf. p. 306). On the whole the tubules seem to be more looped than the tubules of these forms, also when specimens of corresponding ages are compared.

The percentage of long loops is 24 ± 3.6.

The mean length of the proximal tubule is probably slightly lower than the mean of table 21, since the deep nephrons are too numerous in the table. The true mean may be estimated at about 4.0 mm. The thick segment has been measured in 10 nephrons. The mean is 2.0 ± 0.05 mm. The distal tubule is, on an average, 0.6 mm long. The ratio of proximal tubule and thick segment is 2.00, if the corrected

Table 21. *Mus musculus, tubule dimensions in μ.*

Capsule	Prox. tubule	Ind.	Capsule	Prox. tubule	Ind.	Capsule	Prox. tubule	Ind.
112× 80	3400	(15.6)		3760×40		112× 96	4300×42	16.8
112× 88	3440×40	14.0	105× 95	3800×43	18.1	110× 88	4320	(18.3)
104× 90	3500	(15.3)	112× 90	3840×40	15.2	120× 80	4320×42	18.9
96× 88	3520×40	16.7	105× 95	3900×41	17.7	120×100	4950×42	17.3
120× 85	3550	(14.3)	112× 96	3920×41	14.9	120×112	5200×42	16.3
104× 88	3600	(16.1)	104× 88	4000	(17.9)	120×105	5340×44	18.6
112× 80	3680	(16.8)	112×104	4000×42	14.4	125× 90	6000	(21.9)
104×104	3680×40	13.6		4000×41		136×104	6880×44	21.4
120× 96	3700×42	13.5	105×100	4160×42	16.6	130×130	8550×42	21.2
120× 88	3760	(14.6)	120× 90	4180×41	15.9			

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	90×75	3600×37	450×5	1900×21	500×35	56	7	29	8	19.7
h	90×75	3700×33	500	1950×19	500×30	56	8	29	8	18.1
dd		(8550)	(8000)	(1500)	(1000)	(45)	(42)	(8)	(5)	
Mean	103	4276×41 ±200								16.9

figure for the proximal tubule is accepted, or 2.15 ± 0.10 if no correction is applied.

The kidney of *Mus musculus* has been repeatedly examined by various authors. The form of the papilla is shown in a figure by Hamburger (1890). The microscopical structure has been investigated in particular by Peter (1909). The agreement with my findings is close, quantitatively also. The variation in length of the proximal tubules, however, does not appear from his data. v. Möllendorff (1922) emphasizes this feature, which is clearly shown by his material, and also by Peters' data (1928). The latter author gives relatively very low values for the dimensions of the capsule. This raises the ratio of the surfaces of the proximal tubule and the capsule of a single nephron up to 70, with means of this ratio up to 49. It is difficult to explain this fact. It may have some connection with her taking the kidneys from the living animal, since it is possible that the glomeruli contract more than normally in this procedure. It is possible also that her technique, which includes mounting in glycerine-

jelly, has a part in this. Almost certainly it is one cause of the great variation shown by her data.

SCHWEIGGER-SEIDEL (1865) and RINDOWSKY (1867) have also examined mouse kidneys. The paper by AUERBACH (1925) contains little that had not already been mentioned by PETER (1909).

Mus flavicollis Melch.

Material. The kidneys of a number of young and old specimens.

Form. The total kidney weight varies from 0.32 to 0.78 gm in mature specimens of my material. The lowest weights occur in young specimens, and the highest in old. The dimensions are normally about 11 × 6.5 × 4.5 mm. The cortex is 1.4—2.0 mm thick, the outer zone 1.0—1.4 mm, the inner zone about 3—4 mm. It may be mentioned that the central part of the cortex does not contain any glomeruli, as is often the case in other species also. The following specimens have been more thoroughly examined after maceration.

	Dimensions, mm	Cortex, mm	Outer zone, mm	Inner zone, mm	Weight, gm
Young male	9.5×5.5×4	1.2	1.1	3.3	0.23
Female	11 ×6.5×4.5	1.4	1.3	3.1	0.40
Male	12 ×7 ×5	1.5	1.3	3.0	0.42
Old male	12 ×8 ×5.5	1.8	1.2	3.2	0.54
Old female	14 ×8 ×6	1.9	1.7	2.8	0.74

The pelvis is provided with distinct processes and the papilla is pointed. In young specimens the papilla is longer and more slender than in old ones (fig. 9 *C*, *D*, *E*).

The tubules. There is no neck. The proximal tubule is on the whole of uniform thickness, but the last part of it may be thicker or slenderer than the preceding parts. This terminal segment has normally a more transparent epithelium, but the difference is small, and the transition gradual. The transition into the thin segment is abrupt and, normally, occurs at the same level in all nephrons. The short loops turn slightly peripheral to the zone boundary and the bend lies at or near the transition between thin and thick segment (Pl. 2, fig. *2*, *3*). The thick segment of the high nephrons is differentiated into a thicker and a thinner part, but in the "Young male" this differentiation is faint. In this specimen there is normally also an intercalated segment which is absent in

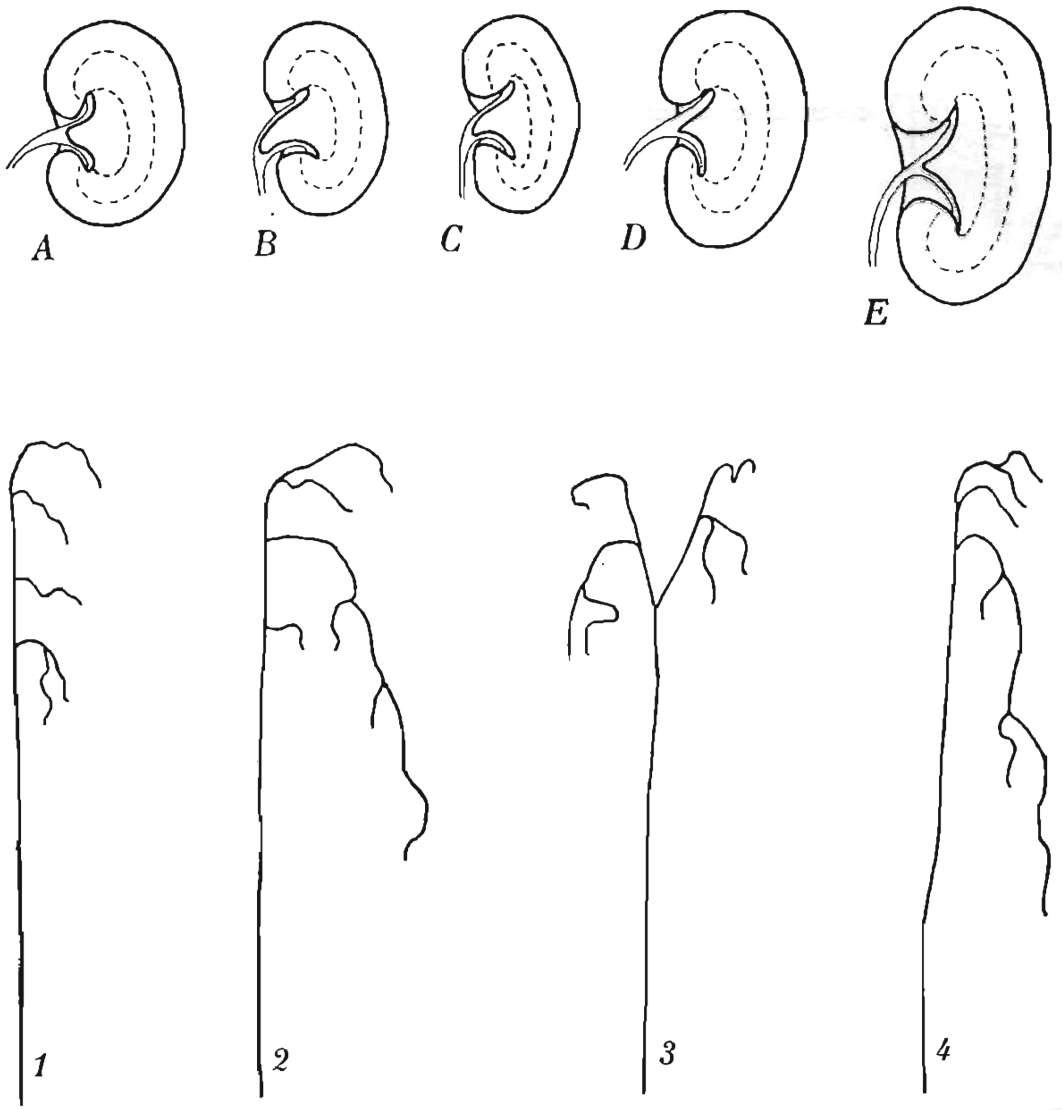

Fig. 9. Kidneys of *A Epimys rattus* (L.), *B Mus musculus* L. 2 ×, *C, D, E Mus flavicollis* Melch. 2 ×. Collecting tubules of *Mus sylvaticus* L. *1, 2, 3, 4* about 40 ×.

the others. The collecting tubules are often formed by direct junctions, but small arcades are also common (cf. fig. 9: *1*, *2*, *3*, *4*). The collecting tubules are relatively thin, 0.020—0.030 mm, except in the inner parts of the medulla, where they are thicker.

The percentage of long loops is: "Young male": 20.2 ± 3.1 %, "Female": 19 ± 2.8 %, "Male": 27 ± 4.3 %, "Old male": 23 ± 2.9 %, "Old female": 18.3 ± 3.0 %.

In the "Young male" there was a swelling to about 10 %.

Thus the mean length of the proximal tubule is 3.2 mm. The uncorrected mean is 3.53 ± 0.030 mm. The mean length of the thin segment has been calculated from measurements of 16 short and 4 long loops. It is 0.89 mm. The thick segment, also calculated from 20 measurements, is 1.84 ± 0.035 mm long, and the distal tubule 0.57 mm. The proximal tubule forms 52 %, the thin segment 13 %, the thick segment 27 %, and the distal tubule 8 % of the total length of the tubules. The value for the thin segment is the least reliable of these figures. In the

Table 22 a. *Mus flavicollis, young male, proximal tubule lengths in small samples.*

Sample	High (h) and middle (m) proximal tubules, length in mm													Deep prox. tub. length in mm	Mean length
	2.8 h m	2.9 h m	3.0 h m	3.1 h m	3.2 h m	3.3 h m	3.4 h m	3.5 h m	3.6 h m	3.7 h m	3.8 h m	3.9 h m	4.0 h m		
a			1		2	1	1 1		1					3.7 4.8	3.511 ± 0.176
b				1	3	2	1		1	1				3.9 4.4	3.482 ± 0.115
c			1				3 1	1 1						4.4	3.500 ± 0.140
d			1	1	1	1		1 1		1				3.8 3.9	3.444 ± 0.105
e	1	1	1	1		1			1	2	1			3.9 4.5 5.0	3.608 ± 0.189
f				1	1	1	1 1	1 1						4.4	3.475 ± 0.141
g			1	1	2	1		1						4.4	3.385 ± 0.179
h		1	1	1	1	2	1		1					4.5 5.3	3.560 ± 0.240
i		1	1		1 1	1 1	1							3.9 4.1	3.368 ± 0.132
k			1		1		1	1	1	1	1	1		4.3 5.2	3.760 ± 0.197
l		1			1		1 1		2 1					3.7 4.4	3.533 ± 0.136
m			3		1	1				1				3.6 4.3	3.388 ± 0.162
n				1	2	1					1 1			3.9 4.6	3.613 ± 0.181
o			1	1	1	1	1	1 1	1				1	4.9 5.0	3.682 ± 0.208
p				1	1	1 2	1	1	1					4.7 5.3	3.670 ± 0.231
	1	4	12	9	19	17	16	11	10	6	4	1	1		3.532 ± 0.030

Table 22 b. *Mus flavicollis, young male, distribution of deep prox. tubules according to length, including those of table 22 a.*

Length in mm	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9
Number of tubules	3	6	6	10	2	7	2	4	7	5	4	2	3	3	2	0	2	3	0	0	1	0	1	1

Table 22 c. *Mus flavicollis, young male, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
h	77×62	2800		*h*	96× 73	3500	
h	80×76	2900		*m*	105× 75	3500	
h	87×75	3000×33	15.2	*h*	84× 73	3500	
h	75×68	3000×35	20.6	*m*	98× 82	3500	
h	85×80	3000		*m*	95× 90	3500	
h	80×70	3000		*h*	80× 65	3600×34	23.5
m	83×82	3000		*m*	90× 90	3600×35	15.6
h	84×76	3100×34	16.5	*m*	94× 76	3600	
h	84×83	3100		*m*	90× 82	3700×36	18.0
m	90×75	3100		*h*	90× 68	3700	
m	85×82	3100		*m*	105× 75	3700	
h	82×74	3100		*m*	95× 90	3700	
m	93×77	3200×35	15.6	*d*	113× 83	3700×35	13.8
m	90×75	3200×34	16.1	*d*	105× 91	3700×34	13.2
h	85×68	3200×35	19.4	*h*	87× 82	3800	
h	83×83	3200×36	16.7	*d*	120× 90	3800	
h	90×69	3200×35	18.0	*d*	115× 94	3900×35	12.6
m	97×73	3200		*d*	108× 85	3900	
h	89×76	3200		*d*	109× 83	3900	
m	84×82	3200		*d*	102× 88	3900×37	16.1
h	86×75	3300×35	17.9	*d*	113× 90	4400×36	15.6
h	84×77	3300×35	17.9	*d*	114×105	4400×36	13.2
h	85×73	3300×35	18.6	*d*	120× 84	4400	
h	89×74	3300		*d*	115×105	4400	
m	79×76	3300		*d*	105× 90	4400×36	16.8
h	75×75	3300		*d*	115× 84	4500	
h	89×80	3300		*d*	115×100	4500	
h	90×75	3400×35	17.6	*d*	115× 94	4500×37	15.4
m	90×84	3400×37	16.6	*d*	135×120	4700×40	11.6
h	76×76	3400×36	21.2	*d*	118× 87	4800×36	16.8
m	97×72	3400×33	14.6	*d*		4800×38	
h	92×76	3400×35	17.0	*d*	125×100	4900×38	15.4
h	90×81	3400×34	15.9	*d*	122×114	5000	
h	88×74	3400×36	18.8	*d*	130×115	5200×41	14.3
m	85×72	3400		*d*	120×115	5300	
h	90×76	3400		*dd*	150×120	5800×46	14.8
m	95×81	3500×36	16.4	*dd*	135×125	5900×45	15.7
h	82×75	3500×34	19.3	Mean		36.1	16.55

Table 22 d. *Mus flavicollis, male, tubule dimensions in μ.*

Capsule	Prox. tubule	Ind.	Capsule	Prox. tubule	Ind.	Capsule	Prox. tubule	Ind.
83×68	1730×36	11.0	105×83	3530×38	15.4	160× 90	5250×40	14.6
118×75	3150×38	13.5	100×83	3680×37	16.4	120×120	5330×40	14.8
98×80	3200×38	15.5	120×91	3750×39	13.4	154×103	5360×41	13.9
118×83	3230×36	11.9	101×90	3850×39	16.5	148× 98	5550×41	15.7
90×94	3380×37	14.8	105×87	4130×38	17.3	158×112	6300×45	16.0
105×93	3450×38	13.4	122×90	4150×39	14.7	150×131	6380×44	14.3
93×94	3500×38	15.2	131×98	4500×40	14.0	158×120	6450×44	15.0

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h		3080×38	420×10	2250×22	600×25	49	7	35	9	
h	113×113	3300×38	410×10	2030×22	650×30	52	6	32	10	9.8
m	120×112	3600×41	1500×10	2250	675	44	19	28	8	11.0
h	113×100	4050×38	375× 9	2100×23	820×29	55	5	29	11	13.6
m	125×113	4350×40	1300×10	2200×24	700×31	51	15	26	8	12.3
m	128×105	4500×42	1500× 9	2300×22	750×28	50	17	25	8	15.0
	135×105	4700	1400	2000	550	54	16	23	6	13.3
m	150×120	4950×41	2050× 8	2180×23	900×28	49	20	22	9	11.3
d	150×128	5150×41	2900× 9	1750×22	750×30	49	27	17	7	11.0
d	150×120	5480×39	3200× 9	2400×23	900×30	46	27	20	8	11.9
dd		(6500)	(7000)	(1500)	(1000)	(41)	(44)	(9)	(6)	
Mean	112	4291×39.5 ±200	9	2146×23 ±59	730×29					13.9

"Female" 10 proximal tubules, mean 4.6 ± 0.2 mm, and 10 thick segments, mean 2.35 ± 0.06 mm, have been measured. The ratio of these means is 1.96 ± 0.10. This ratio is 1.92 ± 0.044 in the "Young male".

The low nephrons are somewhat too numerous in the measured sample of the "Male". The mean length of the proximal tubule is thus lower than the mean of table 22 d, i.e. about 4.0 mm. The thin segment of the short loops is about 0.4 mm long, and of the long loops about 2 mm; the weighted mean of these is about 0.8 mm; the thick segment is 2.1 mm and the distal tubule 0.7 mm long. If these estimations are correct the mean tubule has the following composition: Proximal tubule 53 %, thin segment 11 %, thick segment 28 %, distal tubule 9 %. In

Table 22 e. *Mus flavicollis, old male, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	110× 95	4350×44	450× 9	2800×23	800×34	52	5	33	10	18.3
m	120× 80	4350×42	800×10	2700×22	1100×31	49	9	30	12	19.0
m	105× 95	4500×45	550× 8	2700×21	800×36	53	6	32	9	20.3
h	110×100	4600×43	600× 9	2400×23	850×34	54	7	28	10	18.0
h	115× 95	4700×42	600× 8	2600×23	900×34	53	7	30	10	18.1
h	115×100	4700×42	650×10	2700×22	750×33	53	7	31	9	17.2
m	105× 95	4700×41	550× 8	2900×20	800×32	53	6	32	9	19.3
h	105×100	4900×43	500× 8	2750×24	850×31	54	6	31	9	20.1
d	115× 85	5200×46	2000× 9	2800×21	750×34	48	19	26	7	24.5
d	130×100	5300×43	3400× 8	2800×20	900×30	43	27	23	7	17.5
dd[1]	165×100	7500×50	6500× 9	1900×25	1300×35	44	38	11	8	22.7
Mean	104	4730×43 ±120	1010× 9	2715×22 ±50	850×33					19.2

Table 22 f. *Mus flavicollis, old female, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
h	135×115	5500×52	18.4	*m*	150×130	6100×56	17.5
h	140×110	5600×56	20.4	*d*	150×120	6200×58	20.0
h	130×110	5600×54	21.1	*m*	165×135	6400×55	15.8
h	135×120	5900×55	20.0	*h*	165×115	6600×56	19.5
m	130×105	6000×57	25.1	*d*	170×135	7400×59	19.0
				Mean	133	6130×56 ±180	19.7

the "Old male" the nephrons of table 22 e, except the deepest one, formed a single small piece, not containing other nephrons. There was a swelling of about 10 %. A "mean tubule", calculated from these 10 nephrons, has the following composition: Proximal tubule 51 %, thin segment 11 %, thick segment 29 %, distal tubule 9 %.

In the "Old female" the thin segment is 0.65—0.95 mm in the short loops; on an average 0.8 mm long. In the long loops the thin segment is most often about 2.5 mm or shorter. As some thin segments are very

[1] Not included in the mean.

long, the average length in long loops is perhaps nearer 3 mm than 2.5 mm. The average length when both long and short loops are included is about 1.2 mm. The mean length of the thick segment is 3.1 ± 0.07 mm (13 data), and the distal tubule is about 0.84 mm long.

The mean tubule ought to have this composition: Proximal tubule 54 %, thin segment 11 %, thick segment 28 %, distal tubule 7 %. The ratio of proximal tubule and thick segment in the last three specimens is 1.90, 1.74 ± 0.05 and 1.97 ± 0.08 respectively.

Mus sylvaticus L.

Material. Several specimens have been examined, but only one kidney has been macerated.

