THE JUXTAGLOMERULAR CELLS IN MAN AND THEIR RELATIONSHIP TO THE LEVEL OF PLASMA SODIUM AND TO THE ZONA GLOMERULOSA OF THE ADRENAL CORTEX *

JAMES A. PITCOCK, M.D.,† and PHYLLIS M. HARTROFT, Ph.D.

From the Department of Pathology, Washington University School of Medicine, St. Louis, Mo.

A relation between levels of plasma sodium and potassium and the adrenal cortex has been demonstrated in both animals and man. Evidence has indicated that the zona glomerulosa of the adrenal cortex is concerned specifically with the production of mineralo-corticoids. Adrenocorticotrophic hormone (ACTH) primarily affects the zona fasciculata but an analagous trophic hormone has not been found for the zona glomerulosa.[1-3]

Dunihue has demonstrated hypergranulation of the juxtaglomerular cells of the kidney in adrenalectomized animals.[4,5] The Hartrofts have shown a correlation in rats and dogs between levels of dietary sodium, the degree of granulation of the juxtaglomerular cells, and the width of zona glomerulosa of the adrenal cortex.[6,7] Therefore, adrenals and kidneys obtained at necropsy were examined to see if any of the above relationships might be demonstrated in man. Previous work on the juxtaglomerular apparatus in man has emphasized changes associated with various disease entities.[8-10]

MATERIALS AND METHODS

Kidneys from an unselected series of 200 necropsied patients were sectioned and stained by a modification of the Bowie technique, as described by Cowdry,[11] in order to demonstrate granules in the juxtaglomerular cells. The degree of granulation of the juxtaglomerular cells was determined by a semiquantitative method previously described.[9] This procedure yields a juxtaglomerular granulation index (JGI) which can be correlated with clinical and other pathologic findings.

Staining Technique

Thin slices of tissue are fixed in Helly's fluid (Zenker's solution without acetic acid but with addition of 5 cc. of formalin per 100 cc. immediately before use) for 48 hours and washed in running tap water

* Supported by a grant from the Nutrition Foundation, Inc., New York, N.Y., and Grant A-1114 from the U.S. Public Health Service, Bethesda, Md.

Received for publication, January 17, 1958.

† Trainee Fellow of the National Cancer Institute, National Institutes of Health, Bethesda, Md., during a portion of this investigation.

for 24 hours. Specimens are mounted in paraffin blocks which may be trimmed and treated several hours with Mollifex (The British Drug Houses, Ltd.) in order to soften the tissue. Sections should not be more than 4 μ in thickness. If albumen is used as an adhesive, care should be taken to avoid excessive amounts, as it may interfere with the staining.

Preparation of Bowie's Stock Solution. Dissolve one gram of Biebrich scarlet in 250 cc. of distilled water and filter through a rapid filter paper into a beaker. Dissolve 2 gm. of ethyl violet in 500 cc. of distilled water and filter a small amount at a time into the same beaker with frequent stirring. The end point of neutralization is indicated when a small amount of the mixture placed on a filter paper does not show any color (other than the precipitate itself). The mixture should then be filtered and the precipitate dried. The stock solution is made by dissolving 0.2 gm. of the dried precipitate in 20 cc. of 95 per cent alcohol.[11] Up to 100 cc. of stock solution can be obtained from one batch if the end point is carefully determined.

Staining Procedure. (1) Take paraffin sections rapidly through xylols and alcohols to alcoholic iodine. Immerse for not more than 3 minutes in iodine and 3 minutes in sodium thiosulfate. Wash in running tap water for 5 minutes. (2) Mordant in 2.5 per cent potassium bichromate at approximately 40° C. over night. (3) Rinse with distilled water and immerse sections over night in 20 per cent ethyl alcohol to which has been added 10 to 15 drops of Bowie's stock solution per 100 cc. (4) Blot sections with bibulous paper. (5) Dip quickly 2 to 3 times in 2 changes of acetone to remove excess stain. (6) Differentiate in a 1:1 mixture of xylol and clove oil until section appears red or reddish purple. Microscopically, renal parenchyma should be red (or magenta) in contrast to elastic tissue of vessels which should be blue-purple. Juxtaglomerular cell granules, where present, will be the same color as elastic tissue. The latter provides a convenient criterion for determining completion of differentiation. Red blood cells are usually amber as a result of previous bichromate mordanting. (7) Rinse in 2 changes of xylol followed by 2 changes of benzene. Mount with benzene balsam or Permount.

Selection of Cases

The clinical charts of the 200 patients were examined, and data concerning levels of blood pressure, electrolyte determinations, age, race, and sex were extracted. Of these 200 cases, 24 had had at least 3 determinations of the level of plasma sodium within the last week of life. These 24 cases form the chief basis of this report, as fewer than 3