Table 23. *Mus sylvaticus, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
h	70×55	2600×28	18.9	*h*	96× 80	3700×32	15.4
h	80×72	2700×30	14.1	*h*	110× 80	3700×32	13.5
h	80×70	2900×32	16.6	*h*	143× 95	3700×42	11.4
m	80×65	3000×29	16.7	*m*	82× 66	3800×34	26.7
h	90×65	3000×31	15.9	*m*	90× 80	4000×32	19.4
m		3150×38		*d*	100× 90	4100×37	14.6
h	98×62	3500×35	20.2	*d*	150×120	4700×42	11.0
h	90×72	3600×32	17.8	*d*	150×135	6700×40	13.2

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	100× 65	2600×28	400× 5	1500×18	500×25	52	8	30	10	11.2
h	80× 70	3100×32	8	1800×18	600×20					17.7
h	105×100	3150×37	550× 8	1730×25	980×28	49	9	27	15	11.1
h	112×103	3680×38	600× 7	2030×24	1050×26	50	8	28	14	12.1
m	100× 90	3800×31		1400×18	450×22					13.1
h	132× 95	4100×38	600×11	2000×24	1000×30	53	8	26	13	12.4
d	133× 95	4400×40		2100×22	1100×33					13.9
d	136×110	5900×42		1800×26	1400×28					16.6
d	160×143	6900×45		2000×25						13.6
dd		(6900)	(6400)	(1800)	(1500)	(42)	(39)	(11)	(9)	
Mean	97	3859×35 ±230	8	1820×22 ±80	24					15.3

Form. The agreement with *Mus flavicollis* (fig. 9, p. 307) is very close. In a young male the kidneys weigh 0.25 gm. Dimensions 9.5 × 5.5 × 4 mm, cortex 1.2 mm thick, outer zone 1.3 mm, inner zone 2.7 mm.

The tubules. These agree in essentials with those of *M. flavicollis* (cf. fig. 9: *1—4*). The long loops constitute 17.3 ± 2.4 % of the total number.

The ratio of the mean lengths of the proximal tubule and the thick segment is 2.12 ± 0.16.

Hydromys chrysogaster E. Geoffr.

Material. Two pairs of kidneys in alcohol.

Form. Dimensions of one kidney, which has later been macerated: 25 × 15.5 × 8 mm. The cortex is 2.7 mm thick, the outer zone 2.1 mm, the inner zone 3.7 mm. The area cribrosa lies on a short crest (fig. 10 *L*, p. 317). The surface of the kidney shows a groove ventrally (fig. 10 *M*).

The tubules. The tubules resemble those of *Epimys rattus* in most respects. There is no distinct terminal part of the proximal tubule. The thick segment is markedly differentiated into a thicker and a thinner part. It has not been possible to ascertain the relative frequencies of long and short loops. The dimensions of some proximal tubules are given below:

	Capsule	Prox. tubule	Ind.
m	100× 90	6900×40	30.7
h	120× 90	7500×41	28.5
m	105× 99	7900×38	31.8
d	130×110	8400×39	22.9
Mean	104	7675×40	28.5

6 further proximal tubules have been measured, which are 7.1, 7.2, 7.2, 7.4, 7.5 and 8.0 mm long. The mean is 7.51 ± 0.15 mm. The mean length of 6 thick segments is 4.1 mm. The distal tubule is usually about 1.2 mm long.

A swelling of about 10 % occurred.

Psammomys obesus Cretzschm.

Material. The kidneys of an old female and a young male, in alcohol.

Form. The dimensions are, in the female, 19 × 14 × 9 mm and, in the male, 17 × 10 × 7 mm. The cortex is, after maceration, 2.2 mm thick

in the female, the outer zone 2.5 mm, the inner zone 12 mm. Before maceration the layers could not be clearly distinguished, but their joint depth was 16 mm in the female and 13 mm in the male. The papilla is very strongly developed, (fig. 7 *H*, p. 295), long and broad, and projects into the ureter.

The tubules. There are long loops only. The pars recta of the proximal tubule is always well developed. The transition into the thin segment occurs at different levels in the outer stripe. The loops do not turn in the outermost parts of the inner zone. The thick segment is always differentiated into a thicker part in the outer zone, often wavily tortuous, and a thinner, straight part in the cortex (fig. 7 *I*). There is often a distinct initial collecting tubule. The collecting tubules are fairly thin and have small arcades normally.

The dimensions of some nephrons are given in table 24. It has not been possible to isolate complete nephrons, since the thin segments were connected with one another and numerous blood-vessels in the medulla by tough connective tissue. Further proximal tubules with the lengths 3.2, 3.3, 3.5, 3.7, 4.0, 4.3 mm have been measured, as also thick segments with the lengths 4.1, 4.1, 4.3, 4.6, 4.7, 4.8 mm. Including these the mean length of the proximal tubule is 4.2 ± 0.4 mm and of the thick segment 4.6 ± 0.1 mm. The ratio of these means is 0.91 ± 0.09. It is not possible to give any estimation of the mean length of the thin segment. It must, however, be relatively enormous as compared with normal forms. This is shown by an estimation of the length of a nephron

Table 24. *Psammomys obesus*, *female*, *tubule dimensions in* μ.

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Ind.
h	135× 85	3100×33				8.9
h	105× 90	3300×35		4600×23	700×25	12.2
h	115× 88	3400×34		5200×26	750×27	11.4
h	120×100	3400×37		5000×25	800×30	10.5
m	120×110	3600×36	15	4800×25		9.8
h	130× 90	3800×38		5100×24	830×27	12.3
m	165×112	4900×40		4100×25	1000×27	10.6
d	175×170	5100×41	20	4700×26	900×28	7.0
d	150×135	5600×40		3900×30	550×28	11.1
dd	215×165	9000×45	(26000)	(4000)	(1000)	11.4
Mean	129	38	18	26	27	10.5

reaching the apex of the papilla. The proximal tubule occupies 23 % only of the total length, the thin segment 65 %, the thick segment 10 % and the distal tubule 3 %.

Hystrix cristata L.

Material. Three pairs of kidneys in alcohol.

Form. The shape of the kidneys is different in the three specimens. In a young specimen they are oblong, 43 × 20 × 14 mm, in the other two the dimensions are 45 × 30 × 20 mm and 70 × 43 × 29 mm. The pelvis is small, without processes. In the first and last of the kidneys there are short ducts opening at the extremities of the area cribrosa (fig. 10 *O*, p. 317). In the second specimen I have not been able to find such structures, which are presumably small tubi maximi. The cortex is thick and has many large medullary rays. The medulla is not divided into an outer and an inner zone. In the largest kidney the cortex is about 8 mm thick and the medulla about 12 mm, in the second largest kidney the corresponding values are 7 mm and 12 mm, and in the smallest 4 mm and 6 mm.

The tubules. Maceration preparations have been made from all these kidneys, but as it has been possible to isolate fragments only from the largest one, and as the smallest kidney is obviously not fully developed, the following description mainly refers to the third kidney. There are cortical nephrons, and long loops have not been found in any one of the kidneys examined. The proximal tubules are tortuously looped and pass into the thin segment at very varying levels. In the highest nephrons this transition occurs in the middle parts of the cortex, and in the deepest nephrons as far as 3 mm below the cortico-medullary boundary. The terminal part of the proximal tubule is clearly differentiated from the preceding parts. It suddenly becomes somewhat thicker, and is more transparent (Pl. 2, fig. *1*). The thin segment is absent only in a few of the highest cortical nephrons, but is very short in most nephrons. The collecting tubules are thick and have well-developed arcades.

After maceration swelling to about 10 % occurred. Some proximal tubules have been isolated and measured (table 25). Thick segments have also been measured. The lengths are 7.0, 7.3, 8.0, 8.5, 9.0, 9.5, 9.8, 11.0 mm. The mean is 8.8 ± 0.5 mm. The distal tubules are 1.4—2.5 mm long. In one of the nephrons reaching the area cribrosa the proximal tubule may be assumed to be 13.4 mm long, the thin segment 8 mm, the thick segment 11 mm, and the distal tubule 2.5 mm. The percentages are then 38, 23, 32, and 7 respectively.

Table 25. *Hystrix cristata*, *tubule dimensions in* μ.

	Capsule	Prox. tubule	Ind.
h	205×175	12000×60	20.1
d	260×225	12000×68	13.9
h	200×170	12200×63	22.6
d	265×195	12500×70	16.9
m	260×220	12800×70	15.7
d	260×225	13000×70	15.6
h	205×175	13200×62	22.8
m	250×230	13400×67	15.6
Mean	220	12638×66 ±200	17.9

Rodentia, survey of the form of the kidney.

The statements in the literature on the kidney of the rodents are few, except those referring to rabbit, guinea-pig and rat. Only HYRTL (1872) and GERHARDT (1914) have examined several forms.

The *Duplicidentata* examined, i. e. *Lepus* (HYRTL), *Oryctolagus* and *Ochotona*, have one well-developed papilla, and the pelvis has processes. The medulla is differentiated into an outer and an inner zone. In most *Simplicidentata* the kidneys, too, show this structure. The relatively few deviating forms are treated below. *Aplodontia rufa* (Raf.) has a very small pelvis devoid of processes. In its lateral wall lies the small oblong area cribrosa (fig. 10 *A*). *Castor* has one or two papillae (cf. p. 294). In *Hydromys chrysogaster* E. Geoffr. the area lies on a short crest (fig. 10 *L*). *Hystrix cristata* has a low crest and may possess small tubi maximi (fig. 10 *O*) (cf. p. 315). In *Erethizon dorsatus* L. I have found a short crest, but GERHARDT (1914) says there is a papilla in this species. In *Atherura africana* Gray he finds a crest (op. cit.). *Hydrochoerus capybara* (Erxl.) and *Coelogenys paca* L. have long kidneys with two long tubi maximi (cf. GERHARDT 1914). In *Hydrochoerus* these tubi maximi open at the ends of a short crest (fig. 10 *R*), but in *Coelogenys* a crest can scarcely be said to exist, and the tubi open very near one another, forming a common pore in the wall of the pelvis (fig. 10 *S*). The pelvis has no processes in these forms. Like them *Dasyprocta aguti* L. has tubi maximi, though they are small (fig. 10 *P*), but *Cavia* (GERHARDT 1914), *Chinchilla* and *Dolichotis* each have one papilla (fig. 10 *U*, *T*). *Myocastor* has a crest (fig. 10 *V*, and also GERHARDT 1914). The simple kidney with a papilla

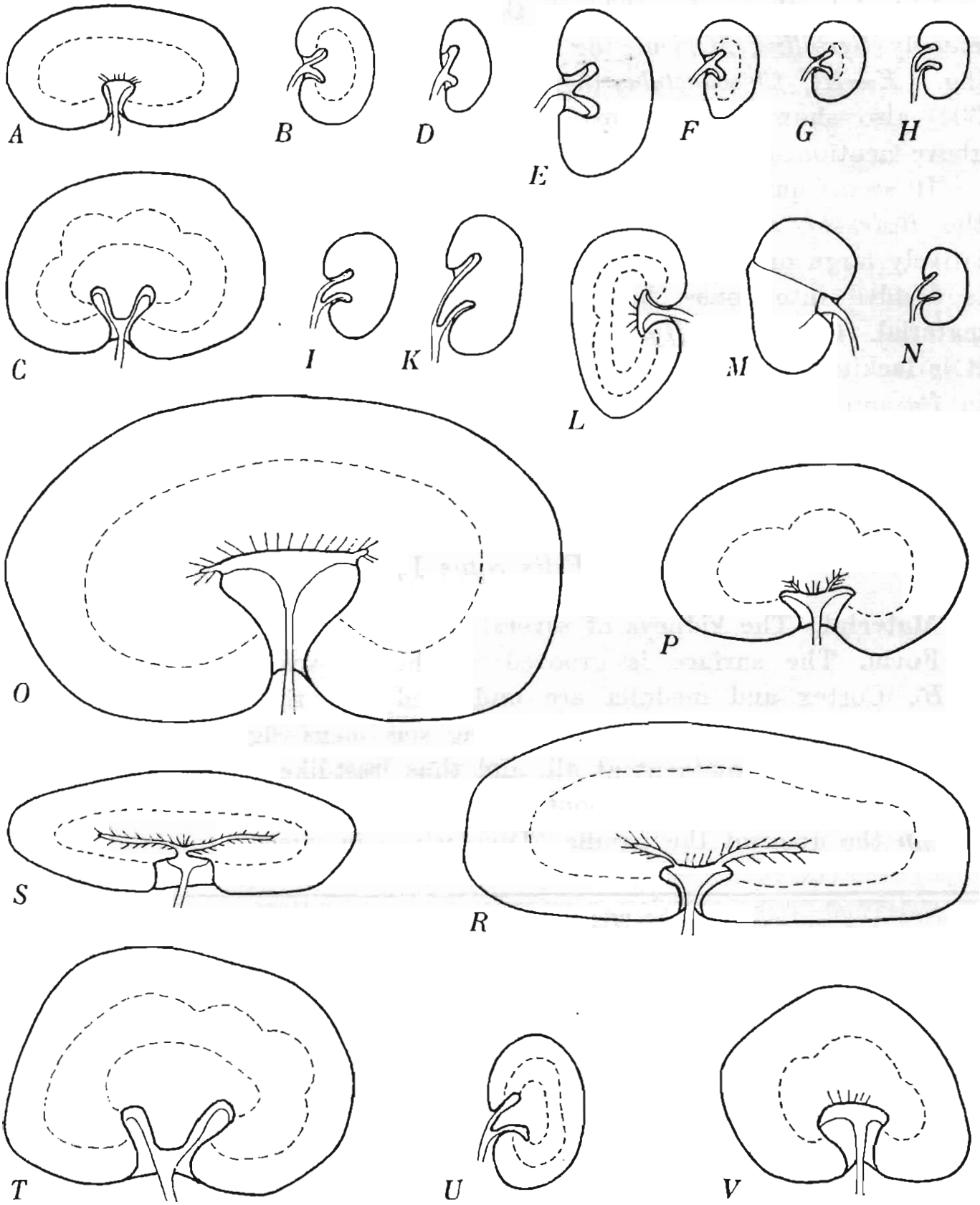

Fig. 10. Kidneys of rodents. *A Aplodontia rufa* (Raf.). *B Geomys tuza* (Ard.). *C Pedetes caffer* (Pall.). *D Spalax typhlus* Pall. *E Cricetus cricetus* (L.). *F Neofiber alleni* True. *G Deomys ferrugineus* Thomas. *H Gerbillus pyramidum* Is. Geoffr. *I Meriones melanurus* Rüppell. *K Psammomys obesus* Cretzschm. *L, M Hydromys chrysogaster* E. Geoffr. *N Ctenodactylus gundi* (Pall.). *O Hystrix cristata* L. *P Dasyprocta aguti* (L.). *R Hydrochoerus capybara* (Erxl.). *S Coelogenys paca* L. *T Dolichotis patagonica* (Shaw). *U Chinchilla velligera* Prell. *V Myocastor coypus* (Mol.).

may show a characteristic deviation in which the papilla is long and projects into the ureter. This is the case in some forms living in deserts, namely *Gerbillus*, *Meriones* (fig. 10 *H*, *I*), *Dipodomys*, *Jaculus*, *Psammomys* (fig. 7 *E*—*H*), *Ctenodactylus* (fig. 10 *N*), and *Hapalotis*. *Mus musculus* (p. 304) also shows this feature, but not in such an extreme form as the above-mentioned genera.

It seems quite clear that the simple kidney is the primitive form in the *Rodentia*, as the types showing deviating kidney forms are all relatively large or adapted to amphibious life. In most rodents the medulla is divided into zones, but this is often indistinguishable in preserved material. *Castor* and *Hystrix* show no such differentiation, and probably it is lacking in *Aplodontia*, *Hydrochoerus*, and *Coelogenys* also, and perhaps in *Dasyprocta* and *Myocastor*. In all these the undifferentiated condition is probably secondary.

Carnivora fissipedia.

Felis catus L.

Material. The kidneys of several specimens.

Form. The surface is grooved; in the grooves there are veins (fig. 11 *B*). Cortex and medulla are undivided and the latter forms a low papilla. The latter is distinct in young specimens (fig. 11 *C*), but in old males it is not prominent at all, and thus crest-like (fig. 11 *A*). The area cribrosa is always oblong (about 3—4 mm long and 1.5 mm broad) and lies on the apex of the papilla. Dimensions in mm:

	Weight of one kidney, gm	Dimensions, mm	Cortex, mm	Out. zone, mm	Inn. zone, mm
Young, 12 days	3.25	23×17×15	2.0	3	7
Young female	6.6	30×23×19	3.2	3.1	10
Young female	9.8	33×25×20	3.5	4	10
Female	11	38×25×18	5	4	11
Male	15 5	44×29×21	5.5	4	10.5
Male	17	44×32×23	6	4.5	10.5

In "Male 15.5 gm" the proportions of the volumes of the cortex and the medullary zones has been estimated at: cortex 77 %, outer zone 17 %, inner zone 6 %. (Hollatz 1922 found 70, 23, 7 % resp.).

The tubules. These have been described in detail by Peter (1909). My findings usually agree with his description (cf. also fig. 12 *A*). The

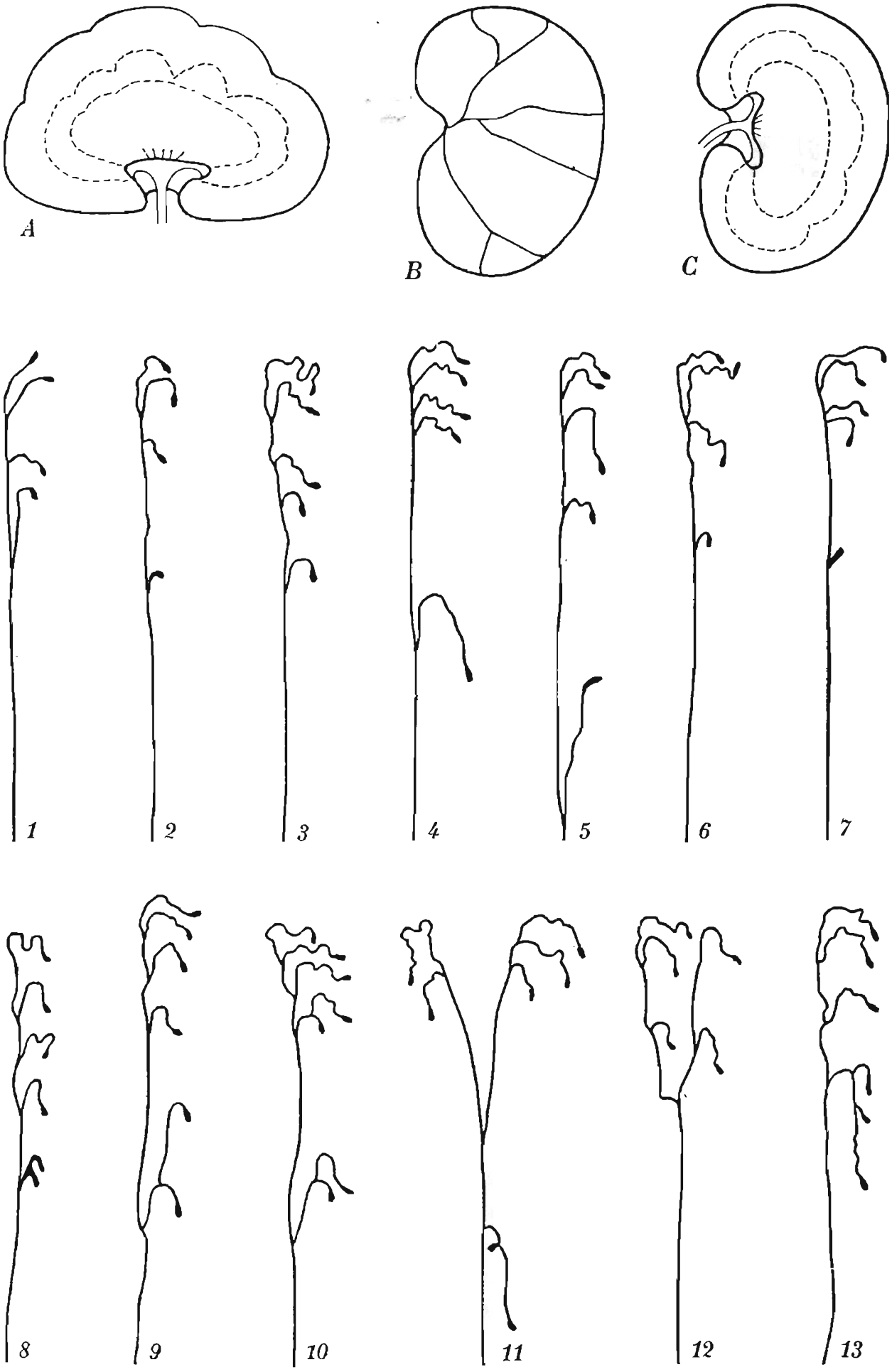

Fig. 11. *Felis catus* L. *A* kidney of "Male 15.5 gm". *B*, *C* kidney of "Female 9.8 gm". *1—13* collecting tubules, (beginnings of distal tubules drawn thick). 15 ×.

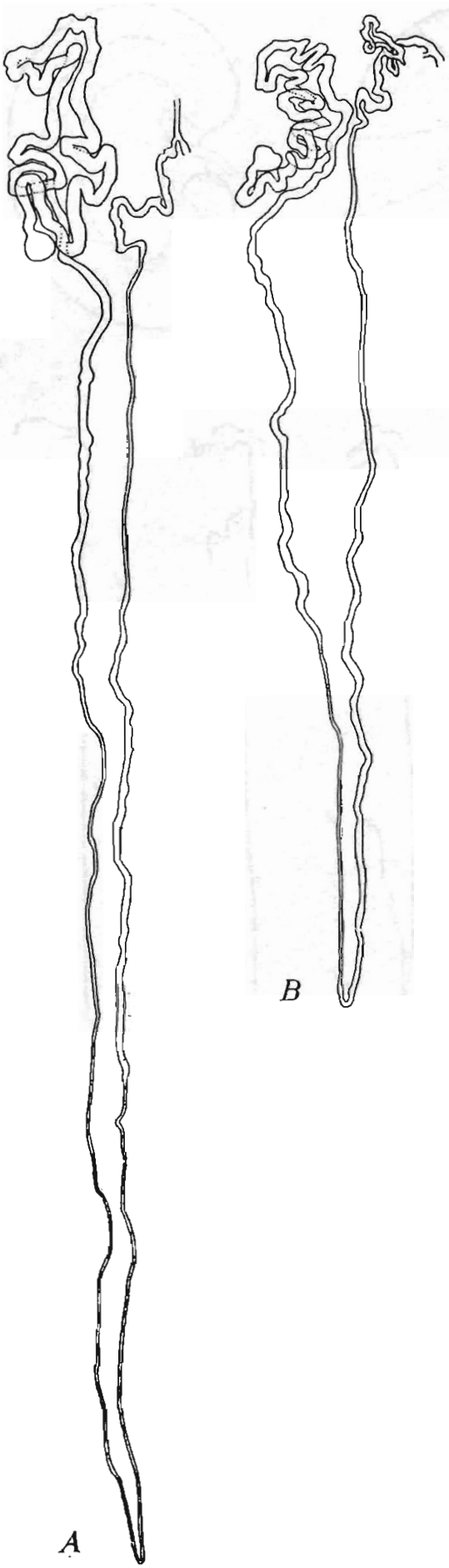

Fig. 12. Nephrons of *A Felis catus* L. 20 ×, *B Lutra lutra* (L.) 20 ×.

proximal tubule is usually fat-laden, except the terminal segment. The latter is almost always markedly thicker than the preceding part. Sometimes the proximal tubule contains little or no fat, or the terminal segment is indistinct. Usually there are long loops only, but in some specimens a very few short loops have been found. The forms of the collecting tubules are shown in fig. 11: *1—13*.

In "Male 17 gm" a number of thin segments have been measured. The average lengths of this specimen are: Proximal tubule 18 mm (corrected for a swelling of about 20 %), 47 %, thin segment 8 mm, 21 %, thick segment 9 mm, 24 % and distal tubule 2.9 mm, 8 %. In "Young female 6.6 gm" the thin segment seems to be at least 5 mm long. The composition of the average tubule is then about 34 %, 30 %, 27 %, 9 % resp. The great difference between the two specimens is certainly not entirely due to errors of estimation, but more probably connected with a very great number of fat-drops in the proximal tubules of the old male.

The cat kidney has been investigated by several authors. The descriptions usually agree with my findings. Zimmermann (1937) states that there are tubi maximi. To prove this he gives a photograph of a section. As no tubi maximi are shown on this, the statement is probably due to some mistake. Marschner (1937) calls the superficial fields, limited by the grooves, 'lobes'. There is little reason for this, and it is apt to cause confusion.

The differentiation of the proximal tubule into a proximal and a terminal segment has been investigated repeatedly (cf. the dog).

Table 26 a. *Felis catus, young, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	85× 75	1200×23	1050× 9	1650×17	550×20	27	24	37	12	4.3
h	90× 75	1400×25	1200× 9	1800×16	600×22	28	24	36	12	5.2
h	85× 68	1550×25	1100×11	1900×15	600×25	30	21	37	12	6.7
h	90× 70	1650×26	1300× 9	1900×16	650	30	24	35	12	6.8
m	90× 70	1900×30	1500×10	2250×17	600×26	30	24	36	10	9.0
m	94× 75	2000×33	1950×11	2700×16	800×23	27	26	36	11	9.4
m	95× 80	2300×39	2200×10	2800×18	900×23	28	27	34	11	10.0
d	110×105	2600×35	4400×13	3100×21	900×35	24	40	28	8	7.6
d	115× 95	4000×38	5800×12	3000×21	1000×34	29	43	22	6	13.9
d	180×135	5800×40	8000×14	3000×20	750×35	33	46	17	4	9.5
Mean	94	2440×31 ±450	2850×11	2410×18 ±180	735×27					8.2

Table 26 b. *Felis catus, young female, kidney weight 6.6 gm, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Ind.
h	105× 90	5000×44		4900		23.3
m	135×115	5200×50		4500		16.7
m	135× 90	5200×43		4500×23	1500×30	18.4
h	120×120	5300×44		4800		16.2
h	115×110	5400×42		4900		17.9
h	130×105	5400×46		5300×21	1600×28	18.2
h	135×110	5500×49		5000		18.1
h	130×100	5600×45		5000		19.4
m	150×115	5800×46		4200		15.5
m	150×135	6000×45		4600×22	1500×30	13.3
m	155×130	6100×44		4000		13.3
d	175×125	6150×51		3100×28	1600×34	14.3
h	190×120	6400×46		4700×24	1800×32	13.9
m	150×130	6500×48		4600×23	1400×33	16.0
d	190×170	7800×52		2800×29	2000×30	12.6
Mean	131	5823×46 ±180		4460×24 ±160	1629×31	16.5

Table 26 c. *Felis catus, young female, kidney weight 9.8 gm, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
	195×185	7800×54	11.7		200×200	8600×54	11.6
		8000×57			230×185	9200×57	12.3
		8200×46			250×230	9900×58	10.0
	240×185	8600×53	10.2		230×185	10400×56	13.7
				Mean	210	8838×54	11.6

Table 26 d. *Felis catus, young female, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
	154×119	8200×50	22.4		150×125	11100×55	32.6
	152×125	9600×51	25.8		150×145	11300×52	27.0
	186×133	10900×53	23.4		180×146	12800×53	25.8
				Mean[1]	152	11038×53	25.9

Table 26 e. *Felis catus, female, kidney weight 11 gm, tubule dimensions in μ.*

Capsule	Prox. tubule	Ind.	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
165×165	7500×70	19.3	210×145	8300×71	19.4		190×160	8800×63	18.2
185×150	7600×63	17.3	190×170	8400×64	16.6		170×150	9100×67	23.9
175×160	8000×71	20.3	175×170	8400×64	18.1		210×150	9400×69	20.6
190×165	8200×72	18.8	165×165	8600×62	19.6	Mean[1]	171	8469×66 ±130	19.4
190×165	8300×67	17.7	195×150	8700×68	19.1				

Table 26 f. *Felis catus, female, kidney weight 13 gm, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.
		8100×50	
	210×205	8600×55	11.0
	220×175	9800×54	13.7
	230×205	10000×55	11.7
		13000×53	
Mean	208	9900×53	12.1

[1] Including the data of table 26 k.

Table 26 g. *Felis catus, male, kidney weight 15.5 gm, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
	225×225	10500×75	15.6		253×203	12000×71	16.6
	248×210	11300×73	15.8		248×248	12400×75	15.1
	248×203	11700×75	17.4		278×195	12400×74	16.9
	240×233	11800×76	16.0		270×248	14000×77	16.1
	240×220	11800×72	16.1		300×300	15300×75	12.8
	225×220	12000×74	17.9	Mean	240	12290×74 ±400	16.0

Table 26 h. *Felis catus, male, kidney weight 17 gm, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.
h	300×225	20300×110	33.1
m	285×210	22000×115	42.3
d	195×195	22500×115	68.0
h	225×190	23800×120	66.8
Mean	228	22150×115	52.6

Table 26 i. *Felis catus, male, kidney weight 20 gm, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.
	195×195	13900×69	25.2
	190×190	14700×72	29.3
	210×195	16800×75	30.8
	260×190	18800×74	28.2
Mean	203	16050×73	28.4

Table 26 k. *Felis catus, young female* (1) *and female, kidney weight 11 gm* (2), *tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s	th. s.	d. t.	
(1) *h*	200×170	11700×56	5500×15	7000×25	2000×31	45	21	27	8	19.3
(1) *m*	150×150	12700×54	6300×17	5700×28	1800×30	48	24	22	7	30.5
(2) *h*	190×130	8300×61	6500×12	4700×29						20.5
(2) *h*	165×165	8900×65	7300×14	4600×28	1300×31	40	33	21	6	21.2
(2) *h*		9000×62	5100×11	4700×30	1200×37	45	26	24	6	

Table 27. *Arctitis binturong, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
hc	110×110	3500×29	0	1900×15	1100×18	54	0	29	17	8.4
hc	100× 95	3700×28	50×5	2100×14	1000×15	54	1	31	15	10.9
h	90× 90	3800×30								14.1
m	95× 90	4800×31								17.4
m	115× 90	5100×29								14.3
d	115× 90	5200×31	1500×6	3700×16	900×20	46	13	33	8	15.6
d	115× 75	5800×24		3800×16	1200×15					16.1
m	110×105	6000×30	500×7	2900×16	1800×18	54	4	26	16	15.6
dd		(5800)	(4500)	(3800)	(1200)	(38)	(29)	(25)	(8)	
Mean	100	4738×29	6	2880×15	1200×17					14.1

Arctitis binturong Raffl.

Material. One pair of kidneys in alcohol.

Form. The kidneys are oblong, 37 × 20 × 12.5 mm. The cortex is relatively thick, about 5 mm, the medulla undivided, about 7 mm. The papilla is low and the area cribrosa oblong (fig. 14 *B*, p. 334); thus the former represents a transitional type between a common papilla and a crest.

The tubules. There are cortical nephrons, but no typical long loops. The epithelium of the capsule is often high and opaque where the proximal tubule emerges. The proximal tubules are highly tortuous and always have a well-developed pars recta. It is not possible to distinguish structurally a terminal part. The cortical nephrons often have no thin segment. The loops turn in the thick segment, except in the deepest nephrons, in which the bend lies within the thin segment. It might thus be permissible to speak of long loops, but the ascending part of the thin segment is very short. The thick segment is normally divided into a thicker and a thinner part, but the difference is slight and may be entirely absent both in deep and high nephrons. The distal tubule is of the common type and the initial collecting tubule is often absent. The collecting tubules normally have well-developed arcades. The central junctions most often occur in the medulla, but there may be some in the inner parts of the cortex, too.

After maceration there is a shrinkage of about a third of the initial dimensions.

Canis familiaris. L.

Material. One pair of kidneys.

Form. Dimensions: Right kidney 54 × 37 × 31 mm, left kidney 53 × 36 × 30 mm. Weight 34 gm and 33 gm respectively. The medulla forms a short crest, and the area cribrosa is about 10 mm long. At the extremities of the latter there are two recesses, about 2 mm deep (fig. 13 *A*). Several collecting ducts open into these recesses. The pelvis has

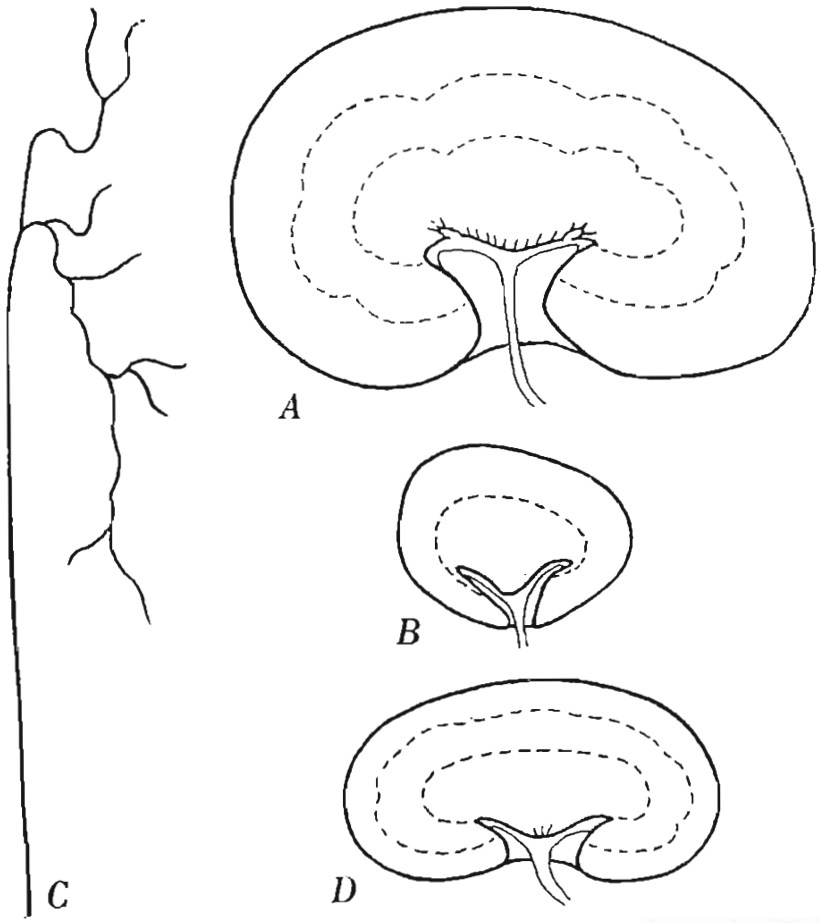

Fig. 13. *A* kidney of *Canis familiaris* L. *B* reneulus, *Ursus arctos* L. *C* collecting tubule, *Ursus arctos* L. *D* kidney of *Mustela erminea* L. 2 ×.

well-developed processes. The cortico-medullary boundary is distinct but wavy (fig. 13 *A*). The cortex is 6.5—7.5 mm thick, the outer zone about 6 mm (outer stripe about 3 mm), the inner zone 10—11 mm.

The tubules. There are only long loops. The shape of the capsule varies, but roundish types are most common. There is usually a distinct neck, which is, in some cases, up to 0.15 mm long. The proximal tubules consist of two parts. The first of these mainly occupies the convoluted portion and has a uniform, relatively small diameter (about 0.045 mm). The terminal segment is considerably thicker at its beginning (up to 0.08 mm), but gradually narrows. The transition is gradual, and in the specimen examined by me the structure is relatively uniform

throughout the proximal tubule. The transition into the thin segment occurs at different levels, but always in the outer stripe. The proximal tubules of the deepest nephrons end most centrally. The epithelium of the thin segment is extraordinarily low and transparent. All loops turn in this segment, but in the highest nephrons its ascending part is short, since their loops turn quite near the zone boundary. The thick segment is distinctly differentiated into a thicker and a thinner part. The latter is only about 0.020 mm thick, and its cells are low and transparent. The distal tubule consists of distinct segments. The first of these is the intercalated segment, which is sometimes absent. The next portion is thick and opaque (Pl. 3, fig. 3). It narrows gradually, becomes more transparent, and passes into a part which is perhaps best referred to the initial collecting tubule. It is thin and light, and is provided with small hemispherical protuberances. Then follows, in some cases, the initial collecting tubule proper, which has no such protuberances, but is otherwise quite like the segment last mentioned. The collecting tubules may show the same types as those of the cat (cf. fig. 11, p. 319). They are thin and transparent, except in the innermost parts of the medulla. Since the collecting tubules are thin (mainly about 0.020 mm thick) a relatively large part of the inner zone is occupied by thin segments.

In addition to the measurements of table 28 the following proximal tubules have been measured: High 15.6, 15.7 and 16.1 mm, middle 13.6, 14.5 and 15.3 mm, deep 13.2 and 13.6 mm long. The mean length is then 14.78 $\pm$ 0.25 mm. The mean length of the thin segment has been estimated from a portion of the medulla containing 49 loops. The mean is about 10 mm. The thick segment has been measured in 12 further nephrons, and its mean length is 8.3 $\pm$ 0.28 mm; the mean length of the distal tubule is 3.2 mm. The composition of an average nephron may thus be estimated at: Proximal tubule 41 %, thin segment 27 %, thick segment 23 %, distal tubule 9 %.

The macroscopical structure of the dog kidney has been investigated by several authors. Their results are usually entirely in accordance with my findings. The tubules have been examined by Peter (1909), who gives some statements on the structure of the proximal tubule and the loops. Foote and Grafflin (1938) have given data as to the length and structure of the proximal tubule and its terminal part. These authors find the terminal segment distinguished by the epithelium containing numerous refractive drops. This agrees with statements by other authors, and certainly represents the common condition. Further statements concerning the structure of the proximal tubule are given by Schachowa (1876), Zimmermann (1911), Nakamura (1935), Foote (1936), and Grafflin and Foote (1938).

Table 28. *Canis familiaris*, tubule dimensions in μ.

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
d	240×145	12800×53		5500						19.5
d	190×180	13100×54								20.7
m	210×190	13200×58								19.2
d	220×195	13500×56								17.6
d		13500×58		5500×32	3500×36					
d	260×170	13700×56	15000×18	6000×35	3900×40	35	39	16	10	17.4
h	180×175	14200×55	5200×12	9500×32	3000×35	45	16	30	9	24.8
h	195×170	14600×56	6400×15	10200×36	3200×40	42	19	30	9	24.7
d		14800×60	18							
h	235×160	15400×60	9000×16	8600×35	3300×40	42	25	24	9	24.6
h	205×165	15600×53	8000×14	9300×31	3300×39	43	22	26	9	24.4
h		15900×55								
m	195×195	16000×56								23.6
h	250×180	16100×55								19.7
h	250×240	16500×54								14.9
h	190×165	16500×53		8800×33	3700×38					28.8
h	180×160	16500×54	6700×15	9500×34	3600×31	45	18	26	10	30.9
dd		(15000)	(24000)	(5500)	(3500)	(31)	(50)	(11)	(7)	
Mean	196	14818×56	15	34	37					22.2

Ursus arctos L.

Material. Several pairs of kidneys in alcohol.

Form. The bear kidney is composed of typical renculi, which are held together chiefly by the branches of the ureter and the blood-vessels. In one kidney, which has later been macerated, there are 34 renculi. The dimensions are 95 × 65 × 45 mm, and the dimensions of the renculi are on an average 20 mm. The cortex is 4.0—4.5 mm thick, and the medulla 7—9 mm. The zones are indistinguishable, but after maceration the outer zone is 4 mm and the inner zone 4.5 mm thick. Each renculus has a small pointed papilla (fig. 13 *B*, p. 325).

The tubules. The capsule usually lies central to the convolutions of the proximal tubule. In the deepest nephrons the capsule thus lies at or below the cortico-medullary boundary. The proximal tubules are thickest at the beginning and narrow gradually until they broaden abruptly some way from the transition into the thin segment. The terminal segment then

narrows continually towards this transition, which occurs at varying levels: in the highest nephrons at the cortico-medullary boundary and in the deepest ones some 1.5 mm below this. There is always a thin segment. The loops of the highest nephrons turn at the stripe boundary and most often within the thick segment. The difference between the thicker and the thinner part of the thick segment is indistinct, especially in the deepest nephrons. The distal tubule has about the same diameter as the thick segment, and is tortuous with an irregular contour. There is normally an initial collecting tubule. The collecting tubules are mostly formed by an arcade with 4 adjoining nephrons, one or two nephrons joining it where it turns towards the medulla (fig. 13 *C*).

48 short and 10 long loops have been counted.

It is, of course, difficult to estimate the average composition of a nephron on the basis of this material. The mean lengths of the proximal tubule and the thick segment as given in the table may be accepted as the means of the alcohol kidney. As the proximal tubule forms about 50 % of the nephron length both in high and deep nephrons this figure must apply to the average nephron also. The thin segment constitutes

Table 29. *Ursus arctos, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	150×130	8800×43	1300×15	5000×27	2200×32	51	8	29	13	19.4
d	150×150	9000×46								18.4
h	160×145	9800×44								18.6
h	160×135	10100×42								19.6
m	165×135	10200×51	2700	5400	2500×30	49	13	26	12	23.4
h	175×140	10500×45	1400×13	5500×30	3600×28	49	7	26	17	19.3
h	165×150	10500×40								17.0
d	160×150	10600×46		5000×33	2000×31					20.3
h	175×130	10900×48								23.0
m	180×130	11000×49	2700×12	6000×29	1800×30	51	13	28	9	23.0
m	165×165	11300×50	2500×14	5400×30	2300×34	53	12	25	11	20.8
m	190×165	11700×52								19.4
m	215×165	12800×47								18.1
d	195×165	13100×48		3800×33	2200×35					19.5
dd	210×190	16500×53	(11000)	(3800)	(2200)	(49)	(33)	(11)	(7)	21.9
Mean	162	11120×47 ±490	14	5157×30	2371×31					20.1

about 10 % of the total length in high and middle nephrons. In deep nephrons the percentage may rise to 30—35, and is probably not over 25 on an average. The average percentage of the thin segment may be estimated at 13—15. As the thick segment is usually somewhat more than twice as long as the distal tubule, the former is probably about 25 % and the latter about 11 % of the nephron length.