TABLE I

Summary of Data from 24 Patients

Case number	JGI*	Width(μ) zona glomerulosa	Serum sodium	Serum potassium	NPN (BUN)†	Age	Race, Sex	Heart wt. (gm.)	Kidney wt. (gm.)	Adrenal wt. (gm.)	Arteriolar hyalinization	Blood pressure	Disease process
18098	50	434	133	4.6	283	24	CF	600	170	36	+	230/135	Basophilic pituitary adenoma, adrenal hyperplasia
18190	46	420	124	5.6	143	60	WM	480	550	17	+	110/60	Cirrhosis, hepatoma
18338	40	388	118	5.7	68	36	WM	530	410	18.5	0	100/60	Rheumatic heart disease
18163	32	342	132	2.7	236†	47	CM	510	320	28.5	+++ (with necrosis)	220/130	Malignant nephrosclerosis
18107	32	404	127	4.2	59†	43	CF	330	420	14	0	120/85	Viral hepatitis
18148	24	294	121	5.1	55	48	WM	690	446	27	0	100/80	Rheumatic heart disease
18287	20	315	134	3.7	26	65	WF	362	298	11	+	150/90	Carcinoid of ileum with pulmonic stenosis
18319	14	383	132	3.5	38	74	WF	270	320	20	0	130/70	Carcinoma of pancreas
18211	12	300	127	4.4	47	78	WF	330	245	15	+++	150/80	Myocardial infarction
18127	10	292	136	3.6	61	67	WM	350	320	13	+	160/100	Pulmonary emphysema
18292	9	365	125	4.1	19	55	CM	740	480	16	0	110/70	Rheumatic heart disease
18294	8	342	120	4.7	190†	68	CF	313	231	7	+++	180/110	Diabetes, renal abscess
18167	4	311	141	4.1	62	73	WF	360	160‡	11.5	++	146/56	Carcinoma of kidney
18368	4	373	136	3.7	8	59	WF	434	365	13	++	100/82	Carcinoma of breast
18114	2	243	155	3.0	38	39	WF	350	300	22	+	150/90	Glioblastoma multiforme
18193	2	316	135	4.5	50	62	WM	No permit	310	20.5	+++	200/135	Arteriolar nephrosclerosis, cerebrovascular accident
18217	2	310	146	3.9	75	49	WF	610	330	15	++	140/98	Rheumatic heart disease
18112	0	254	136	4.4	19	49	CF	680	250	18	++	120/95	Cirrhosis
18129	0	116	144	3.9	18	1.1	CF	66	123	10	0		Lung abscess
18145	0	363	140	4.5	50	60	WM	500	300	26	+++	170/100	Parathyroid adenoma
18182	0	355	134	7.0	227†	47	WF	250	450	11	+	160/94	Hypoxic nephrosis
18250	0	321	140	3.9	83	50	WF	400	250	20	+++ (with necrosis)	140/90	Malignant nephrosclerosis
18312	0	358	132	4.9	335	19	WF	290	520	14	0	150/70	Hypoxic nephrosis
18348	0	284	135	3.2	317	36	CF	No permit	162	28	+++ (with necrosis)	180/110	Malignant nephrosclerosis

* JGI indicates juxtaglomerular granulation index.

† Symbol indicates blood urea nitrogen; no symbol indicates nonprotein nitrogen.

‡ Right kidney only; left kidney resected.

determinations within the last week of life did not give an adequate representation of the levels of plasma electrolytes for correlation with cytologic findings at death. Some of the observations on the remainder of the 200 cases, however, are also included here. The average was taken of levels of plasma sodium, potassium, and nonprotein nitrogen determined during the last week of life. In some cases where the nonprotein nitrogen was unavailable, the level of blood urea nitrogen was substituted.

Adrenal glands were examined from the selected group of 24 cases. The reticulum pattern proved the most satisfactory method for defining the limits of the cortical zones.[12] Frequently the boundary between zona glomerulosa and zona fasciculata was extremely irregular and difficult to determine. Consequently, the thickness of the zona glomerulosa was measured at 20 to 30 randomly selected sites and an average taken. All measurements and counts were done without the observer knowing the clinical data from the case.

Weights of heart, kidneys, and adrenals were noted at necropsy, and the degree of hyalinization of the preglomerular afferent arteriole was recorded as none, slight, moderate, or advanced (0, +, ++, +++). The statistical relationships between these elements were evaluated. Data from this group of cases are found in Table I.

Results

In the entire series of 200 cases, the degree of granulation of the juxtaglomerular apparatus was less in children under one month of age than in older children or adults. (Seven of 12 had no detectable granules, and the remainder only a few.) No elevated JGI was noted before one month of age, and only one instance occurred in the one-month to one-year group. There was great overlap in the range of values found in the remainder of the age groups. Because of the skewness of the distribution of values of JGI (a few values were greatly elevated, but most were less than 10), the median rather than the arithmetic mean perhaps gives a better picture of the normal. Although the average JGI for males (10.9) was higher than that for females (5.6), and the average for whites (9.0) higher than that for colored (6.9), the median values were not significantly different (males 4, females 2, white 2, colored 2), and there were great overlaps in the range of values. Consequently, significance could not be assigned to these factors in this series. See Table II for a summary of characteristics of the series as a whole (200 cases).

In the smaller group of 24 cases defined above, the JGI correlated

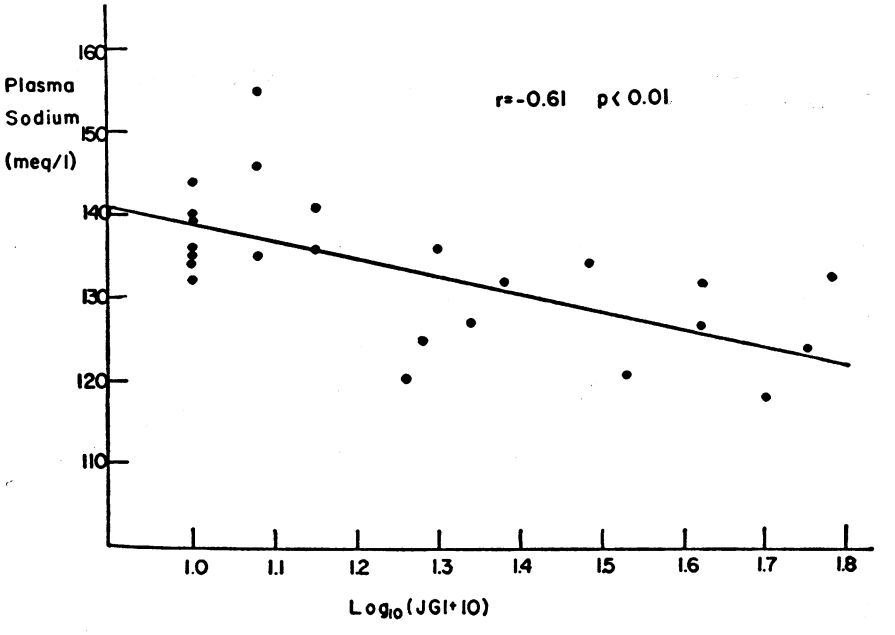
inversely with the level of plasma sodium (Text-fig. 1) and directly with the width of the zona glomerulosa (Text-fig. 2). The $\log_{10}$ (JGI + 10) was used for correlation in order to obtain linearity.[13] In the group of cases with 0 or 1+ degrees of hyalinization of the preglomerular arteriole, the JGI was significantly higher than in those with