Mustela erminea L.

Material. The kidneys of three males.

Form. The kidney weight is about 1.5 gm, and the dimensions about 18 × 9 × 8 mm. The surface is even. The papilla is somewhat oblong and low (fig. 13 *D*, p. 325), but the area cribrosa is small and nearly round. The pelvis has distinct processes. The cortico-medullary boundary is even, or slightly wavy. The zone boundary is even and distinct. The cortex is about 1.5 mm thick, the outer zone about 1.7 mm, the inner zone 4.0—4.5 mm. The outer stripe is distinct only after maceration, 0.5—0.6 mm thick.

The tubules. There are few short loops and numerous long loops. The capsule is round or nearly round, with few exceptions. There is seldom a neck. The last portion of the proximal tubule is slightly thinner than the preceding part in two of the specimens investigated, but in the third the first part of this portion is thicker than the part immediately preceding it. It has not been possible to find any certain structural differentiation between the portions of the proximal tubule. The pars recta is very short in the deepest nephrons, and it narrows abruptly at the transition into the thin segment in all nephrons. The loops turn in the thin segment, which makes it difficult to distinguish between short and long loops. The short loops turn near the zone boundary. The relation between short and long loops has not been accurately determined, since these last two circumstances make it nearly impossible to do so. It is, however, quite certain that the long loops are far more numerous than the short. The thick segment is always differentiated into a thicker and a thinner part. The latter is long and narrow in the high nephrons, but relatively broad and indistinctly differentiated in the deep nephrons. The distal tubule has an irregular contour and often shows some small projections. The collecting tubules often possess small arcades. Their central junctions occur in the inner zone. The collecting tubules are thin except in the innermost parts of the medulla.

The means of the table may be accepted as the true means, as there is probably no marked over-representation of the deep nephrons.

Table 30. *Mustela erminea, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
m	98× 95	3300×39	2900×10	2300×24	1050×25	35	30	24	11	13.8
h	105× 90	3400×38	1400× 8	2600×23	1000×25	40	17	31	12	13.7
h	100× 90	3400×38								14.4
h	103× 90	3500×39	1400× 9	2300×22	1100×26	42	17	28	13	14.7
m	110× 80	3500×38								15.1
h	90× 86	3600×40	2300× 9	2400×25	1200×25	38	24	25	13	18.6
h	115× 94	3700×42								14.4
m	115× 95	3800×41	3100×10	2300×24						14.3
h	105× 90	4000×35	1000×10	3000×27	900×31	45	11	33	10	14.8
m	108×105	4100×39	2200×10	2300×26	1200×26	42	22	23	12	14.1
m	113× 85	4500×40	4400× 8	2300×27	1400×28	36	35	18	11	18.7
d	133×105	4900×45		2100×28						15.8
dd[1]		6200	(9000)	(2000)	(2000)	(32)	(47)	(11)	(11)	
Mean	100	3808×39.5 ±140	9	2400×25 ±90	27					15.2

Lutreola vison (Schreb.).

Material. The kidneys of a large male.

Form. The kidneys in most respects resemble those of *Mustela*, but the papilla is lower still (fig. 14 *L*, p. 334). The dimensions of the right kidney are 36 × 20 × 16 mm and the weight 6.3 gm. The corresponding figures for the left kidney are 36 × 20 × 17.5 mm and 6.8 gm. The cortico-medullary boundary is distinct and wavy. The cortex is about 3.5 mm thick, the outer zone 3.0—3.5 mm, the inner zone 7.0 mm. The area cribrosa is small, and concentrated at the apex of the papilla. The pelvis has processes. Both the ventral and the dorsal surface of the kidney are covered by the peritoneum.

The tubules. These are very like those of *Mustela erminea*. The terminal part of the proximal tubule is distinctly thicker and more opaque than the preceding part. The thick segment is differentiated into a thicker and a thinner part. The short loops agree with those of *Mustela* and are relatively few — 27 short and 78 long loops have been counted. The dimensions of some nephrons are given below.

[1] The deepest proximal tubule has been measured in another kidney of similar size, and is not included in the mean.

Table 31. *Lutreola vison, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	165×155	6200×45	2500×11	3900×30	1900×35	38	15	36	12	10.9
m	185×185	7700×50		5200×35	2300×36					11.2
m	185×150	8000×50								14.4
h	195×195	8600×52	2300×12	6600	2900	42	11	32	14	11.8
h	196×184	9000×50								12.5
m	230×195	9200×50								10.3
h	215×190	9400×58								13.3
h	210×195	9700×50								11.8
d	215×185	10000×54								13.6
d	230×205	11000×54								12.6
dd	240×240	12200×57	(15500)	3200×24	3500×34	(35)	(45)	(9)	(10)	12.1
Mean	198	9182×52 ±490	12	30	35					12.2

Lutra lutra (L.).

Material. The kidneys of an old female and a young male. They had been kept in weak formaldehyde solution for a short while before I had the opportunity of examining them, but as the solution had penetrated only into the outer layers, it is improbable that the dimensions had been altered to any significant extent.

Form. The weight of the kidneys of the female is 52 gm, and that of the male 34 gm; the dimensions of one kidney are 67 × 29 × 29 mm, and 64.5 × 23.5 × 21 mm respectively. In the former kidney there are 11 renculi, in the latter 13. Each renculus has a pointed papilla, and there are processes emerging from the pelvis of the renculus, which is itself a branch of the pelvis of the kidney. The cortex is 3.0—3.5 mm thick, the outer zone 3—4 mm, the inner zone 6—8 mm.

The tubules. The proximal tubules show no differentiation of the terminal part comparable to that occurring in the cat and the dog, but this part is usually slightly more slender than the main part of the proximal tubule (fig. 12 *B*, p. 320). The transition into the thin segment is gradual, and occurs at the same level in all nephrons. The short loops most often turn within the thick segment, and their apices normally lie a short distance peripheral to the zone boundary. The thick segment is differentiated into a thicker and a thinner part. The distal

Table 32 a. *Lutra lutra, female, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
h	180×145	6300×43	10.4	*m*	170×160	7600×45	12.6
h	190×135	6400×43	10.7	*h*	200×150	7700×44	11.3
m	170×160	7100×44	11.5	*m*	173×165	7800×40	10.9
h	180×150	7300×47	12.7	*d*	170×170	8100×44	12.3
h	188×150	7500×45	12.0	*m*	165×150	8200×46	15.2
h	180×150	7500×43	11.9	Mean	166	7409×44 ±160	12.0

Table 32 b. *Lutra lutra, male, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.
m	160×150	6000×45	11.3
d	165×135	6600×51	15.1
h	158×143	6800×50	15.0
h	165×143	6900×49	14.3
h	158×113	7300×48	19.6
h	165×150	7400×45	13.5
Mean	150	6833×48	14.8

Table 32 c. *Lutra lutra, female* (1) *and male* (2), *tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %			
						p. t.	t. s.	th. s.	d. t.
(1) *h*	180×150	7300×47	2400×10	5200×27	1500×35	45	15	32	9
(1) *m*	165×150	8200×46	4000×11	5200×30	1700×34	43	21	27	9
(1) *dd*		(8200)	(15000)	(4000)	(1700)	(28)	(52)	(14)	(6)
(2) *h*	165×150	7400×45	1900×11	5200×30	2000×32	45	12	32	12
(2) *m*	160×150	6000×45	3800×10	3600×26	1300×35	41	26	24	9

tubule is irregularly bent and its diameter varies (fig. 12 *B*). The initial collecting tubule is short in most cases. Arcades are seldom found, and are short. In the male the long loops constitute 46 ± 4.3 % of the total number.

The kidneys of *Lutra* have been examined macroscopically by several

authors. The number of renculi normally given is about 10—12 (MILNE-EDWARDS 1862, GERHARDT 1914, ANTHONY 1922, cited according to FREUND 1939). I, too, have found this number in some alcohol specimens, in addition to those described above[1].

Carnivora fissipedia, survey of the form of the kidney.

All *Viverridae* investigated have simple kidneys with one papilla. The papilla may be very low and crest-like, as in *Arctitis* and *Crossarchus obscurus* F. CUV. (GERHARDT 1914). In this case the area cribrosa is lengthened as compared with the area cribrosa in forms with a more prominent papilla. Such forms are *Cryptoprocta ferox* Benn. (fig. 14 *C*), *Prionodon linsang* (Hardw.) (fig. 14 *D*) and *Viverra sp.* (fig. 14 *A*), examined by me, and *Viverra zibetha* L., *Paradoxurus hermaphrodyta* Schreb., *Suricata tetradactyla* Schreb., *Nandinia binotata* (Reinw.), *Genetta tigrina* (Schreb.), *Herpestes ichneumon* (L.) — all according to GERHARDT (1914). The pelvis has processes in *Viverra* and *Herpestes* (HYRTL 1872). There are some branching veins on the surface of the kidney of *Herpestes griseus* (INOUYE 1931, p. 99), and this is probably the case in other species, too. They are, however, difficult to see in preserved material.

Hyaena has been investigated by HYRTL (1872), GERHARDT (1914) and the author. There is a typical short crest (fig. 14 *E*). The area cribrosa in my specimen lies in a shallow groove in the crest; this groove is slightly deeper at the one extremity. The pelvis has well-developed processes, and the surface of the kidney is grooved by veins.

The kidneys of the *Felidae* are of fairly uniform structure. The surface shows richly arborescent veins, and the pelvis has processes (cf. especially HYRTL 1872). The medulla forms either a papilla or a short crest. There is no clear difference between the papilla shown by the kidney of a young cat, for example, and the short crest in the kidney of an old cat or the larger *Felidae* (fig. 11 *A*, p. 319). In both cases the area cribrosa is oblong, but not so long as in most kidneys with a crest. In the cat the form of the papilla seems to depend on the age of the specimen (cf. fig. 11 and p. 393). This is probably the case with the lion also. Thus, in the young lion examined by me, there is a short papilla (fig. 14 *F*), in the specimen examined by GERHARDT (1914) the papilla is very low, and in a large kidney HECKING (1940) finds a short crest. In *Felis onca* L. and *Lynx* (fig. 14 *G*, *H*) the area cribrosa shows at its extremities small recesses, somewhat reminiscent of those of the dog.

Canis familiaris, *Canis lupus* L. (fig. 14 *I*), *Canis latrans* Say. (GERHARDT 1914), and *Cuon alpinus* Pall. (GERHARDT 1914) have typical short

[1] A young American *Lutra* has about 100 renculi (cf. Kingsley 1917, p. 369).

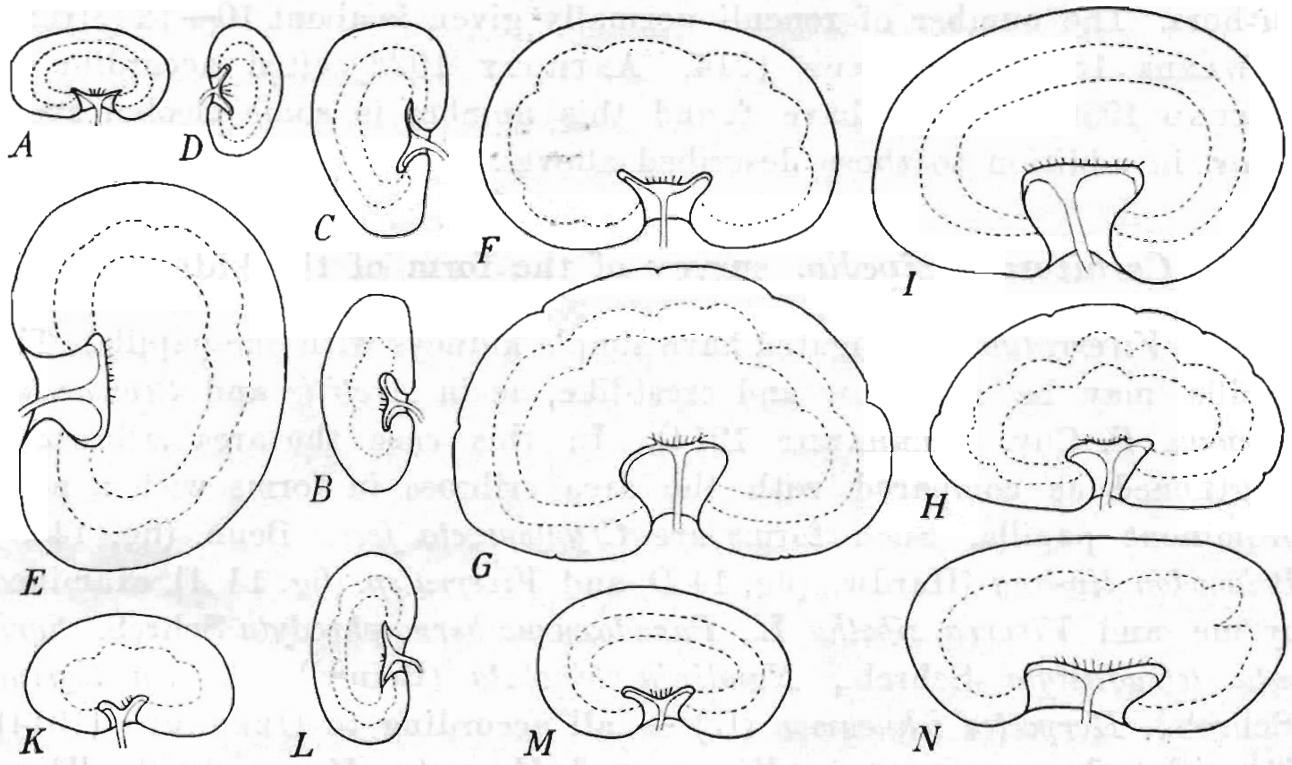

Fig. 14. *Carnivora*, kidneys. 1/2 ×. *A Viverra sp. B Arctitis binturong* Raffl. *C Cryptoprocta ferox* Benn. *D Prionodon linsang* (Hardw.). *E Hyaena sp. F Felis leo* L. pull. *G Felis onca* L. *H Lynx lynx* (L.). *I Canis lupus* L. *K Nasua narica* (L.). *L Lutreola vison* (Schreb.). *M Meles meles* (L.). *N Gulo gulo* (L.).

crests. GERHARDT (1914) does not mention any recesses in the crest, nor have I found any in the wolf kidney. It seems doubtful if there are always such structures in the dog (cf. p. 325), as they are very easily overlooked. Still more doubtful is their morphologic interpretation. They would seem to agree closely with the corresponding structures in the crest of the large *Felidae* and in *Hyaena*, which are only dents in the crest. The tubi maximi, on the other hand, are certainly in most cases enlarged collecting ducts. If this is so it would be rash to rank these recesses with tubi maximi.

In the *Procyonidae Nasua narica* (L.) (GERHARDT 1914; also fig. 14 *K*), and *Potos flavus* Schreb. have a distinct papilla. *Ailurus fulgens* F. Cuv. has a crest-like papilla (GERHARDT 1914), and *Procyon cancrivorus* G. Cuv. (GERHARDT 1914) and *Procyon lotor* (L.) have a crest. As GERHARDT points out, the smaller species have a papilla and the larger ones a crest.

Ailuropoda, the systematic position of which is somewhat uncertain, but which is often referred to *Procyonidae*, has kidneys divided into six lobes (RAVEN 1936).

All bears have renculi-kidneys. Examined are: *Ursus arctos* (several authors), and, according to GERHARDT (1914), *Ursus isabellinus* Horsf., *Ursus malayanus* Raffl. and *Melursus ursinus* Shaw.

Among the *Mustelidae* there is a papilla in the following forms: *Mustela* (cf. also GERHARDT 1914), *Martes martes* (L.) and *Lutreola vison*

(Schreb.). GERHARDT states that *Lutreola lutreola* (L.) has a crest, but it seems more probable to me that there is in this species, as in *L. vison*, a low, crest-like papilla. *Gulo* (GERHARDT 1914; also fig. 14 *N*) and *Galictis barbara* (L.) (GERHARDT 1914) have a crest. GERHARDT (1914) states that *Meles meles* (L.) shows the papilla divided into two parts, each with an area cribrosa. In a specimen examined by me the papilla is low, and the area cribrosa is oblong; it thus shows an intermediate state between papilla and crest (fig. 14 *M*). *Lutra* has renculi-kidneys, as has *Latax* (106 renculi, STELLER 1753).

From this survey it is evident that all small carnivores have kidneys with a papilla. Most of the other forms have kidneys with a crest, or transitional forms towards such. In respect of this, it is clear that the lobulated kidneys of the bears and the otters have developed independently. If it is assumed that *Ailuropoda* is a close relation of the bears, it may be supposed that the lobation of its kidneys is a feature developed in connection with the lobation of the bear kidneys. It seems, however, more likely that the lobation of the *Ailuropoda* kidney has developed independently, and if *Ailuropoda* is considered more allied to the *Procyonidae* this must be the case.

The medulla of the kidney in *Carnivora* is usually divided into zones. *Arctitis* has no distinct inner zone, and in the bear kidney it is relatively low. In the lion kidney, on the other hand, the inner zone is unusually thick.

Carnivora pinnipedia.

Phoca hispida Schreb.

Material. One pair of fresh kidneys, which have been macerated, and several kidneys in alcohol.

Form. The fresh kidneys weigh 130 gm and 113 gm. The dimensions are 119 × 56 × 37 mm, and 113 × 58 × 31 mm. The kidneys are surrounded by a layer of tough connective tissue. When this has been removed a large number of renculi are seen on the surface of the kidney (Pl. 2, fig. *4*). The surface of each renculus shows a number of arborescent veins. The boundaries of the renculi are distinct only on the surface of the kidney, as the connective tissue uniting them is poorly developed. This does not mean that there are no boundaries at all, for the nephrons of each renculus lie exclusively between nephrons of the same renculus, touching nephrons of the other renculi only at the renculus surface. Each renculus also has blood-vessels of its own, with the exception that the veins of the surface may be joined by small veins from two neighbouring renculi. Each renculus has, normally, a papilla (fig.

15 *A*, *B*). The pelvis of the renculus, which is only an end branch of the renal pelvis, has no processes.

In one of the kidneys examined there are about 75 renculi reaching the surface of the kidney, and about 10 entirely situated in its interior (fig. 15 *C*). The cortex is of about the same thickness in all renculi, i. e. 2.2 mm. The outer zone is about 3.0 mm thick, the inner zone 5—6 mm.

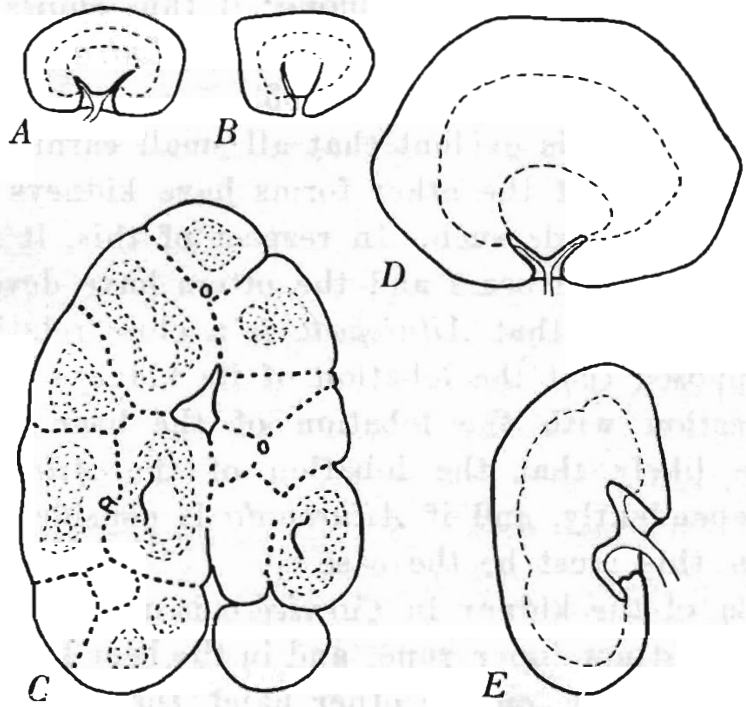

Fig. 15. *A*, *B*, *C* *Phoca hispida* (Schreb.). *A*, *B* renculi, *C* cross section of the kidney, outer zone dotted. *D* *Balaenoptera musculus* (L.), renculus. *E* *Procavia capensis* Pall., kidney.