TABLE II

Summary of Characteristics of 200 Cases

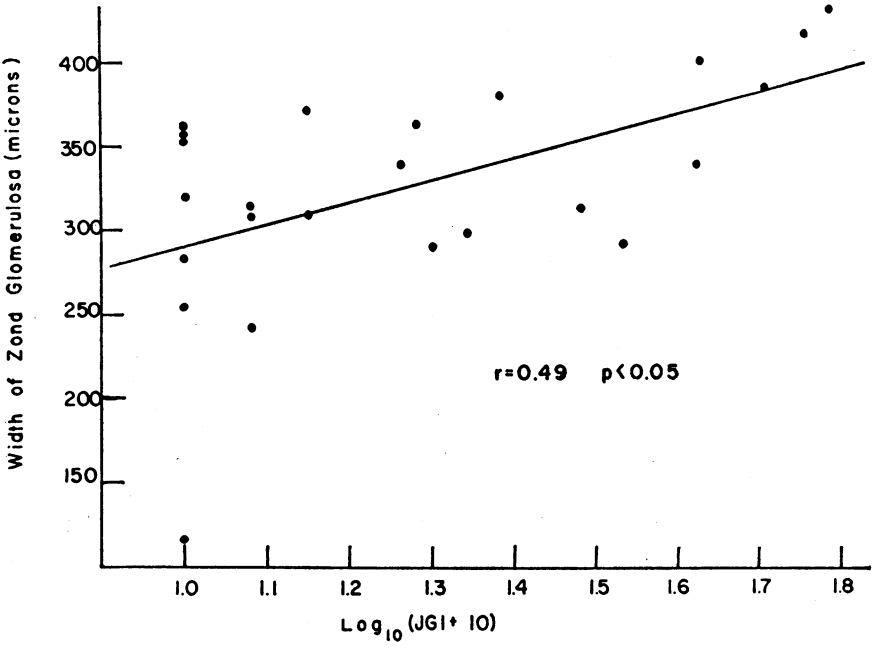
Number of cases					Age		JGI		
Males	Females	White	Colored	Total	Average	Range	Average	Median	Range
110	90	159	41	200	45.6	0–86	8.6	2	0–120

2+ or 3+ hyalinization. ($t = 2.15$; $p < 0.05$). No significant correlation of JGI was found with levels of blood pressure, plasma potassium, nonprotein nitrogen or with the weights of the heart, kidneys, or adrenals. On the other hand, the correlation established by Peschel and Race between the thickness of the zona glomerulosa and the dietary sodium intake in man was supported, because the width of the zona glomerulosa was found to correlate inversely with the levels of plasma sodium[5] (Text-fig. 3; Figs. 9 and 10).

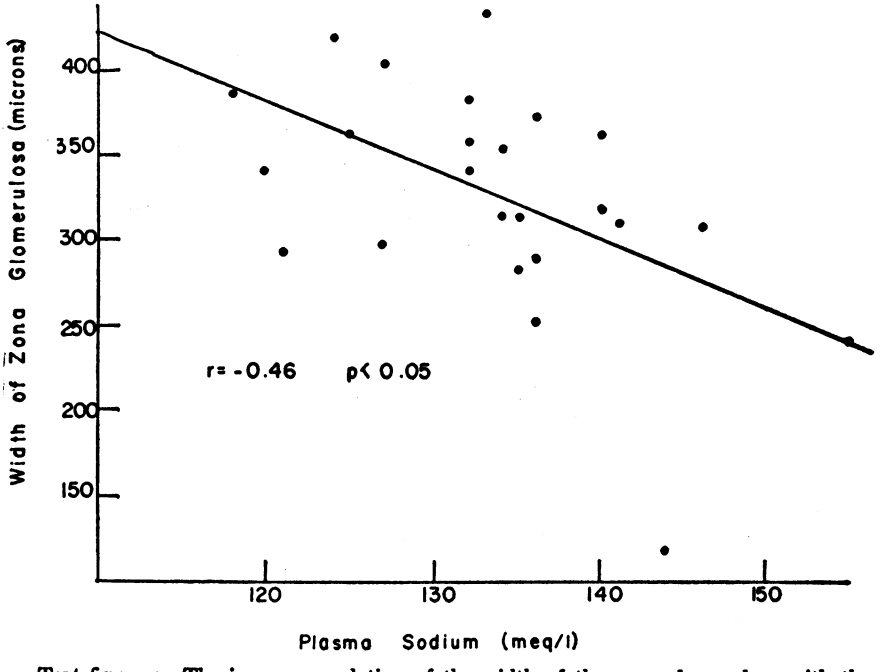


Text-figure 1. The inverse correlation of the juxtaglomerular granulation index (JGI) with the level of plasma sodium in 24 selected cases.

The anatomic changes of the juxtaglomerular cells with hyper-



Text-figure 2. The direct correlation of the JGI with the width of the zona glomerulosa in 24 selected cases.



Text-figure 3. The inverse correlation of the width of the zona glomerulosa with the level of plasma sodium in 24 selected cases.

granulation were fairly consistent. When only a few granules were present in the cell, they were usually found in perinuclear sites, although they could be found anywhere in the cytoplasm (Fig. 1). Granulation could be of sufficient amount, however, to fill the cell completely (Fig. 3). Such degrees of granulation were unusual in these studies on man. Granules were, in general, more difficult to find in human kidneys than in those of most laboratory animals. In view of the very low JGI normally found in man, degranulation could not be evaluated as readily as in animals. In the rare instances of extreme hypergranulation, the granular cells extended proximally from the glomerulus nearly down to the origin of the arteriole (Fig. 4). Those surrounding the preglomerular arteriole increased in number. The wall of the arteriole became thicker in an eccentric manner and appeared to bulge into the lumen of the tubule (Figs. 5 and 6). The thicker side lay next to the *macula densa*. Intermingled with the granular cells, cells with clear agranular and afibrillar cytoplasm could be seen (Figs. 1 and 4). Although hyperplasia of the juxtaglomerular elements usually was associated with hypergranulation, hyperplasia was not studied sufficiently to state whether dissociation of hyperplasia and hypergranulation occurred frequently.

In the sections stained with hematoxylin and eosin, advanced degrees of hyperplasia could be detected and increased granulation assumed. If many glomeruli with unusually large nodules of cells at their vascular poles were seen, or the walls of the afferent arterioles were unusually thickened by several layers of cells, then hypergranulation was frequently present (Figs. 1 and 2). Hypergranulation was not always found in such cases, however, so that a stain to demonstrate granules was always necessary (Fig. 7). In this laboratory the Bowie stain was the most satisfactory for this purpose, but the Masson trichrome and the McManus periodic acid-Schiff stains also served to demonstrate granularity.

The juxtaposition of the *macula densa* and juxtaglomerular cells suggested an associated function. The primary emphasis of this study was not on the *macula densa* but upon several types of changes which were noted in it. The *macula densa* cells ranged from cuboidal to columnar in height (Figs. 5 and 6). In some cases the ratio of the number of *maculae densae* to glomeruli was increased over normal, indicating an increase of the former. Basilar vacuolization was noted frequently (Figs. 5 and 6). In some instances in which tubular degeneration was observed, the *macula densa* appeared relatively spared. No correlation of these changes with the clinical factors studied was demonstrated.

Discussion

The specialized elements in the walls of preglomerular renal arterioles referred to as the juxtaglomerular apparatus were first noted by Ruyter[14] in 1925 although it was not until 1927 that their existence in the human kidney was established.[15] Goormaghtigh pioneered the attempt to define the function of this group of cells. He felt that they had an endocrine function and postulated that they were the source of the vasopressor, renin.[16,17] Hypergranulation of the juxtaglomerular cells has been shown to occur during the early stages of experimental renal ischemia[18] but has not been noted to accompany benign hypertension in man. The early work in this field was concerned primarily with the phenomenon of hyperplasia rather than hypergranulation.

Variation of granulation in the juxtaglomerular apparatus with the level of plasma sodium further suggests an endocrine function. The behavior of the granulation, if hypergranulation can be equated with increased function, is that which would be expected if the granules represented a trophic hormone or its precursor. In response to a low level of plasma sodium, hypertrophy of the zona glomerulosa and increased secretion of mineralo-corticoids would be anticipated. This concept is also compatible with the observation of Dunihue (supported by a case in this series of primary atrophy of the adrenals) that hypergranulation is found in adrenalectomized animals.[4,5] However, these data are not in accord with the conception suggested by Dunihue and Robertson[19] that granulation is correlated inversely with the blood level of mineralo-corticoids.

Juxtaglomerular cells have been proposed as the source of renin.[16,17] The data presented here are compatible with this hypothesis if it is assumed that the renin-hypertensin system is essentially a homeostatic mechanism analagous to the carotid sinus reflex. A fall in blood pressure would call forth a renin response, and a rise would decrease the output and be reflected by the presence of fewer granules in the juxtaglomerular apparatus (low JGI). Other evidence, however, suggests that renin is found primarily in the proximal convoluted tubules.[20]

The possibility that the juxtaglomerular apparatus produces a hormone which has combined vasopressor and sodium retaining properties should be considered. Renin extracts have been shown to increase the thickness of the zona glomerulosa, and thus appear to have a trophic as well as a vasoconstrictor effect.[21] The relationship of blood pressure and sodium metabolism is so intimate, however, that their regulating mechanisms may well be combined at times.

Although in this group of cases the level of nonprotein nitrogen

(NPN) did not correlate significantly with the JGI, many of the cases with an elevated JGI were noted also to have an NPN which was elevated to some degree. However, in the absence of a low plasma sodium level, an elevated JGI was not found even with a greatly elevated NPN. A high level of plasma potassium, although not significant in itself, seemed in some cases to enhance the effect on the JGI of low plasma sodium levels. Some of the cases with the highest JGI had, in addition to low plasma sodium levels, evidences of hyperkalemia. The specific nature of the disease process did not appear important with respect to the elevation of JGI. Indeed, as indicated by McManus,[22] cirrhosis, hypoxic nephrosis, malignant hypertension, and Addison's disease were frequently noted to be associated with hypergranulation of the juxtaglomerular cells. A number of these patients also had low plasma sodium levels at death, but in those cases in which the plasma sodium was normal terminally, no hypergranulation was found.

The height of the blood pressure, which has frequently been related to the juxtaglomerular apparatus, was not found to be correlated significantly with the JGI in this group. The tendency, if any, appeared to be an inverse one. In animals an inverse relationship of this nature has been established.[23] Perhaps a larger group of cases would show significant correlation, but if this were so, it would probably be readily obscured by any associated changes in levels of plasma sodium. The definite inverse correlation of JGI with preglomerular arteriolar hyalinization is somewhat surprising in view of this observation and suggests that further studies should be done.

It is tempting to try to associate the sparsity of granules in the juxtaglomerular apparatus in the kidney of the very young with the known immaturity of renal function in the infant. However, this feature may only be indicative of the nature of the disease and the rapidity with which infants die.

The relationship demonstrated between the JGI, the width of the zona glomerulosa of the adrenal cortex, and the plasma sodium level extends the earlier work carried out in animals to man.

Summary

Sections of kidneys procured from an unselected group of 200 patients at necropsy were stained to demonstrate granules in the juxtaglomerular apparatus. A sub-group of 24 cases was selected on the basis of the availability of adequate studies of plasma sodium levels during the last week of life. Three determinations during this period were deemed sufficient for this purpose.

The degree of granulation of the juxtaglomerular apparatus was found to be correlated inversely with levels of plasma sodium and directly with the width of the zona glomerulosa of the adrenal cortex. Other factors considered in the study were thought to play subsidiary roles in this association. An inverse relationship between the levels of plasma sodium and the thickness of the zona glomerulosa has been demonstrated in animals; this study shows that the relationship holds true in man, as well.

The possible functions of the juxtaglomerular cells are discussed.