The cortex constitutes about 72 % of the weight of the kidney, the outer zone about 24 %, the inner zone 4 %.

The tubules. The proximal tubule is divided into a more proximal and a terminal part. The former is thickest at the beginning, and narrows continually. At the beginning the latter is thicker than the last portion of the proximal part, and its diameter diminishes continually until immediately before the transition into the thin segment, which is abrupt. The highest proximal tubules end slightly above the stripe boundary. The highest loops turn as much as 1 mm. above the zone boundary. The bend usually occurs at the transition between thin and thick segment. The latter is always differentiated into a thicker and a thinner part. The initial collecting tubule and the collecting tubule are thin and transparent. The peripheral junctions are direct, normally, but there may be small arcades.

The percentage of long loops is 42 ± 4.5. The terminal segment occupies on an average 28 % of the proximal tubule. The thin segment is on an average 3.5 mm long, the thick segment 3.8 mm (8 more data), the distal tubule 1.0 mm.

Table 33. *Phoca hispida, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
	135×120	4150×42	10.8	*d*	150×135	5200×41	10.5
h	155×124	4400×38	8.7	*d*	153×124	6080×47	15.1
h	140×130	4430×39	9.5	*d*	160×135	6200×43	12.3
h	145×115	4650×39	10.9	*d*	195×140	6230×46	10.5
m	160×150	4750×42	8.3	*d*	165×150	6750×40	10.9
m	135×130	4800×40	10.9				

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
	135×135	4200×40	1300× 6	3750×22	800×30	42	13	37	8	9.2
h	145×105	4730×38	1650× 8	4050×26	900×24	42	15	36	8	11.8
h	140×112	4800×40	1500× 8	4200×25	1200×30	41	13	36	10	12.2
h	150×145	5100×38	1800×10	4050×25	900×30	43	15	34	8	8.9
h	165×135	5550×41	1950×10	4500×23	1150×30	42	15	34	9	10.2
m	190×150	6150×49		4700×26						10.6
d	270×130	6250×41		3380×24	1000×28					7.3
dd		(7000)	(12000)	(3000)	(1200)	(30)	(52)	(13)	(5)	
Mean	146	5245×41 ±200	8	4090×24	992×29					10.5

Phoca barbata Erxl.

Material. One kidney in alcohol.

Form. The dimensions, 205 × 83 × 53 mm, are much larger than in *Phoca hispida*, but otherwise the agreement is close. After maceration there is a swelling of about 30 %, and then the cortex is 3.6 mm thick, the outer zone 5.5 mm, the inner zone 9 mm. The latter measurement is fairly variable.

The tubules. These also agree in essentials with those of *Ph. hispida*. The proximal tubules end at slightly different levels. The transition between thin and thick segment in long loops occurs at varying levels, too. Thus the zone boundary becomes somewhat indistinct.

The long loops constitute 68 ± 3.4 % of the total number.

Table 34. *Phoca barbata, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	195×195	9500×55	6000×15	8000×33		(34)	(22)	(29)		13.7
h	225×180	9700×60	6700	9400×32		(35)	(24)	(34)		14.4
h	225×195	10000×53								12.1
h	240×195	10000×56	6000	10000×34	2100×38	36	18	36	7	12.0
h	195×195	10800×56								15.9
m	240×205	11600×59								13.9
m	275×240	13500×62		9000×33	2800×36					12.7
Mean	214	10728×57	15	9100×33	37					13.5

Carnivora pinnipedia, survey of the form of the kidney.

The kidneys of the *Pinnipedia* are of very uniform structure. They evidently all belong to the renculi type, though the renculi in mature specimens are closely united, instead of being more loosely connected, as in many other kidneys of this type. GERHARDT (1911, 1914) considers the kidneys of the *Pinnipedia* to be a type distinct from the renculi kidney, but this opinion can hardly hold, as not only embryos but also young specimens show typical renculi kidneys. Accounts of kidneys of this order have been given by OWEN (1868), HYRTL (1872), CHIEWITZ (1897), GERHARDT (1911, 1914), ANTHONY and LIOUVILLE (1920), ANTHONY (1922). ANTHONY and LIOUVILLE (1920) state that the kidneys of *Otaria* are only superficially grooved. This is certainly true of mature specimens, but it must be emphasized that the structure of the *Otaria* kidney agrees with that of *Phoca*. This is evident from GERHARDT's account of it (1914), and personal examination of an *Otaria* kidney.

Cetacea.

Phocaena phocaena (L.).

Material. Two pairs of kidneys in alcohol.

Form. The kidneys are composed of renculi, lying in several layers. The renculi are held together by abundant connective tissue. Thus they are easily separated from each other, and there is no tendency to fusion of neighbouring renculi. One kidney in each of the examined pairs has been measured. The dimensions are 105 × 63 × 32 mm and about 140 × 70 × 40 mm. The latter has been macerated, which resulted in

some swelling. After maceration the cortex is 1.7 mm thick, the outer zone 2.4 mm, and the inner zone 3.4 mm.

The tubules. The proximal tubules often begin with a short neck. Their terminal part is not clearly distinguishable, but seems normally to be somewhat slenderer than the preceding part. The short loops turn in the inner part of the outer zone, the highest ones about 0.8 mm from the zone boundary. The bend usually lies at the transition between thick and thin segment. The former has a thicker and a thinner part. The initial collecting tubule is often fairly long. Most peripheral junctions are direct, but there are also small arcades.

The long loops constitute 34 ± 3.5 % of the total number. In addition to the proximal tubules of the table, such measuring 4.3, 4.7 and 5.1 mm have been measured, as also thick segments 3.9, 3.9, 4.0, 4.1 and 4.5 mm long.

My findings agree qualitatively with the description given by INOUYE (1909). The percentage of the long loops is also the same. The length of the proximal tubules given by INOUYE, 4.7 mm, agrees with the mean length I have found, 5.1 ± 0.25 mm. His figure of the average length of the thick segment, however, is 2.5 mm, which deviates markedly from mine, 4.0 ± 0.1 mm. This great discrepancy is difficult to explain. It may, however, be mentioned that though the drawings of thick segments given by INOUYE agree well with his measurements, the two proximal tubules figured by him (op. cit. fig. XIII) are much shorter than any one measured by him. Even if the foreshortening of the loops is taken into account none of them seems to be more than 3.5 mm long. It is possible that differences in shrinkage have occurred between those

Table 35. *Phocaena phocaena, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p.t.	t.s.	th.s.	d.t.	
h	160×130	4100×40	1800×12	3700×30	850	39	17	35	8	7.9
h	145×130	4400×43	1600×14	3700	1000×31	41	15	35	9	10.0
h	155×150	4800×45								9.3
m	160×150	4900×47		3800×26	850					9.6
m	180×135	5100×50		3900×28	1200×30					10.5
h	180×150	5500×45								9.2
m	165×165	6000×49								10.8
dd	250×200	7100×60	(8500)	(3400)	(1000)	(36)	(43)	(17)	(5)	8.5
Mean	163	5238×47	13	28	31					9.5

measured and those depicted. But then it seems possible that such differences have occurred between the proximal tubules and the thick segments measured, also.

Balaenoptera musculus (L.).

Material. A piece of a kidney in alcohol.

Form. The kidney consists of renculi, connected by loose connective tissue. The renculi are often slightly flattened. Their dimensions are about 35 × 30 × 25 mm. The pelvis of the renculus is small, without processes. The papilla is small and obtuse (fig. 15 *D*, p. 336). The cortex is about 6 mm thick, the outer zone 9 mm, the inner zone 9 mm. After maceration an outer stripe, about 3 mm thick, is distinguished.

The tubules. The pars convoluta of the proximal tubules is tortuously looped, and the pars recta is always well developed, often slightly looped. The transition into the thin segment occurs at slightly varying levels. The thick segment is strongly differentiated into a thicker and a thinner part. The former is wavily tortuous. The short loops sometimes turn a fairly long distance above the zone boundary. Their bend lies within the thick segment. The distal tubules, and the collecting tubules in this material are very brittle and difficult to isolate. The former seem most often to be about 2 mm long and 0.035 mm thick. Some small arcades have been seen, but most peripheral junctions are direct.

The dimensions of some segments are given below, table 36. 22 long loops and 38 short ones have been counted.

Table 36. *Balaenoptera musculus*, *tubule dimensions in* μ.

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	190×160	10000×50		10100						16.4
m	230×220	12500×58								15.0
m	220×195	12800×56		12200						16.7
h	220×155	13000×52		11500						19.8
h	230×230	13500×58	7000	12300×38	(2000)	(39)	(20)	(35)	(6)	14.8
d	250×230	15000×60		11500×40						15.7
d	300×210	16000×60		11700						15.2
dd		(16000)	(25000)	(12000)	(3000)	(29)	(45)	(21)	(5)	
Mean	217	13260×56		11550×39						16.2

Cetacea, survey of the form of the kidney.

The kidneys of the *Cetacea* have been investigated by a number of authors. It is clear that all whales have typical renculi kidneys. In addition to the authors cited by FREUND (1939), OMMANEY (1932) may be mentioned. He has given a thorough account of the structure and development of the kidneys of *Balaenoptera physalus* (L.).

In most whales the renculi are disposed in several layers, and they are very numerous. According to ANTHONY (1922) *Mesoplodon* has relatively few renculi, all reaching the surface of the kidney.

Hyracoidea.

Procavia capensis Pall.

Material. One pair of kidneys in alcohol.

Form. The dimensions are 30 × 16 × 9 mm and 32 × 17 × 9 mm. The kidney is thus relatively thin, but is otherwise of the common form. There is a well-developed papilla (fig. 15 *E*, p. 336). The pelvis has distinct processes. The cortex is about 2 mm thick, the outer zone about 4 mm and the inner zone about 5 mm.

The tubules. All segments are of the common form. The highest loops turn about 1.2 mm above the zone boundary. The short loops turn in the thick segment. The collecting tubules have small arcades, but most junctions are direct.

After maceration the material had shrunk about 25 %. 62 short and 13 long loops have been counted. The distal tubules are about 0.7 mm long and about 0.030 mm thick.

	Capsule	Prox. tub.	Ind.
m	135×115	6400×30	12.4
h	138×105	6400×32	14.1
m	120×105	7100×29	16.3
h	140×122	7300×32	13.7
m	148×120	7500×34	14.0
Mean	125	6940×31	14.1

Proboscidea.

Elephas maximus L.

Material. The kidneys of a 2-year-old male in alcohol, and the kidneys of a female. The latter have also been examined after maceration.

Form. The kidneys of the male consist of 4 and 5 distinct lobes respectively. The kidneys of the female had been cut into several pieces, and thus it is difficult to be certain as to their form. One of them weighs 2.8 kg, the other 2.35 kg. The dimensions of the latter are about 220 × 190 × 90 mm. It consists of 7 renculi, and the other of 8. In the interior of the kidneys these are distinctly separated by membranes of connective tissue (and probably, as PETTIT (1907) states, smooth musculature too). On the surface they are separated by shallow grooves, here and there indistinct. The ureter and the blood-vessels enter the kidney ventrally. The former branches in the kidney. A branch goes to each renculus, but it has not been possible to ascertain the exact mode of branching. Within the renculus the branch usually ramifies once more, and the end portion of the last branches widens to envelope a very low papilla (fig. 16). The latter is largely occupied by a roundish area cribrosa. On this open several collecting ducts. One of the latter is usually markedly enlarged, and forms a small tubus maximus up to 10 mm long and 1.5 mm wide. Sometimes there are two tubi maximi on the same area cribrosa. Each area cribrosa belongs to a medullary pyramid (fig. 16 *A*, *B*), which is completely separated from the other pyramid in the same renculus by a cortical ridge and by the sinus renculi (fig. 16 *A*). In the smaller kidney with its 7 renculi there are 12 areae cribrosae.

The cortex contains numerous thick medullary rays. It is 15—23 mm thick, and the medulla 15—27 mm. The medulla is not divided into zones, but the innermost part of the medulla is mainly occupied by the wide collecting ducts, and thus shows a more whitish colour. Nor is any inner zone visible after maceration.

The tubules. There are cortical nephrons, but no nephrons with typical long loops. The capsule is of normal appearance, but is often distinctly flattened. The proximal tubule is very tortuous and always has a pars recta, which is relatively short in the deepest nephrons. The thin segment begins at very different levels in the outer zone and the inner parts of the cortex. Thus the outer stripe is not very distinct. It is about 4.5 mm thick. The loops turn everywhere in the medulla and the medullary rays, except in the outermost parts of the cortex. The higher a loop turns, the shorter is its thin segment. The loops of the

deepest nephrons, which turn near the area cribrosa, consist in their deepest part of two limbs of similar structure. The epithelium is very uneven and opaque. This part of the loop must be referred to the thick segment. The transition into the thin segment is, however, very gradual. The difference between the thicker and the thinner part of the thick segment is slight and often absent, especially in the cortical nephrons.

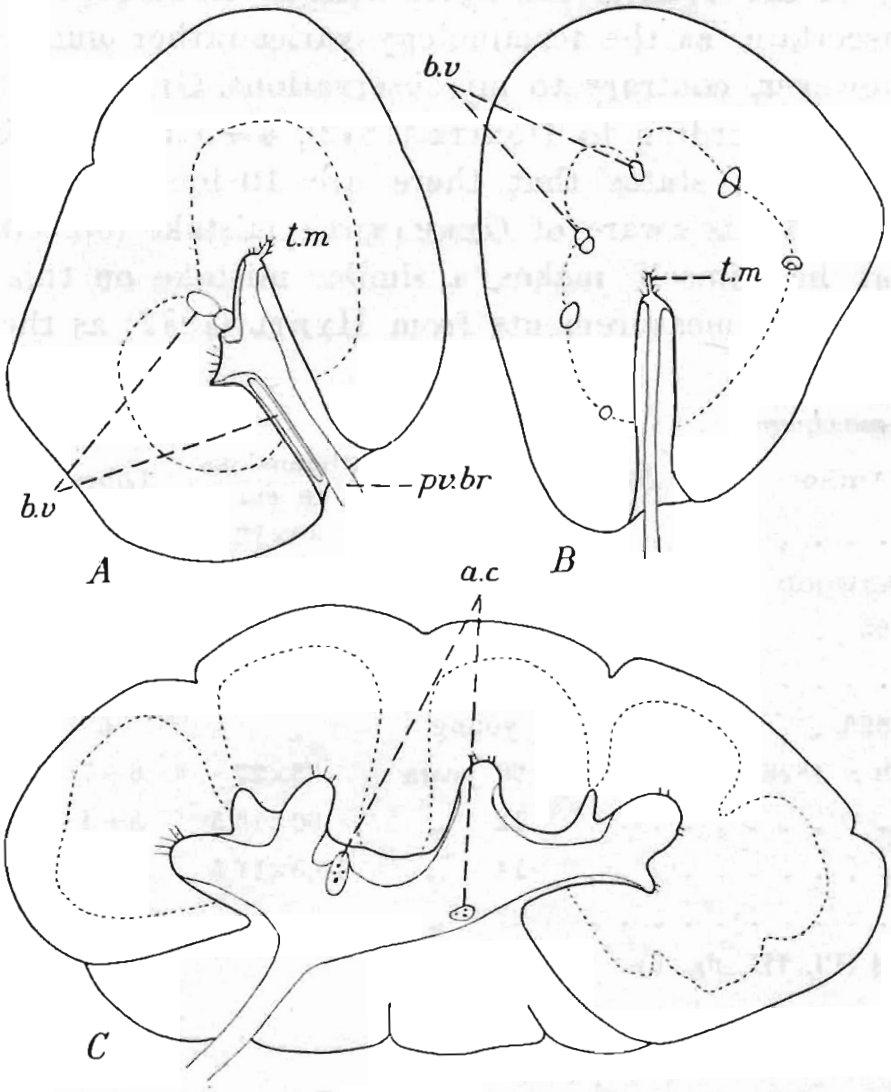

Fig. 16. *A, B Elephas maximus* L., renculi. *b.v* blood-vessel, *pv.br* pelvic branch, *t.m* tubus maximus. $^1/_2 \times$. *C Trichechus manatus* L., kidney. *a.c* area cribrosa. $^1/_2 \times$.

The distal tubule is of the usual appearance. There is usually no initial collecting tubule in the deep nephrons. The collecting tubules are very difficult to examine, as they are very brittle. It is, however, certain that there are arcades, as well as direct junctions. Central junctions occur even in the central parts of the cortex.

The dimensions of some cortical nephrons and proximal tubules are given below, table 37. The longest thin segment I have found is about 10 mm long. The distal tubule is usually about 3.5 mm long. The mean length of the proximal tubules, except those of the cortical nephrons, is about 27 mm. The numerical relation of the cortical nephrons and the

others is not known, and thus the mean length of the proximal tubule cannot be estimated with certainty. This is the case with the other segments, too. Thus, the composition of the average nephron is unknown. It seems clear, however, that the thin segment occupies an unusually small part of it.

The macroscopical structure has been examined by several authors. The majority of the descriptions agree with my findings, but this is often difficult to ascertain, as the terminology varies rather much. Some statements are, however, contrary to my observations. GERHARDT (1911) states that there are, according to DÖNITZ (1872), 4—5 tubi maximi. This is not correct. DÖNITZ states that there are 10 lobes, and tubi maximi, too. FREUND (1939) is aware of GERHARDT's mistake (op. cit. p. 72), but it seems that he himself makes a similar mistake on this same page, when he cites some measurements from HYRTL (1872) as the dimensions

Elephas maximus.

Author	Age	Dimensions in cm	Lobes	Pyramids
WATSON 1873		30×18	5+4	13+10
MIALL & GREENWOOD 1879	young		5+5	2—3 in each lobe
ANDERSSON 1883		26.5×19.5×5.5	8+8	
WATSON 1885			7	
HUNTINGTON 1893	young		6	
PATERSON & DUN 1898	20 years	38×27	6+7	23+27
PETTIT 1908	12 „	30×16.5	5+4	
„ „	14 „	15.5×11.5	6	
FOX 1909	27 „		10	
GERHARDT 1914 (Pl. III, fig. 6)			5	
HAHN 1921			6+6	
„ „			7	
PETIT 1925	7—8 „		8	
SCHULTE 1937	20 „	27.5×22.5	6+7	2—4 in each lobe
BECKMAN 1939	30 „	30×19	6+6	
SPERBER	2 „		4+5	
„		22×19×9	7+8	12

Loxodonta africana.

HYRTL 1872	4 years		9	9
DÖNITZ 1872			10	
FORBES 1879			8	
v. MOJSISOVICS 1879	2.5 „		10	
PETTIT 1907	30 „		8	
PETIT 1925 (ANTHONY)	foetus		8	

of the tubi maximi. HYRTL's measurements refer to the branches of the pelvis (HYRTL's "calices minores"). On the whole FREUND's survey of the literature is difficult to understand, which is probably due to the fact that he has not examined an elephant kidney himself. This is probably essential to an understanding of the often very obscure descriptions. FREUND (1939) accepts the opinion, first advanced by CAMPER (1803) and later supported by PLATEAU and LIÉNARD (1881) among others, that the number of the renculi diminishes with the age of the individual. PETTIT (1907) and PETIT (1925, p. 59) consider the question open to doubt. On p. 344 I give a table of the statements I have found in the literature on the number of renculi in the elephant kidney, together with my own findings.

The statements by CUVIER (1840) and MAYER (1847) have not been taken into account, as the species is not known. PLATEAU and LIÉNARD (1881) thought there were 5—6 lobes in a part of the kidney they examined; this figure has of course not been included in the survey above (cf. PETIT 1925 and FREUND 1939).

CAMPER (1802, p. 40) says there are 8—9 lobes, but from his figures (Pl. IX, fig. 2, 3) it seems that there are more probably 6 or perhaps 7 renculi, showing varying degrees of subdivision.

This survey certainly gives no support to the theory that the number of renculi diminishes with age. It is, however, clear from the descrip-

Table 37. *Elephas maximus*, *tubule dimensions in* μ.

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p.t.	t.s.	th.s.	d.t.	
hc	265×220	10100×41	500×15	3500×16						7.1
hc	240×250	10300×50	250×20	3500×22	3700×40	58	1	20	21	8.6
hc	280×280	10300×48	500×17	4900×17	4000×37	52	3	25	20	6.3
hc	275×230	11500×50	350×17							9.1
hc	380×300	18400×60								9.7
m	380×380	20000×62								8.6
d	520×460[1]	26500×63								
d	460×415	27500×60								8.6
m	450×450[1]	28800×63								
d	460×460	29000×58								7.9
Mean	330	19240×56 ±2600	17		39					8.2

[1] Flattened capsules, not included in the mean.

tions in the literature that the furrows may become indistinct in old animals.