REFERENCES

1. Deane, H. W.; Shaw, J. H., and Greep, R. O. The effect of altered sodium or potassium intake on the width and cytochemistry of the zona glomerulosa of the rat's adrenal cortex. *Endocrinology,* 1948, **43,** 133–153.
2. Peschel, E., and Race, G. J. Studies on the adrenal zona glomerulosa of hypertensive patients and rats, with special reference to the effect of dietary salt restriction. *Am. J. Med.,* 1954, **17,** 355–364.
3. Race, G. J.; Nickey, W. M.; Wolf, P. S., and Jordan, E. J. Studies on functional zonation of the adrenal cortex. *A. M. A. Arch. Path.,* 1957, **64,** 312–323.
4. Dunihue, F. W. The effect of bilateral adrenalectomy on the juxtaglomerular apparatus. (Abstract.) *Anat. Rec.,* 1946, **96,** 536.
5. Dunihue, F. W. The effect of adrenal insufficiency and of desoxycorticosterone acetate on the juxtaglomerular apparatus. (Abstract.) *Anat. Rec.,* 1949, **103,** 442–443.
6. Hartroft, P. M., and Hartroft, W. S. Studies on renal juxtaglomerular cells. I. Variations produced by sodium chloride and desoxycorticosterone acetate. *J. Exper. Med.,* 1953, **97,** 415–428.
7. Hartroft, P. M., and Hartroft, W. S. Studies on renal juxtaglomerular cells. II. Correlation of the degree of granulation of juxtaglomerular cells with width of the zona glomerulosa of the adrenal cortex. *J. Exper. Med.,* 1955, **102,** 205–212.
8. Des Prez, J. The juxtaglomerular apparatus of the hypertensive kidney. *Am. J. Clin. Path.,* 1948, **18,** 953–960.
9. Kaufmann, W. The Goormaghtigh cells in the normal and diseased human kidney. Their possible relationship to renal hypertension. *Am. J. Path.,* 1942, **18,** 783–797.
10. Oberling, C. Further studies on the preglomerular cellular apparatus. *Am. J. Path.,* 1944, **20,** 155–171.
11. Cowdry, E. V. Laboratory Technique in Biology and Medicine. The Williams & Wilkins Co., Baltimore, 1952, ed. 3, 382 pp.
12. Elias, H., and Pauly, J. E. The structure of the human adrenal cortex. *Endocrinology,* 1956, **58,** 714–738.
13. Snedecor, G. W. Statistical Methods. Ames, Iowa, State College Press, Ames, Ia., 1946, ed. 4, pp. 138–168, 374–399.
14. Ruyter, J. H. C. Ueber einen merkwürdigen Abschnitt der Vasa afferentia in der Mäuseniere. *Ztschr. f. Zellforsch. u. mikr. Anat.,* 1925, **2,** 242–248.
15. Oberling, C. L'existence d'une housse neuro-musculaire au niveau des artères glomérulaires de l'homme. *Compt. rend. Acad. Sc.,* 1927, **184,** 1200–1202.

16. Goormaghtigh, N. Existence of an endocrine gland in the media of the renal arterioles. *Proc. Soc. Exper. Biol. & Med.*, 1939, **42**, 688–689.
17. Goormaghtigh, N. La Fonction Endocrine des Artérioles Rénales. Son Rôle dans la Pathogénie de l'Hypertension Artérielle. Librairie R. Fonteyne, Louvain, 1944, 110 pp.
18. Dunihue, F. W. Effect of cellophane perinephritis on the granular cells of the juxtaglomerular apparatus. *Arch. Path.*, 1941, **32**, 211–216.
19. Dunihue, F. W., and Robertson, W. V. The effect of desoxycorticosterone acetate and of sodium on the juxtaglomerular apparatus. *Endocrinology*, 1957, **61**, 293–299.
20. Goldblatt, H. The renal origin of hypertension. *Physiol. Rev.*, 1947, **27**, 120–165.
21. Deane, H. W., and Masson, G. M. C. Adrenal cortical changes in rats with various types of experimental hypertension. *J. Clin. Endocrinol.*, 1951, **11**, 193–208.
22. McManus, J. F. A. Medical Diseases of the Kidney (an Atlas and Introduction). Lea & Febiger, Philadelphia, 1950, pp. 36–38.
23. Hartroft, P. M. Studies on renal juxtaglomerular cells. III. The effects of experimental renal disease and hypertension in the rat. *J. Exper. Med.*, 1957, **105**, 501–508.

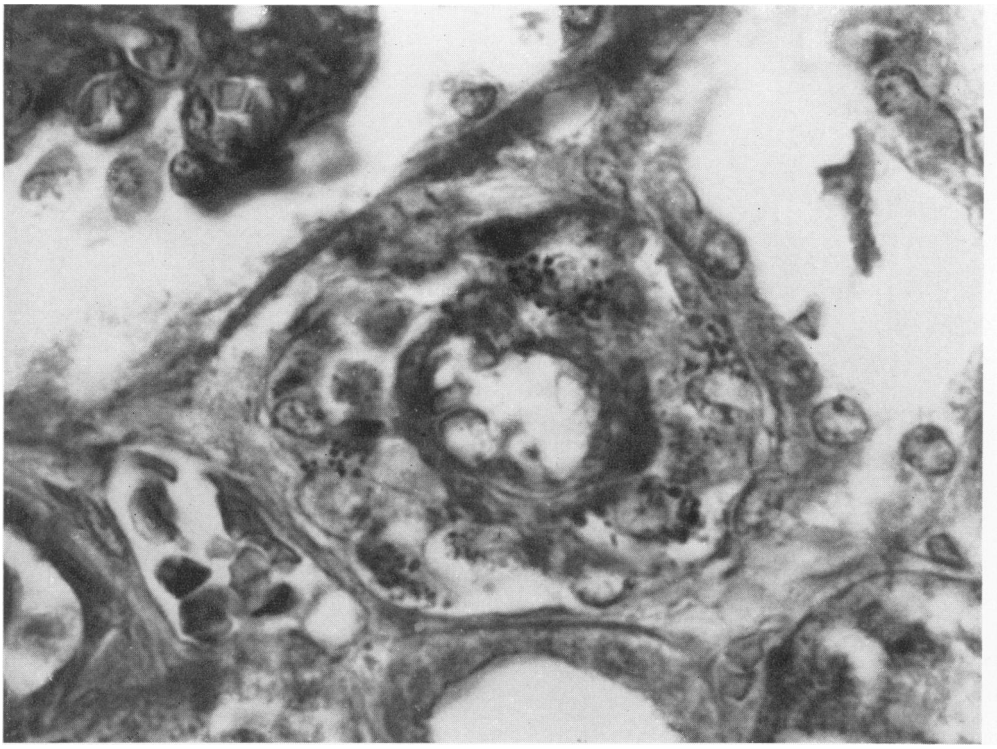
We wish to acknowledge many helpful suggestions and criticisms from Professor W. S. Hartroft and Professor Margaret G. Smith.

[*Illustrations follow*]

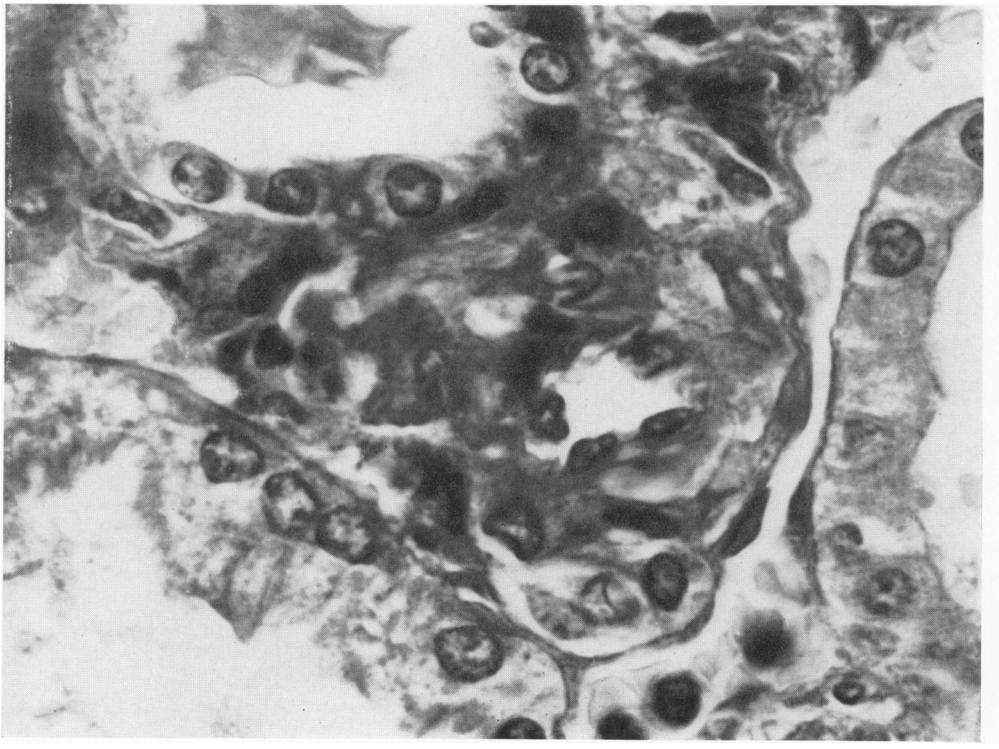
LEGENDS FOR FIGURES

FIG. 1. Case 18133. Cross section of an afferent arteriole adjacent to a glomerulus. Granular and agranular juxtaglomerular cells cause thickening of its wall (JGI = 104). Note the perinuclear distribution of granules when only a few are present. Bowie stain. × 1,200.

FIG. 2. Case 18133. Cross section of an afferent arteriole with cellular thickening of wall. Hematoxylin and eosin stain, to be compared with Figure 1. × 1,200.