The number of renculi in the two kidneys of the same specimen is probably correlated. The mean number of the renculi has been calculated after taking the average number in the individual. This value is 6.35 ± 0.36 in *Elephas*, and 8.83 ± 0.40 in *Loxodonta*. The difference is 2.48 ± 0.54 renculi. The difference is 4.59 times its standard error, and is thus significant, despite the small number of data from *Loxodonta*. Thus it is certain that *Loxodonta* has more renculi than *Elephas*. On the other hand, it is possible that each renculus in *Loxodonta* has only one pyramid, as was the case in HYRTL's specimen, whereas *Elephas* has usually more than one pyramid in each renculus. The tubi maximi, again, may well be better developed in *Loxodonta*, as they are described as conspicuous structures by DÖNITZ, but are, as it would seem, usually not large in *Elephas*. The material hitherto examined does not allow of definite conclusions, but it seems probable that the kidneys of *Elephas* and *Loxodonta* have developed along slightly different lines.

Sirenia.

Survey of the form of the kidney.

I have only examined a kidney in alcohol of *Trichechus manatus* L. The dimensions are about $160 \times 80 \times 40$ mm. The surface has several shallow grooves. The pelvis has short branches (fig. 16 *C*, p. 343), each with an area cribrosa at its end. The collecting ducts do not open on papillae, but the surfaces of medullary pyramids bordering the pelvis are concave. A few of the collecting ducts are larger than the others, and may perhaps be regarded as small tubi maximi. The medullary parts seem to be completely separated by the cortex. The latter is about 7 mm thick, and the medulla at most about 20 mm. No subdivision into zones is visible in the medulla.

PETIT (1925, p. 23—38) has given an account of the kidney structure in *Manatus latirostris* Harlan (= *Trichechus manatus* L.) and *M. senegalensis* Desm. The surface may have grooves or it may not. The structure of one kidney of each of the two species seems to show great resemblance to the kidney examined by me. As PETIT (1925) points out it is difficult to fit the *Trichechus* kidney into any scheme of kidney types. It seems to represent a transitional stage between kidneys with undivided cortex and divided medulla, and the renculi kidneys. The medullary pyramids do not, however, form papillae. In this respect they resemble those of the elephant kidney, but morphologically this resemblance is of little importance.

The kidney of *Halicore* is well known through the investigations of FREUND (1912), RIHA (1911) and PETIT (1925). Their accounts agree as to matters of structure, but their terminology and opinions differ greatly. The *Halicore* kidney is smooth, and much longer than it is broad. The cortex forms a superficial layer. The medulla is divided into two parts, a cranial and a caudal, each forming a long crest. The pelvis is long with a cranial and a caudal branch, both with numerous processes. As FREUND (1912, 1939) points out these branches of the pelvis should not be called recesses, as they have nothing to do with real recesses (= tubi maximi). FREUND, on the other hand, calls the processes calices, which is not correct, as they do not lead to, or envelop, papillae.

The *Halicore* kidney cannot well be referred to any of the common kidney types. It is, perhaps, most like the crest kidney, though the crest has been divided into two parts.

Rhytina had renculi kidneys (STELLER 1753). FREUND (1939, p. 52) doubts this, but gives no sound reasons for his opinion that the *Rhytina* kidney resembled the *Halicore* kidney structurally. In this connection he also writes that in *Manatus* the medulla is originally divided into pyramids, but that later these fuse. It seems that he has interpreted PETIT (1925) thus, but I have not been able to find any such statement in the paper by PETIT. He also states that the papillary parts of the pyramids fuse in *Halicore*. To my knowledge there is no account of the embryonic development of the *Halicore* kidney, and the anatomical facts do not show such a development.

Artiodactyla.

Hippopotamus amphibius L.

Material. One pair of kidneys in alcohol.

Form. Both kidneys had been cut into two parts previous to fixation, which made the examination difficult.

The dimensions of one of the kidneys is 270 × 165 × 85 mm. The surface is grooved (fig. 17). The pelvis is long and narrow (fig. 17, *pv*). At its end it is joined by two tubi maximi. These pass parallel to the lateral margin of the kidney, at intervals giving off branches (fig. 17, *t.m*). The tubi are narrow (0.5—2 mm). Collecting ducts open in their branches as well as in the tubi maximi proper, though only at certain points. The tubi and their branches are surrounded all along their course by medullary substance, which thus forms a continuous branched mass. The medulla in its turn is covered by the cortex. The whole kidney thus presents a lobated appearance, but the lobes are continuous at their bases. The ends of the lobes, on the other hand, are separated by very

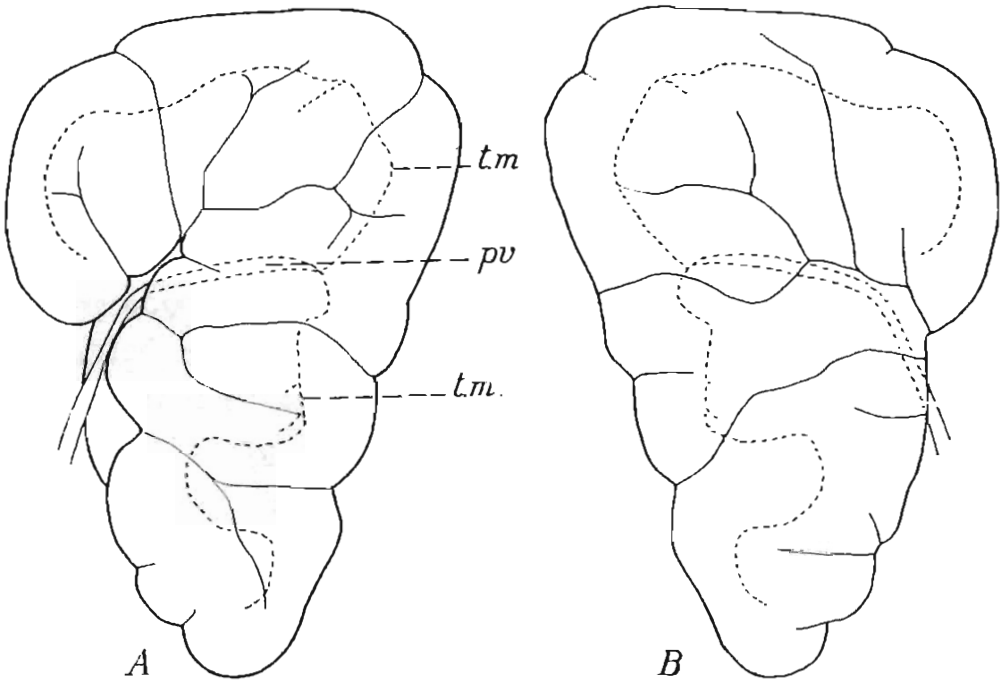

Fig. 17. Kidney of *Hippopotamus amphibius* L. Scheme showing the superficial grooves and the main branches of the tubi maximi. *pv* pelvis, *t.m* tubus maximus. 1/4 ×.

distinct sheaths of connective tissue. The cortex is most often about 12 mm thick, the medulla is about 16 mm thick and shows no division into zones.

The tubules. There are cortical nephrons. Long loops are absent. The proximal tubule narrows continually. The transition into the thin segment occurs at different levels — also in the cortex. The thin segment is at its beginning up to 0.050 mm thick, and though it narrows as it descends it is never less than 0.025 mm thick. The highest cortical nephrons have no thin segments. The loops always turn within the thick segment. The collecting tubules have well-developed arcades, but there are also direct junctions, even in the central parts of the cortex. The central junctions occur already in this region. The collecting tubules are relatively thick in the cortex (0.1 mm).

A cortical nephron and some segments of other nephrons have been measured. It is, of course, not possible to obtain a picture of the average composition of the nephrons from these scanty facts. It is, however, evident that the thin segment constitutes an unusually small part of the nephron; on the other hand the proximal tubules are extremely well developed.

GERHARDT (1911) states that there are 4—5 tubi maximi. His description, however, is very short, and the comparison with *Rhinoceros* and *Elephas* made by him (op. cit. p. 268) only adds to its obscurity. The account of WEHN (1925) is also very difficult to understand, but it seems clear that it is in accordance with my findings. The only exception is that, according to him, the two tubi maximi apparently join

Table 38. *Hippopotamus amphibius, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
hc	240×220	12800×53								12.8
hc	310×285	13800×54								8.4
hc	285×225	14000×51	0	6300×22	3000×40	60	0	27	13	11.1
m	375×340	24000×75								14.1
d	450×320	24300×65								12.2
m	410×300	25000×74								15.0
d	405×310	27800×62								13.7
Mean	320	20242×62								12.5

before opening into the pelvis. It is possible that such is the case in my material, too, but I have not been able to ascertain this. PETIT gives a drawing of the form of a *Hippopotamus* kidney (1925, p. 47) which presents the same features as my specimen, and probably the interior structure would, if investigated, have proved similar, too.

Sus scrofa domestica.

Material. Three fresh kidneys.

Form. The kidneys are relatively long. The surface is even. Two of the kidneys belong to young pigs. The weights of these kidneys are 140 gm and 165 gm, and the dimensions are 130 × 54 × 35 mm, and 137 × 60 × 35 mm. The cortex is about 18 mm thick (15—21 mm), the outer zone about 9 mm, and the inner zone 4—7 mm. The third kidney has been obtained from an old sow, and weighs 360 gm; the dimensions are 194 × 85 × 38 mm. The cortex is about 20 mm thick, the outer zone 7.5 mm, and the inner zone about 6.5 mm. The cortex is not divided, but the medulla is divided into several pyramids, each forming a papilla or a crest (fig. 18 *A*). The pelvis is branched.

The tubules. There are many cortical nephrons. The long loops are few and the thin segments are relatively short. In other respects the nephrons show only slight deviations from the common form, and my findings agree qualitatively with the account by PETER (1909). There are relatively few projections on the surface of the distal tubule in the smallest of the kidneys, but in the largest these projections are very numerous and well developed.

The nephrons are difficult to isolate in their entire length. In the smallest kidney proximal tubules 20.7, 23.0, 26.8 and 29 mm long have

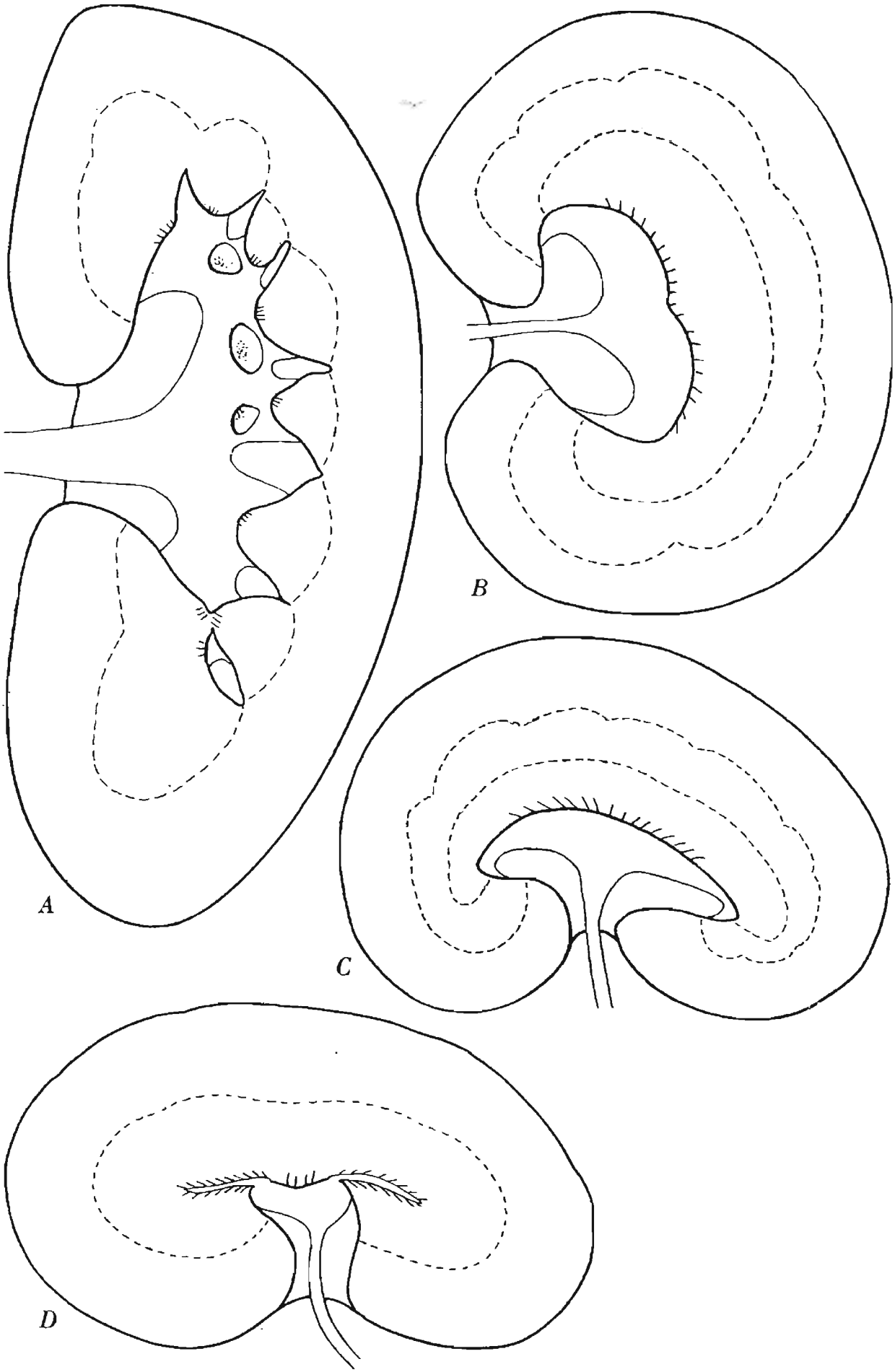

Fig. 18. Kidneys of *A Sus scrofa domestica, B Camelus bactrianus* L. 1/2 ×, *C Alces alces* (L.) 1/2 ×, *D Rangifer tarandus* L.

Table 39 a. *Sus scrofa dom., tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.
h	260×190	17000×68	23.4
h	300×230	17300×70	17.6
m	340×260	23300×75	19.8
d	375×300	28500×80	20.3
d	340×240	30000×83	30.5
d	350×300	30000×80	22.9
Mean	290	24350×76	22.4

Table 39 b. *Sus scrofa dom., old female, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.
h		29000×59	
h		31000	
h	340×240	33000×60	24.3
d	410×250	36000×66	23.2
d	430×300	36500×70	19.8
m	450×340	37000×68	16.4
d	450×300	38000×62	17.5
m		40800×65	
Mean	351	35163×64	20.2

been measured. In the next smallest kidney the lengths of some proximal tubules measured in addition to those of table 39 a are 22.5, 26.3, 27.8 and 29 mm. The mean length is, then, in this kidney 25 ± 1.3 mm. In the largest kidney an entire cortical nephron has been measured. The dimensions are: Prox. tubule 29 × 0.059 mm, no thin segment, thick segment 6.5 × 0.040 mm, distal tubule 4.5 × 0.045 mm. The lengths of the corresponding segments of a very deep nephron may be assumed to be 38 mm, 20 mm, 10 mm, 7 mm. In this kidney thick segments with lengths 5.5, 6.0, 6.5, 8.5, 8.5, 9.2, 9.8, 10.6, 11.0 and 11.2 mm have been measured. The mean is 8.7 mm. The distal tubule is usually 5—7 mm long, on an average 6 mm. The thin segment is 0—3 mm long in cortical nephrons, on an average 1 mm at most. In short loops it is about 4 mm long (1—6 mm) and in long loops less than 20 mm. If it is assumed that there are some 80 % cortical nephrons and about 3 % long loops, the mean length of the thin segment is about 2 mm. This figure is very uncertain but even large errors in it do not much affect the relative figures for the other segments.

The macroscopic structure of the pig kidney has been examined by many authors. The descriptions usually agree with my findings. PETER's (1909) measurements of the lengths of the tubules are much smaller than mine. His material had shrunk considerably (op. cit. p. 261).

Camelus bactrianus L.

Material. One kidney in alcohol.

Form. There is a typical, long crest (fig. 18 *B*). The pelvis has strongly developed processes. The dimensions are 170 × 130 × 60 mm.

The cortex is about 15 mm thick, the outer zone about 15 mm and the inner zone about 25 mm.

The tubules. The capsule and the proximal tubule resemble those of the cow, but all proximal tubules end at the stripe boundary. The short loops turn within the thick segment, the highest ones about 5 mm above the zone boundary. The thick segment has a thicker and a thinner part. The distal tubule, which begins with a portion with an even contour, has in the following part a very irregular surface, and finally it becomes uniform again. The collecting tubules have well-developed arcades.

Some segments of nephrons have been measured, see table 40. The long loops constitute 55 ± 4.2 % of the total number. The mean length of 11 thick segments is 22 ± 0.9 mm. 5 distal tubules are 3.2—3.7 mm long. A high nephron has been "reconstructed" from parts of two high nephrons. The lengths are: Proximal tubule 33 mm, thin segment 7 mm, thick segment 23 mm, distal tubule 3.7 mm. The available data do not permit an estimation of the proportions of the average nephron. It seems, however, that the thin segment is relatively longer than in the cow, as there are more long loops in *Camelus*. The thick segment is also relatively longer.

Table 40. *Camelus bactrianus, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
d	325×310	26000×57	14.7	*m*	330×240	28500×54	19.4
m	330×285	27000×54	15.5	*m*	270×270	29000×54	21.5
d	315×270	27800×55	18.0	*m*	310×280	29000×55	18.4
m	290×285	28000×60	20.3	*h*	300×290	29300×58	19.5
m	310×280	28000×61	19.7	*m*	300×260	30000×53	20.4
m	300×285	28500×52	17.3	*h*	300×280	33000×53	20.8
d	315×300	28500×51	17.0	*h*	345×285	34500×56	19.6
				Mean	295	29079×55 ±590	18.7

Dama dama (L.).

Material. One pair of kidneys in alcohol.

Form. Dimensions: 80 × 50 × 38 mm. The pelvis is small with slight processes. There is a short crest and the area cribrosa is oval. The cortex is 9 mm thick, the outer zone 11 mm, the inner zone 8 mm.

The tubules. There are a few cortical nephrons. Their loops turn in the central parts of the cortex, and have, normally, a thin segment. There are arcades. The dimensions of some capsules and proximal tubules are given below. The distal tubules have a distinct intercalated segment. Their length is about 3—4 mm, their thickness about 0.037 mm.

	Capsule	Prox. tubule	Ind.
d	285×230	15500×52	12.3
m	280×240	17800×53	14.0
m	300×300	20300×55	12.4
h	260×230	22500×53	19.9
Mean	266	19025×53	14.7

Alces alces (L.).

Material. One pair of fresh kidneys, and one pair in alcohol.

Form. The weight of one of the fresh kidneys is 540 gm. The dimensions are 155 × 105 × 50 mm. The area cribrosa is about 5 cm long, and lies on a low crest (fig. 18 *C*, p. 350). At the extremities two collecting ducts are distinctly larger than the others; they may be regarded as approaches to tubi maximi. The pelvis has slight processes. The cortex is 20—25 mm thick, the outer zone 10—15 mm and the inner zone 10—15 mm. The cortex constitutes about 10 % of the kidney volume.

The tubules. There are cortical nephrons. The proximal tubule is usually thickest in its middle parts. It ends at varying levels, from the stripe boundary to the outer parts of the cortex. The thin segment is absent in the high cortical nephrons, and very short in the low cortical nephrons and the highest nephrons with short loops. The short loops turn within the thick segment. In the high cortical nephrons the thick segment is of uniform thickness, somewhat thicker than the thinner part of the thick segment in the other nephrons.

A nephron with the loop descending to the zone boundary has been "reconstructed" from segments of such nephrons. The lengths of the segments are approximately these: Proximal tubule 26 mm, thin segment 6 mm, thick segment 14 mm, distal tubule 6 mm. The very deepest nephrons ought to have the following segment lengths: Proximal tubule 30 mm, thin segment 35 mm, thick segment 12 mm, distal tubule 8 mm.

Kidneys of an embryo of *Alces* have been examined by Lönnberg (1907). His description is, however, somewhat obscure, and it is difficult

Table 41. *Alces alces, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
hc	200×175	9400×55	15.0	*d*	320×320	26400×75	19.3
hc	240×200	10800×60	13.5	*m*	385×320	27000×75	16.4
hc	240×160	12800		*d*	360×305	27200×75	18.6
h	270×240	16100×72	17.9	*m*	400×275	28000×78	19.9
m	280×280	24000		*d*	335×320	28000×75	19.6
m	330×320	26000×80	19.7	*d*		29500×73	
				Mean	285	22100×72 ±2170	17.8

to understand if there are really separate papillae, as he indicates, or if there are secondary pyramids only. The latter interpretation seems more probable, in view of the structure in the mature specimens examined by me.

Rangifer tarandus L.

Material. One pair of fresh kidneys, one pair in alcohol.

Form. The fresh kidneys weigh about 65 gm each, and the dimensions are 75 × 45 × 27 mm. The cortex is relatively thick, about 15 mm. The medulla is also about 15 mm thick, and not divided into zones visible to the naked eye. The pelvis is small, without processes. There is a small papilla-like crest. At the extremities of the area there are two small tubi maximi (fig. 18 *D*, p. 350). The ratio of the volumes of the cortex and the medulla is about 10: 1 in one of the fresh kidneys.

The tubules. Material from one of the fresh kidneys has been macerated. There is much tough connective tissue, and the tubules are very brittle.

Table 42. *Rangifer tarandus, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
d	165×130	12800×37	22.1	*m*	180×175	15000×42	20.0
	175×175	14300×41	19.1		190×165	17000×44	23.9
h	175×130	14300×42	26.4	*m*	205×165	17300×45	23.0
m	190×175	15000×41	18.5		190×180	17300×44	22.3
h		15000×45		*d*	205×175	18000×43	21.6
				Mean	175	15600×42 ±500	21.9

There are cortical nephrons. The proximal tubules are very looped. In the outer part of the cortex the pars convoluta consists mainly of almost straight segments placed at right angles to the surface of the kidney. These segments are of varying lengths, and are connected by sharp bends. The following nephron segments have not been isolated entire, but they seem to be of normal structure. The long loops are very few, and the inner zone, which is visible microscopically after maceration, is very low. The dimensions of some capsules and proximal tubules are given in table 42. There was a shrinkage of about 20 %.

Ovis aries L.

Material. The kidneys of a young sheep.

Form. One of the kidneys weighs 57 gm, and its dimensions are 71 × 50 × 35 mm. There is a relatively long crest. The pelvis has processes. The cortex is about 7 mm thick, the outer zone 7 mm, of which the outer stripe constitutes 2 mm, and the inner zone 10 mm.

The tubules. The tubules show no marked deviation from the common form, and they also agree in essentials with the description given by PETER (1909). The distal tubules have often small processes (cf. PETER 1909). The dimensions of some capsules and proximal tubules are given below. A high nephron has been isolated: Proximal tubule 21 mm, thin segment 4 mm, thick segment 13 mm, distal tubule 2.3 mm. The very deepest nephrons ought to have about the following dimensions: Proximal tubule 16 mm, thin segment 23 mm, thick segment 8 mm, distal tubule 2 mm. The long loops constitute 36 ± 3.8 % of the total number.

Table 43. *Ovis aries, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.
h		16000×52	
d	240×230	16100×52	15.2
d		16600×53	
m		18000×55	
m	320×240	20000×55	14.3
m	225×225	21000×60	25.1
h	300×240	21900×52	15.8
h	230×220	22000×55	23.9
Mean	247	18950×54	18.9

The sheep kidney has been investigated by several authors (e. g. TOEPPER 1896, DUMONT 1909, BRASCH 1909, AGDUHR 1917, MARSCHNER 1937). Their descriptions usually agree with my findings. CHIEWITZ (1897) states that there are tubi maximi. From the account by MÜLLER (1883) it is clear that there may be small recesses at the extremities of the area cribrosa. It is probable that these structures are the tubi maximi of CHIEWITZ (these recesses seem to be similar to those of the dog and the *Felidae*, cf. p. 333).

As mentioned above PETER (1909) gives a full account of the microscopic structure of the sheep kidney. There is little to add to his description. His material had probably shrunk after maceration, and thus the tubule lengths given by him are probably too low.

Bos taurus L.

Material. Several pairs of kidneys.

Form. The following kidneys have been more thoroughly examined: "Young calf": weight of one kidney 65 gm, dimensions 90 × 48 × 21 mm, cortex 3 mm, outer zone 3 mm, inner zone 8 mm; "Calf": weight of one kidney 290 gm, dimensions 145 × 90 × 45 mm, cortex 4.5 mm, outer zone 8 mm, inner zone 8 mm; "Young cow": weight of one kidney 600 gm, dimensions 210 × 100 × 45 mm, cortex 9 mm, outer zone 9 mm, inner zone 8—10 mm; "Cow": weight of one kidney 500 gm, cortex 9—12.5 mm thick, outer zone 8—10 mm, inner zone 10—12 mm. The surface of the kidney is deeply lobated in the calves (and especially in embryos) and shows distinct, but usually shallow furrows in the old specimens. These furrows correspond to ridges on the inner surface of the cortex. Some of these ridges reach the sinus renis, and divide the kidney into several relatively well-separated lobes (fig. 19 *C*). Most of these lobes are themselves more or less subdivided. On the whole each superficially distinguishable lobe corresponds to a papilla. The superficial grooves in the "Young cow" are shown in fig. 19 *A*, *B*. The main furrows are drawn thicker than the others, though they are not always more distinct on the kidney surface. The upper, well-demarcated lobe *a* contains 3 papillae, two of which resemble crests. The next lobe, *b*, is also distinct and corresponds to 5 papillae, as does the lobe below it. There is one more large lobe, *d*, containing 4 papillae. The small lobe *e* is in close connection with this lobe. There are 3 more small, less distinct lobes in the lower end of this kidney: *g*, *h*, *f*. The pelvis is branched, with a main branch to each of the large lobes, and usually a secondary branch to each distinct papilla. The end part of such a secondary branch may enclose 2—3 papillae. This description refers to the "Young cow",

but the other kidneys examined show a similar structure, though their form varies greatly according to whether they are right or left kidneys.

In the "Cow" the ratio of the volumes of cortex, outer zone and inner zone has been estimated at 81 : 16 : 3.

The tubules. In the "Cow" there are some cortical nephrons, but such have not been found in the other kidneys. In the "Young calf" the proximal tubules end in the whole outer stripe, but in the others they end at the stripe boundary (except, of course, in cortical nephrons).

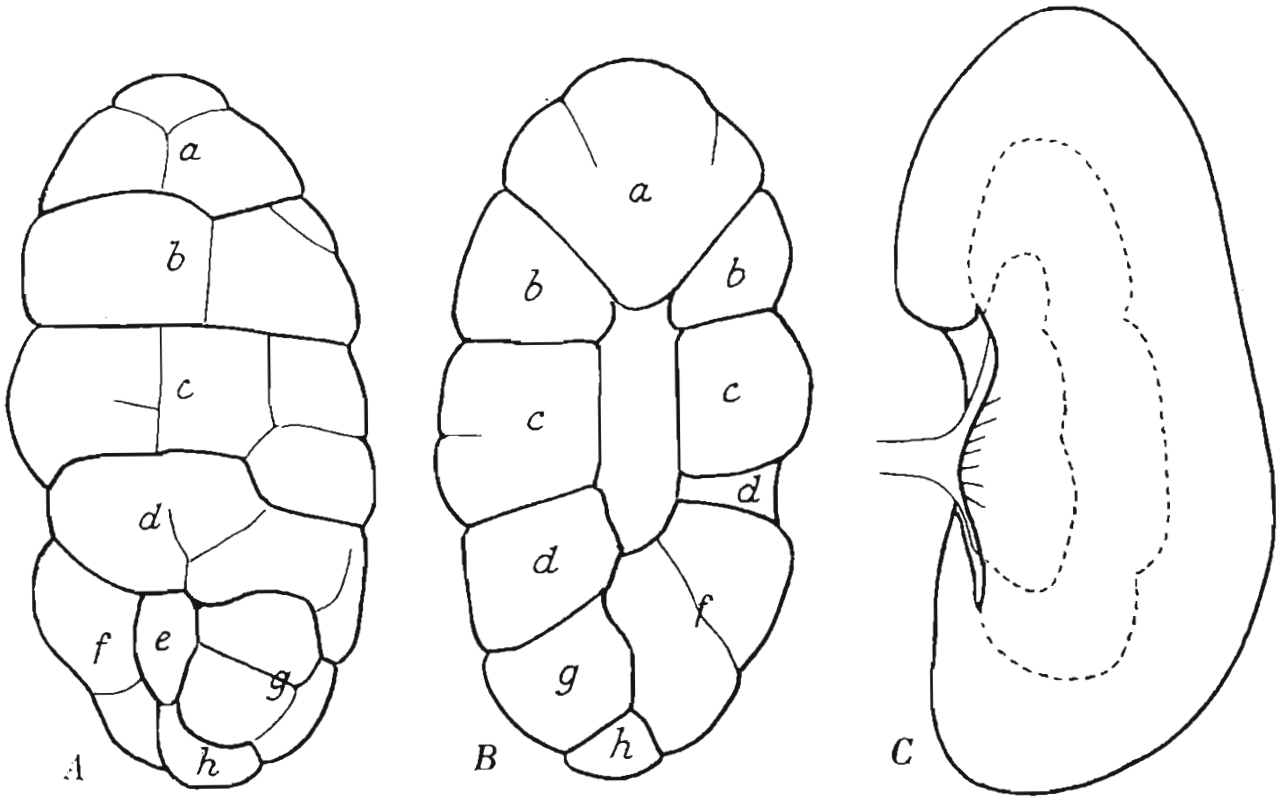

Fig. 19. *A* dorsal, *B* ventral surface of cow kidney. *a*—*h* designate the main lobes. 1/4 ×. *C* section through lobe.

The proximal tubules show a uniform calibre, except in the "Calf", where the terminal part is distinctly thinner and more transparent, with visible cell boundaries. The short loops turn in the central part of the outer zone. In the "Young calf" the macroscopic zone boundary is the region where most short loops turn, but the transition between thin and thick segment in long loops occurs about 1.5 mm below this region. This transition is relatively indistinct, and the long loops are not very numerous; thus the real zone boundary is only distinguishable after microscopic examination. The short loops turn at the transition between thin and thick segment. The thick segment is, in mature specimens, distinctly differentiated into a thicker and a thinner part, but in the "Young calf" no such differentiation is visible, and in the "Calf", too, it is indistinct. The distal tubules are generally divided into three seg-

Table 44 a. *Young calf, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	105×105	4800×29	1300 × 8	4000×14	1200×21	42	12	35	11	12.6
h	125×110	5100×30	1750 × 7	4300×15	1280×22	41	14	35	10	11.1
h	105×105	5200×30	1650 × 8	4300×15	1350×23	42	13	34	11	14.1
h	115×115	5300×29	1500 × 8	4300×15	1100×23	43	12	35	9	11.6
h	120×110	5600×29	1800 × 8	4400×14	1200×24	43	14	34	9	12.3
m	115×105	5700×30	1900 × 9	4700×16	1150×22	42	14	35	9	14.2
m	115×100	5700×31	2200 × 8	4800×15	1050×23	41	16	35	8	15.4
m	120×105	5800×30	2000 × 8	4700×16	1200×22	42	15	34	9	13.8
dd	130×100	5900×29	(12000)× 9	4800×16	1000×22	(25)	(50)	(20)	(5)	13.2
d	145×110	6300×33	5600 ×10	4900×16	900×23	36	32	28	5	13.0
Mean	113	5540×30 ±75	2188 × 8	4520×15 ±94	1143×23					13.1

Table 44 b. *Calf, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
d	180×165	14300×47	14	9800×23	3400×40					22.6
h	195×175	17000×45	3800×12	11000×25	3000×40	49	11	32	9	22.4
h	190×170	17200×45								24.0
h	195×190	18000×43		11000×23	3500×41					20.9

Table 44 c. *Cow, tubule dimensions in μ.*

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
h	275×250	17100×45	11.2	*h*	375×335	26000×64	13.2
d	270×260	20000×50	14.2	*h*	375×300	30800×60	16.4
d	295×250	20300×53	14.6	*h*	300×280	32000×68	25.9
m	295×240	22500×58	18.4	*h*	325×280	33800×62	23.0
m	330×265	23500×61	16.4	*h*	335×315	34000×70	22.6
h	375×375	25000×62	11.0	*h*	370×290	35000×70	22.8
m	325×255	25500×68	20.1	Mean	305	26576×61 ±1650	17.7

ments (cf. INOUYE 1909). The collecting tubules have well-developed arcades.

The dimensions of some nephrons are given in tables 44 a, b, c. In the "Young calf" there was a shrinkage of about 10 %. The mean of the table may be accepted as representing the average nephron. In the "Calf" the long loops constitute 20.8 ± 2.4 % of all loops. Proximal tubules 15.8, 16.5, 16.8, 17.0, 17.3 and 18.2 mm long have been measured in addition to those of the table, and also thick segments 10.0, 10.2, 10.5, 10.7, 10.8, 10.8 and 11.1 mm long. The corresponding means are 16.8 and 10.6 mm. In the "Young cow" there is a shrinkage of about 10 %. The proximal tubule measures 17.8 ± 0.4 mm (17 data) and the thick segment 11.5 ± 0.2 mm (15 data). The long loops constitute 21 ± 2.8 % of the total number (INOUYE's countings give 24 ± 1.2 %).

In the "Cow" the segments in a high nephron are 35, 5, 16, 7 mm long resp. The proximal tubule is about 27 ± 1.6 mm long, the thick segment is, on an average, 15 ± 0.5 mm, and the distal tubule about 5 mm. The thin segment is about 5 mm long in short loops. The mean length of long thin segments may be estimated at 10—15 mm, probably about 12 mm, the mean of all thin segments at 7 mm. The proximal tubule would thus constitute about 50 % of the average nephron, the thin segment 13 %, the thick segment 28 %, the distal tubule 9 %.

The form and structure of the cow kidney have been described by several authors. Their accounts most often agree with my findings. ELLENBERGER and BAUM (1926), and also MARSCHNER (1937), and FREUND (1939), state that the lobes merge in the outer zone. This is not true. All papillae are separate up to the cortex. The lobes are connected by the cortex and the blood-vessels, the pelvis, and the connective tissue.

Artiodactyla, survey of the form of the kidney.

Neobunodontia. In *Sus* there are several papillae. In *Phacochoerus* there is either a crest as PETIT (1925, p. 131) states (also my own examination of an embryo), or there are some papillae (GERHARDT 1911, LÖNNBERG 1912). I have re-examined LÖNNBERG's specimen (fig. 20 *A*); it is akin to the crest kidney. HYRTL (1872) states that the renal pelvis of *Dicotyles* is similar to that of *Sus*. CHIEWITZ (1897), on the other hand, found a crest with two tubi maximi. This agrees with the structure in a young specimen examined by me (fig. 20 *B*). The processes of the pelvis are very faint in my specimen.

It seems that the kidney structure varies greatly in *Suidae*. It is most probable that the crest kidney is the most primitive condition, and from this the kidney with papillae and the kidney with tubi maximi have developed. If this is so the kidneys with papillae in *Sus* and in

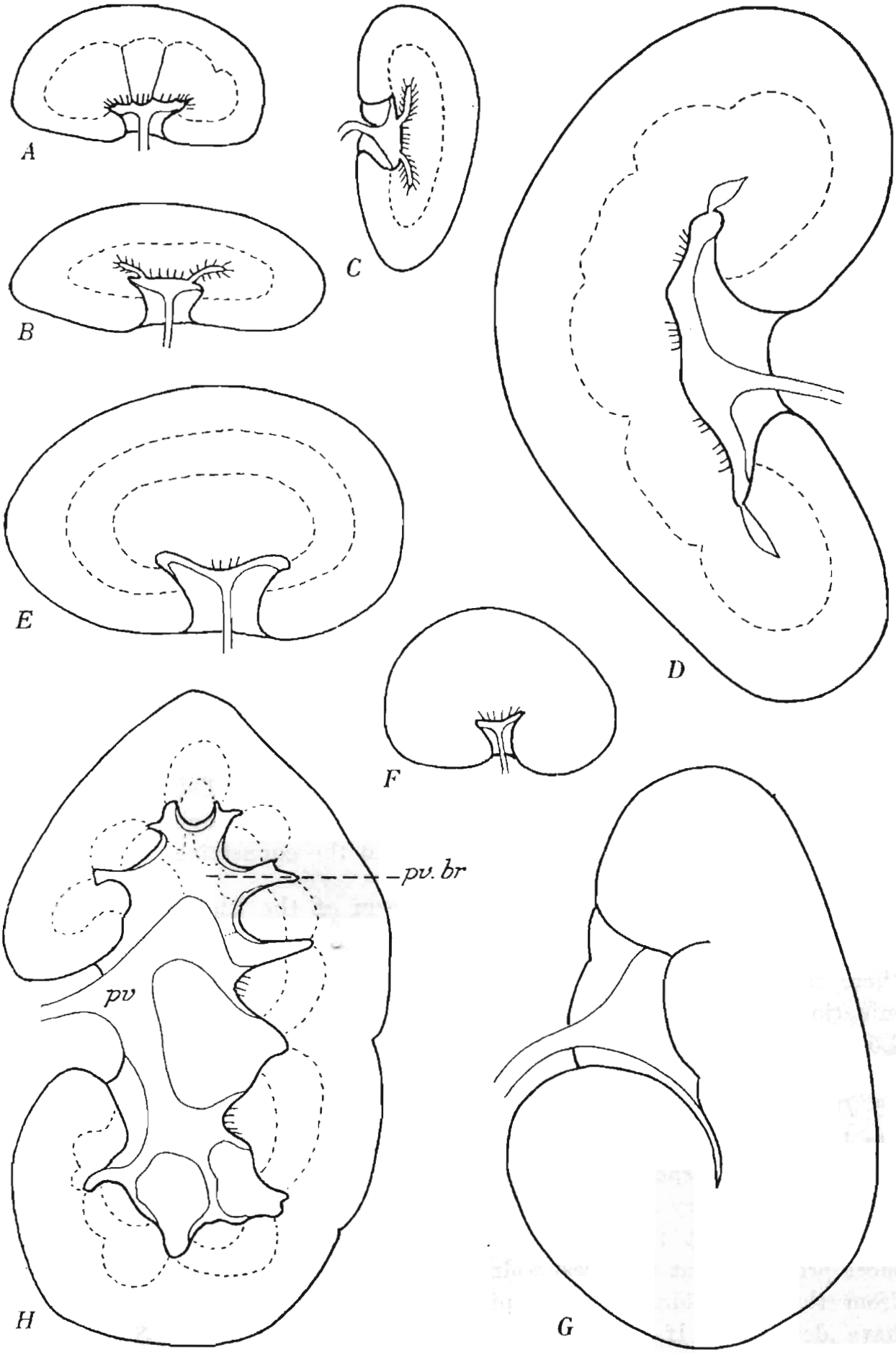

Fig. 20. Kidneys of *A Phacochoerus sp.*, *B Dicotyles tajacu* L., *C Tragulus javanicus* Osb., *D Cervus elaphus* L., *E Antilope cervicapra* L., *F Cephalophus melanorhoeus* Gray, *G*, *H Anoa depressicornis* H. Sm. *pv.br* pelvic branch.

Phacochoerus must be considered to have developed independently of one another.

In *Hippopotamus* there are branched tubi maximi, which condition is unique among the mammals hitherto examined.

Ruminantia. *Camelus* and *Lama* both have typical crest kidneys (HYRTL 1872, 1873, GERHARDT 1899, LESBRE 1903, p. 106, FREUND 1939). In *Camelus* the crest is long.

Tragulus javanicus Osb. has oblong kidneys. Two tubi maximi open at the extremities of the area cribrosa, which lies on a short crest (fig. 20 *C*). The medulla is not divided into zones, and there are no pelvic processes.

HYRTL (1872) has examined the form of the pelvis in *Capreolus*, *Cervus barberinus* and *Cervus pseudoaxis* (= *Sika* Sclater). There is a crest, and the pelvis has processes. Similar statements are given by CHIEWITZ (1897) on *Dama dama* (L.), and *Odocoileus virginianus* Bodd. PETIT (1925, p. 126) describes the kidneys of *Rucervus eldi* Guthrie and *Rusa unicolor* Bechst. He states that, in the latter, there is a long crest. He calls the cranial and the caudal end of the pelvis recessus terminales (= tubi maximi). From the description it seems that there are no true tubi maximi. I have myself made dissections of the kidneys of *Dama* and *Cervus elaphus* L. only. In the latter there is a long crest, and the area cribrosa is divided into some groups of pores. In one of the specimens examined there are two wide, flattened tubi maximi (fig. 20 *D*); in the other the tubi maximi are very narrow.

It seems that the kidney structure in other *Cervidae* also may be more complicated than most of the statements in the literature imply.