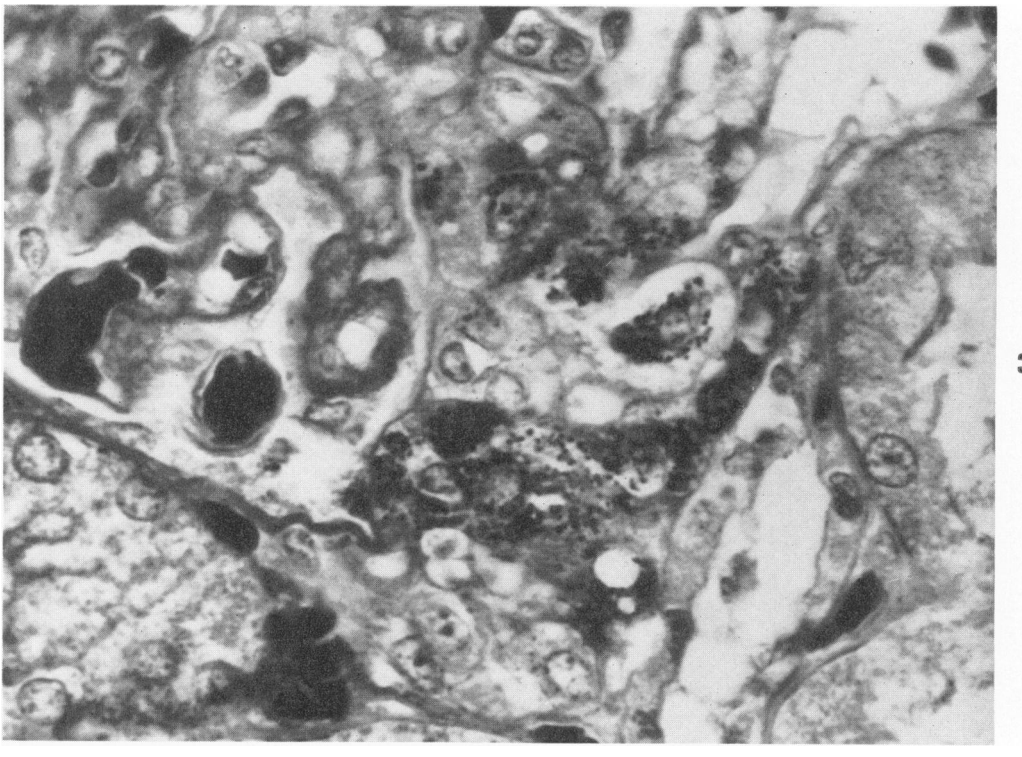
1



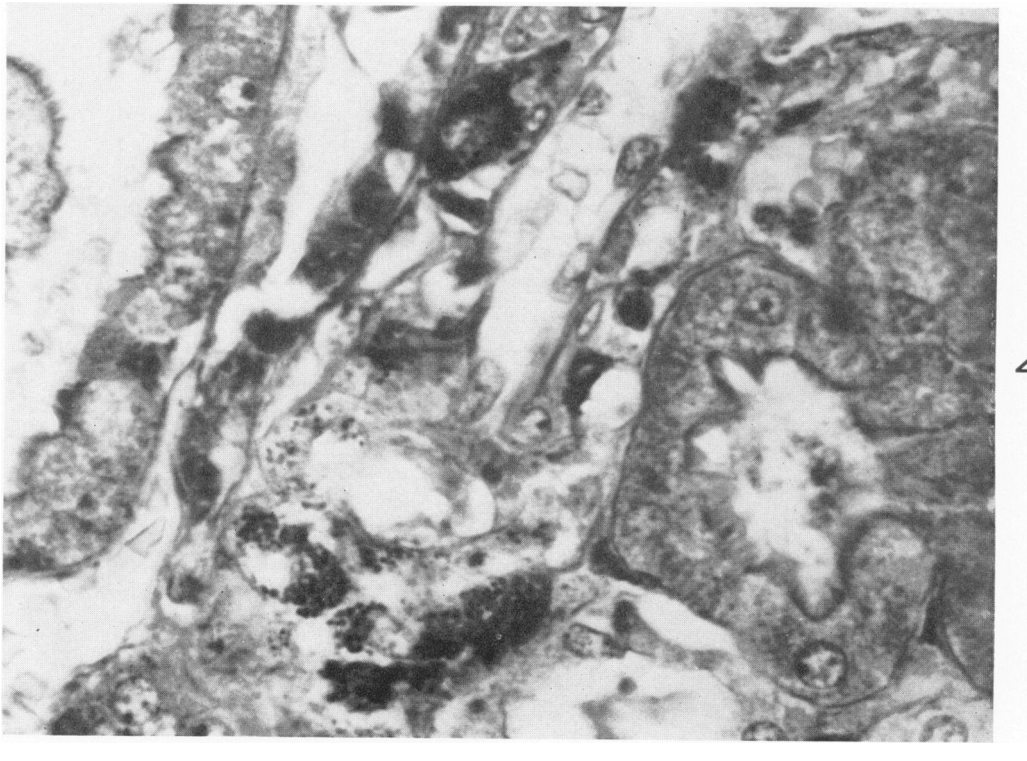
2

FIG. 3. Case 18133. Section through a glomerular root, demonstrating advanced hypergranulation of the juxtaglomerular cells. (JGI = 104). Bowie stain. × 1,000.

FIG. 4. Case 18133. Section of an afferent arteriole proximal to a glomerulus, showing granular cells extending down an arteriole. The glomerulus is above the field shown. (JGI = 104). Bowie stain. × 1,000.



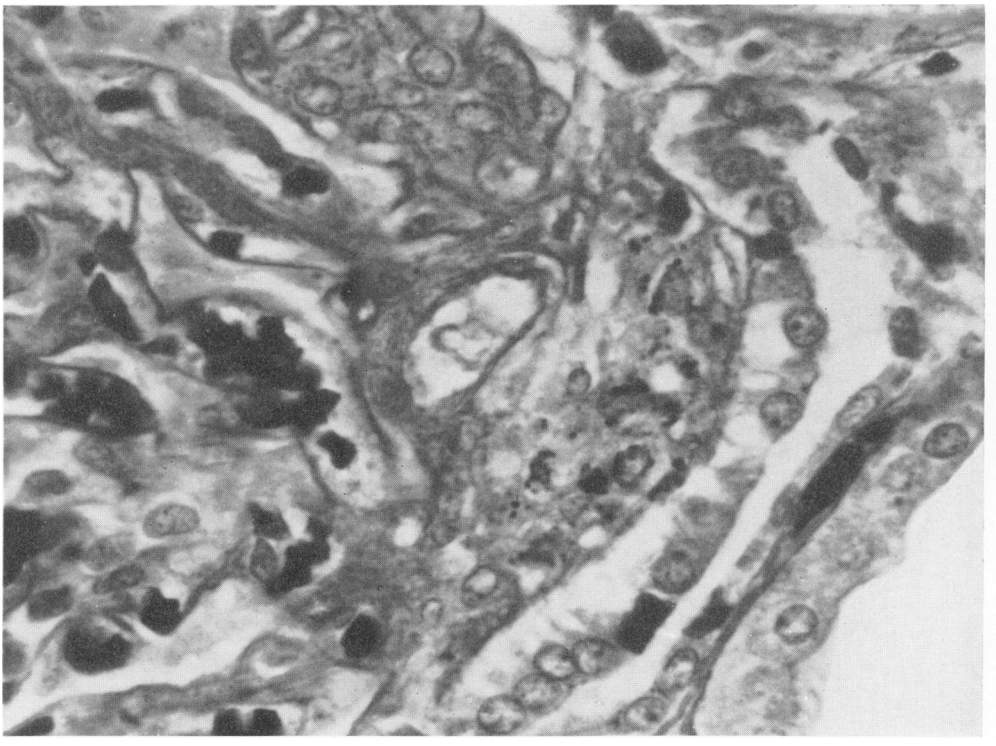
3



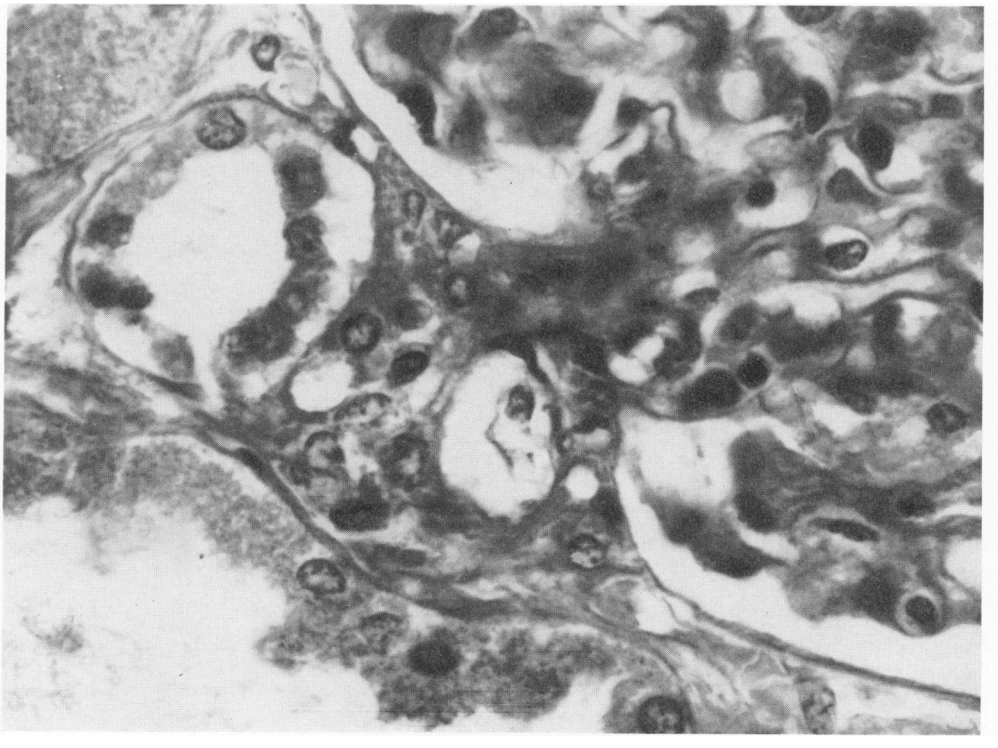
4

FIG. 5. Case 18338. Section of a glomerular root. Eccentric hyperplasia of juxtaglomerular cells causes bulging into the lumen of the distal tubule (JGI = 40). Note basilar vacuolation of *macula densa* cells. Bowie stain. × 1,000.