HYRTL (1872) states that the *Capreolus* kidney he examined showed superficial lobation. FREUND (1939) is convinced that this statement must be due to some error, as he has not found any lobated kidneys among several examined by him. In this connection it may be mentioned that WIEDERSHEIM (1909, p. 701) figures a *Capreolus* kidney with marked lobation. It seems possible that there may be individual variations in this respect.

Rangifer has a short crest with small tubi maximi (p. 354). In *Alces* there is a long crest with only traces of tubi maximi.

All antelopes hitherto examined have simple kidneys. Most often there is a crest, but in *Antilope cervicapra* L. there is a low papilla (fig. 20 *E*). The following have been examined by LÖNNBERG (1901, 1903, 1912), and PETIT (1925): *Connochaetes gnu* Zimm., *Connochaetes taurinus* Burch., *Cephalophus ogilbyi* (Waterh.), *C. melanorhoeus* Gray (cf. also fig. 20 *F*), *C. harveyi keniae* Lönnb., *C. dorsalis* Gray, *Nesotragus moschatus* v. Dueben, *Rhynchotragus guentheri wroughtoni* Drake-Brockman, *Cobus*

ellipsiprymnus (Ogilby), *Antidorcas euchore* Sparm., *Antilope cervicapra* L., *Gazella dorcas* L., *Taurotragus livingstoni* (Sclater), and *Gazella rufina* Thomas. *Taurotragus livingstoni* (Sclater) has been investigated by AGDUHR (1917), and the pelvis of *Antidorcas euchore* Sparm. by HYRTL (1872). The descriptions are, however, usually so short and incomplete that it is difficult to obtain a clear picture of the structure of the kidneys described. This is still more the case in some reports of MURIE (e. g. 1870). HYRTL (1872) states that the renal pelvis of *Antilope pygmaea* is branched. I doubt this, as does FREUND (1939). In a specimen of *Antilope euchore* HYRTL thought that he had found a small papilla, separated from the main papilla, and enclosed by the pelvis in a similar way to a normal papilla. FREUND (1939) cites this. This is obviously erroneous. The part of the medulla taken by HYRTL for a papilla is only partly separated from the rest of the medulla (cf. HYRTL 1872, Pl. III, fig. 5). The processes of the pelvis surround it circularly; a papilla is surrounded by a cup-shaped calix.

All sheep and goats examined have kidneys with a crest, and the pelvis has distinct processes.

Ovibos moschatus Zimm. has a typical crest (LÖNNBERG 1900).

Among the *Bovinae*, *Anoa* has a grooved surface to the kidney, and there are several papillae (LÖNNBERG 1903). The grooves are shallow, and the cortex projects slightly between the papillae (fig. 20 *H*). The pelvis is branched. In the cow the grooves are deeper and the kidney is divided into lobes, but these are not so well separated and independent as in a typical renculi kidney. According to LÖNNBERG (1912) and PETIT (1924 a) the kidney of *Bubalus* is a more typical renculi kidney. The kidney of a calf of *Bison bonasus* (L.) is similar to that of a cow. *Bison bison* (L.) has a branched renal pelvis (HYRTL 1872). The kidney of *Poëphagus* is similar to that of *Bos* (LÖNNBERG 1907).

The kidney of *Giraffa* has a long crest (HYRTL 1873, GERHARDT 1899).

From the facts hitherto known it seems most probable that the crest kidney, or some similar type, is most primitive in *Ruminantia*. From this have developed types with tubi maximi and types with lobes. The former condition is known from *Tragulus* and the *Cervidae*. In these two groups tubi maximi must have developed independently. It is not possible to say with certainty if this type has been developed more than once in *Cervidae* also. The development towards the renculi kidney can be traced in *Bovinae*.

Kidneys with papilla occur only among the antelopes (*Antilope cervicapra*). It is, of course, possible that these are the most primitive (cf. p. 400), but if the order is studied without regard to other orders there is little reason to think so.

The medulla is divided into zones in *Camelus, Dama, Alces, Antilope cervicapra, Taurotragus, Connochaetes, Ovis, Capra, Anoa, Bos.* The inner zone is absent in *Tragulus,* and is very faint in *Rangifer* and probably in *Cephalophus melanorhoeus.* It seems most likely that the primitive condition is the occurrence of distinct zones, and the reduction of the inner zone has taken place independently in several types.

The occurrence of pelvic processes varies, but the material is too small to allow of any conclusions as to which condition may be the primitive one.

Perissodactyla.

Equus caballus L.

Material. One pair of fresh kidneys, one kidney in alcohol.

Form. The total weight of the fresh kidneys is 1570 gm. The dimensions are 185 × 130 × 60 mm, and 165 × 165 × 60 mm. The corticomedullary boundary is somewhat indistinct, owing to the numerous thick medullary rays. The cortex is about 14 mm thick, the outer zone about 16 mm, of which a distinct outer stripe occupies 5—6 mm, the inner zone up to 21 mm. The pelvis is small with slight processes. The area cribrosa lies on a small crest, at the extremities of which open two long and large tubi maximi (fig. 21).

The tubules. The capsule is transversely oval or round. There is sometimes a very short neck. The proximal tubule first widens and then remains of uniform thickness for a considerable length. The last part of the convoluted portion becomes more narrow and transparent; this appearance is retained throughout the pars recta. The highest proximal

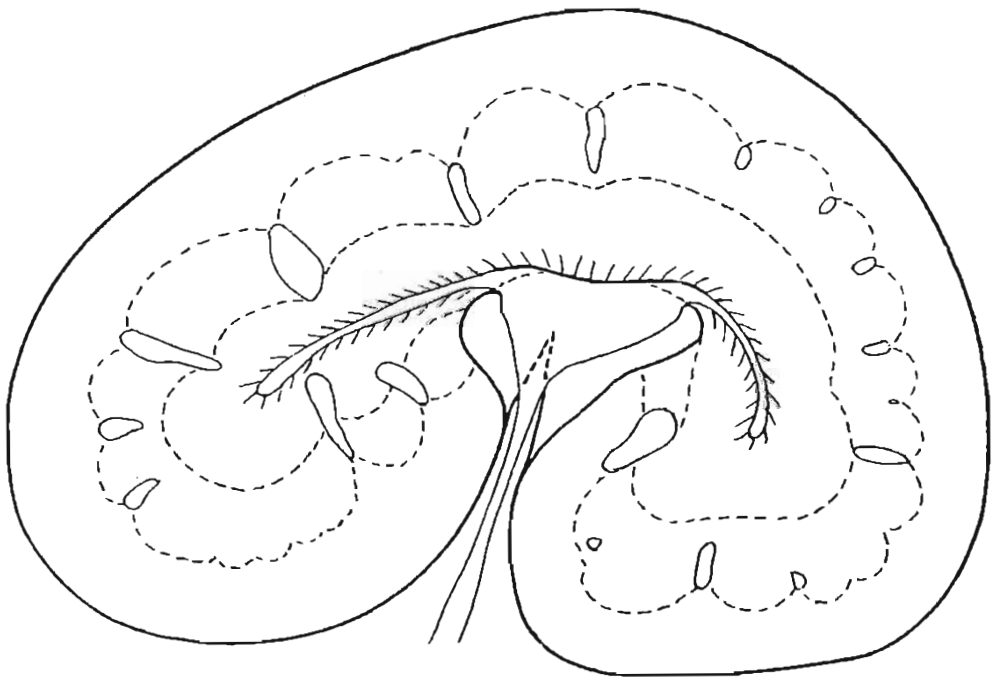

Fig. 21. *Equus caballus* L., kidney. ½ ×.

tubules end at the cortico-medullary boundary. In some of these the thin segment may be absent. Thus, though strictly speaking there are no cortical nephrons, there are nephrons quite comparable to such. The short loops turn within the thick segment, which is always differentiated into a thicker and a thinner part. The distal tubule begins with an intercalated segment, which resembles the thinner part of the thick segment. Then the true distal tubule follows. This is thick and opaque. It narrows towards the end. In some nephrons there is a segment between the distal tubule and the collecting tubule, resembling the latter. It is not, however, transparent, as initial collecting tubules normally are, but may, of course, deserve this name notwithstanding. The distal tubules most often open directly into the collecting tubules. The latter have arcades, and their first central junctions usually occur in the outer zone. The arcades often collect about 10 nephrons, but a few arcades turn already in the inner part of the cortex, and then collect only a small number of nephrons. The collecting tubules are relatively thick, also in the cortex (up to 0.12 mm). In addition to these thick collecting tubules, there is in the medulla much connective tissue. Thus, the thin segments constitute a relatively small part of the volume of the medulla.

The dimensions of some nephrons and segments are given below. There was a shrinkage of about 10 %. 13 long and 54 short loops have been counted, together with 2 loops without thin segment.

Table 45. *Equus caballus, tubule dimensions in* μ.

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	270×250	28000×59	5000×18	17000×26	2500×45	53	10	32	5	24.5
m	335×230	25000×60	5800×20	16600×28	2200×40	50	12	33	4	19.5
dd		(22000)	(40000)	(14000)	(3000)	(28)	(51)	(18)	(4)	

	Capsule	Prox. tubule	Ind.		Capsule	Prox. tubule	Ind.
d	330×265	21000×64	15.4	*m*	300×240	23500×65	21.2
m	300×235	21400×61	18.5	*h*	280×250	24500×60	21.0
d	315×240	21500×60	17.1	*m*	375×225	25500×63	19.0
m	280×230	21800×59	20.0	*h*	370×220	27000×56	18.6
m	250×240	23300×58	22.5	Mean	274	23863×60 ±710	19.8

The mean length of the thick segment is about 15 mm (12 measurements), and that of the distal tubule 2.9 mm (15 measurements). These segments are on an average 0.027 and 0.042 mm thick. The thin segment is about 3.5 mm long in short loops. The average length of the thin segment in long loops is probably not over 20 mm. The mean length of this segment may thus be estimated at about 7 mm. The values for the segments of the nephron have been corrected for the shrinkage. If this is done with the mean length of the proximal tubule, too, it becomes about 26 mm. The average nephron may thus be assumed to have the following composition: Proximal tubule 51 %, thin segment 14 %, thick segment 29 %, distal tubule 6 %.

The structure of the horse kidney has been investigated by several authors (cf. esp. Skoda 1914). Toepper (1896) states that the tubi may be absent, but this is not accepted by most later writers. Siewert (1927) has examined the form of the tubules. Most of his statements hold for the specimen examined by me. He found, however, a long neck and, also, typical cortical nephrons.

Perissodactyla, survey of the form of the kidney.

The horse and the zebra have kidneys with tubi maximi (Hyrtl 1872). The kidney of the tapir also has tubi maximi (Hyrtl 1872, Gerhardt 1911, Petit 1925).

Gerhardt (1911) states that there are 4—5 long tubi maximi in *Rhinoceros*, and compares the structure with that of *Hippopotamus* and *Elephas*. This comparison makes his statement dubious, as the elephant kidney is a renculi kidney, and the *Hippopotamus* kidney probably has only two tubi maximi (cf. p. 347). The figure of a *Rhinoceros* pelvis given by Hyrtl (1872, Pl. II, fig. 3) shows a condition very similar to that of the elephant, with a branched pelvis, the ends of which seem to have enclosed low papillae. Thus it would seem most probable that the *Rhinoceros* kidney is also composed of renculi. This conception is supported by my finding the kidneys of a *Diceros bicornis* embryo to be strongly lobated. They appear to be typical renculi kidneys, but their inner structure is not so differentiated as to allow of any definite conclusion.

It thus seems that there are in the *Perissodactyla* two types of kidneys, neither of which can be assumed to have developed from the other. There is also no clue as to what common type they may have developed from.

Primates.

Chiromys madagascariensis (Gmelin).

Material. One pair of kidneys in alcohol.

Form. The dimensions of one kidney are 20 × 12 × 9 mm. The cortex is about 2.5 mm thick, the outer zone 3 mm, the inner zone nearly 5 mm. The papilla is long and pointed (fig. 22 *A*).

The tubules. The capsules are usually round. The proximal tubules are thickest at the beginning, and their distal part is more slender (normally about 0.030 mm thick). The short loops turn near the zone boundary. They often turn within the thin segment. This makes it difficult to distinguish between short and long loops. The thick segment is slenderer in the outer zone than in the cortex — the reverse of the normal condition. The distal tubules frequently have a short intercalated segment, which is often slightly thinner than the last part of the thick segment. The transition into the initial collecting tubule is very indistinct; thus, it is very difficult to determine where the distal tubule ends. There are a few small arcades.

The dimensions of some nephrons are given below. 8 long and 25 short loops have been counted. The average length of the thick segment is 3.4 ± 0.1 mm (11 data). The mean length of the proximal tubule is 5.11 ± 0.22 mm including the following data: 4.5 × 0.038, 4.7 × 0.040, 4.8, 5.1, 5.3 mm. The mean length of the distal tubule is 1.53 mm.

Table 46. *Chiromys madagascariensis, tubule dimensions in μ.*

	Capsule	Prox. tubule	Thin segment	Thick segment	Dist. tubule	Segment length %				Ind.
						p. t.	t. s.	th. s.	d. t.	
h	130×105	4400×40	1100×8	3800×29	1100×36	42	11	37	11	12.9
h	140×115	5100×42	1400×8	3800×28	1600×34	43	12	32	13	13.3
d	140×140	5200×43		2900×28	1400×35					11.4
m	140×115	5300×41	1400×8	3500×26	1600×38	45	12	30	14	13.5
dd	150×140	6700×40	(11000)	(2800)	(2000)	(30)	(49)	(12)	(9)	12.8
Mean	132	41	8	28	36					12.8

Primates, survey of the form of the kidney.

The macroscopical structure of the primate kidney has relatively recently been the subject of an investigation by Straus (1934). Straus makes a critical and almost complete examination of the relevant literature.

Thus, there is no need here to give more than a summary of his paper, and a few additional notes.

In *Lemuroidea* there is a papilla (cf. figs. 22 *A*—*C*). In a kidney of a *Galago sp.* I have, however, found a transitional type to the crest type (fig. 22 *D*).

In *Tarsioidea* there is a papilla (cf. fig. 22 *E*).

Among the New-World monkeys *Ateles* may have a crest or two papillae, but usually there is a papilla in the other forms.

Among the Old-World monkeys there are forms with papilla and

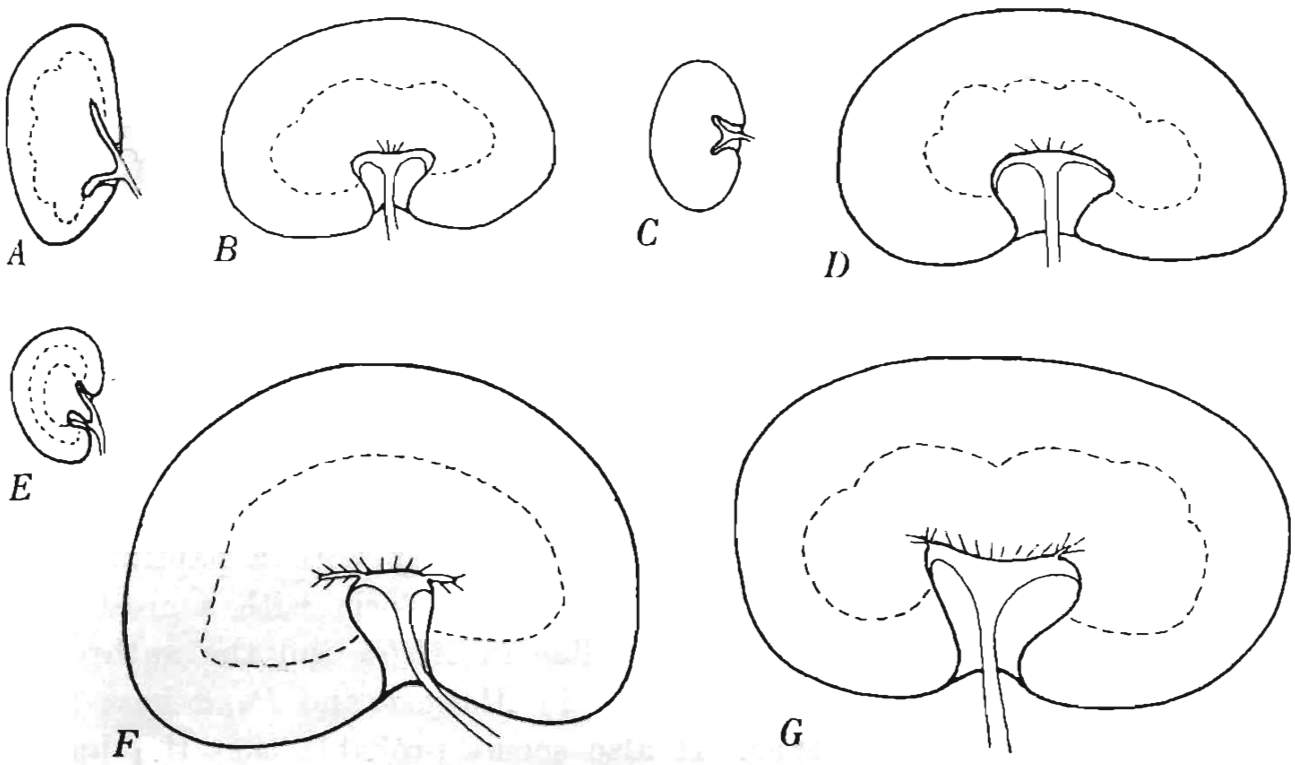

Fig. 22. Kidneys of *A Chiromys madagascariensis* (Gmelin), *B Lemur catta* L., *C Galago sp.*, *D Galago sp.*, *E Tarsius tarsius* Erxl., *F Macacus sylvanus* L., *G Papio sp.*

with crest. In *Macacus sylvanus* L. there are, however, distinct but small tubi maximi, and similar but still less developed structures exist in a *Papio sp.* (fig. 22 *F* and *G*). There are a number of statements that the anthropoid apes possess several papillae. Like STRAUS I am convinced that the majority of these statements refer to subdivisions of a single papilla. STRAUS is of the opinion that the description of two papillae in an Orang-utan by MIJSBERG (1923) must be accepted. STRAUS seems to have overlooked the figure of a branched *Hylobates* pelvis given by HYRTL (1873, Pl. X, fig. 4). This pelvis must have belonged to a kidney with 6 papillae. STRAUS does not mention the paper by GERHARDT (1906), where the latter states that the kidneys of a Gorilla female had 5 and 6 papillae. It seems, however, that these kidneys are the same as those figured by GERHARDT in 1914 (Pl. III), as the measurements are identical

and the source probably the same. From these figures it is clear that there is a crest in each kidney. Later KOCH (1937) has given a short description of the kidneys in a Gorilla male. He says there are 4 papillae (op. cit. p. 6). WESTENHÖFER (1937, p. 30) says, however, with reference to the same kidney, that there are 3 groups, each with two medullary pyramids. From the photograph given by KOCH (1937) it seems clear, however, that there must be a division of the medulla into true papillae. The cortex is thick, and shows no traces of division. Thus it seems that the kidneys of Orang-utan and Gibbon are normally simple, but sometimes show more than one pyramid. So little material from Gorillas has been examined that it is impossible to know what the normal condition is. In the Chimpanzee only simple kidneys are known (cf. also RUMPF 1937, who figures a crest kidney of this form). I myself have examined one kidney from Orang-utan and from Gibbon, and 4 pairs from Chimpanzee, all simple.

In Man only kidneys with more than one papilla are known. The number of papillae varies greatly, however. Though the surface is normally smooth, the human kidney is structurally a lobated kidney, rather closely resembling the typical renculi kidney. The closest resemblance seems to be with the cow kidney.

From the hitherto examined material it seems hardly possible to draw any other conclusion than that the simple kidney with a papilla is the primitive type in the *Primates*. From this the form with a crest must have developed; the kidney with papillae in *Ateles* and the anthropoid apes, and the kidney with tubi maximi in *Macacus* and *Papio* have probably originated from that type. It also seems probable that the human kidney type has developed from the crest kidney, probably via some transitional stage similar to that of *Ateles*. BOLK (1921), MIJSBERG (1923) and WOOD JONES (1929) consider the human kidney the most primitive among the *Primates*. From the viewpoint of comparative anatomy there seems to be nothing to support this opinion, at least as far as the *Primates* are concerned. STRAUS is of opinion that "the phylogenetic history of the kidney is by no means clear". It is probable that the position of the human kidney can be correctly estimated only after a wider survey (cf. p. 400).

The medulla is divided into zones in *Lemur catta*, *Chiromys*, *Tarsius* and *Homo*, but in *Lemur* the inner zone is very low and there are some cortical nephrons, as in Man. In *Macacus sylvanus* and *Papio sp.* there is no inner zone, but many cortical nephrons.