FIG. 6. Case 18338. Section at a different angle from that shown in Figure 5, demonstrating eccentric hyperplasia of the juxtaglomerular cells. Hematoxylin and eosin stain. × 1,000.



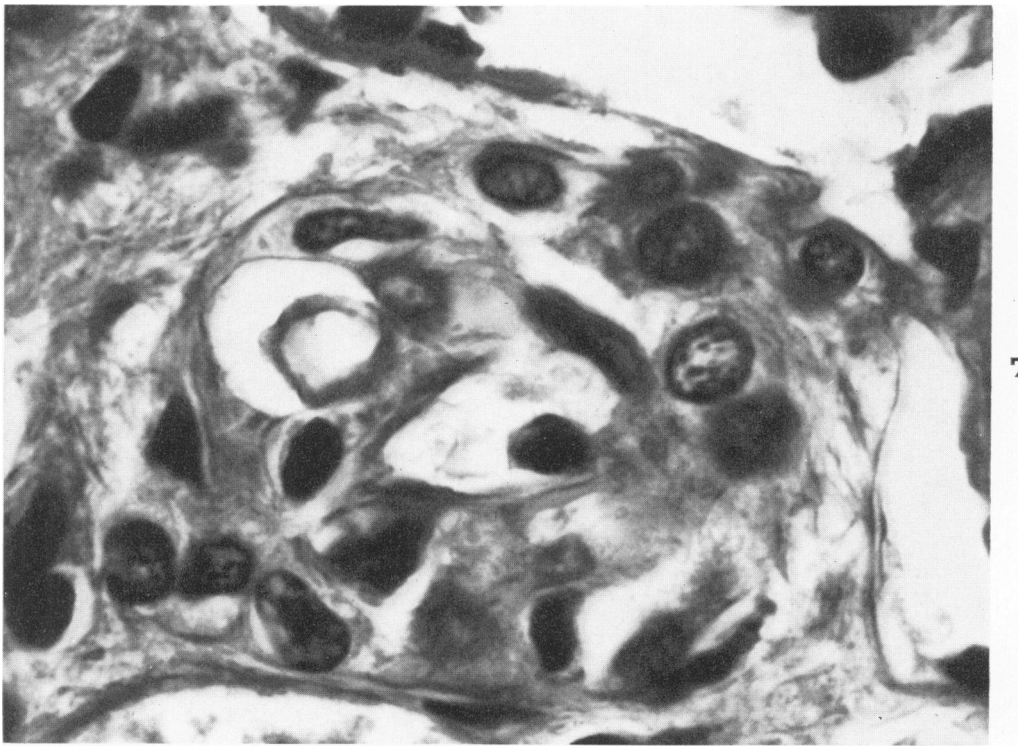
5



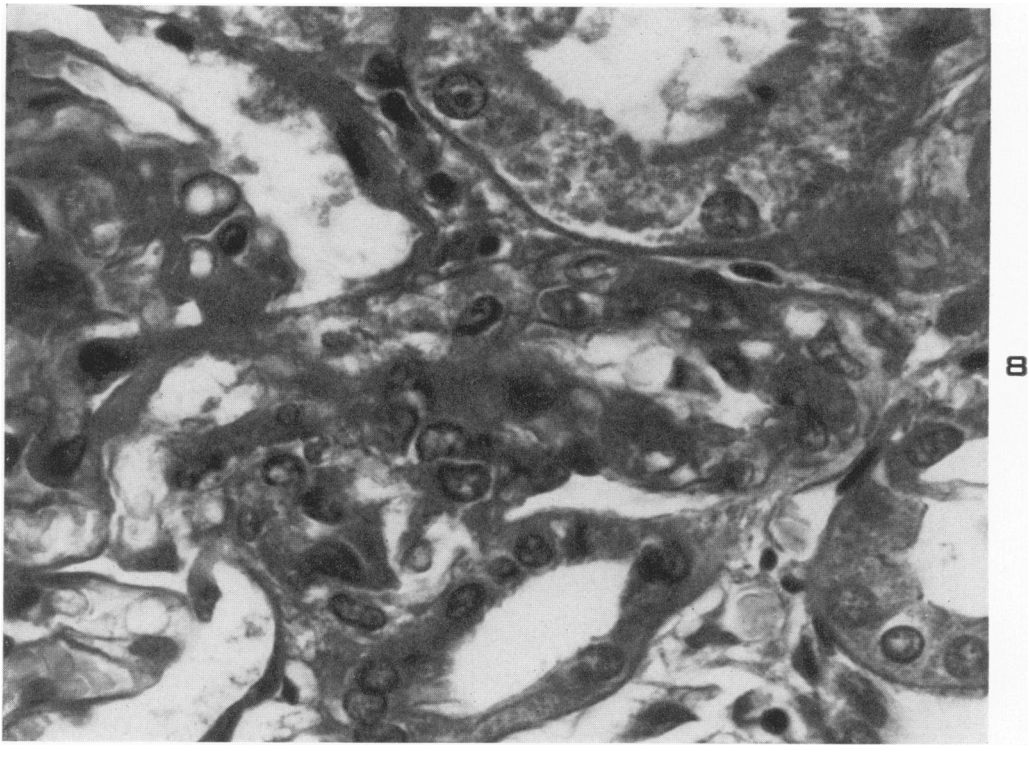
6

FIG. 7. Case 18217. Cross section of an afferent arteriole with apparent thickening of its wall. In a section stained with Bowie's stain increased granulation was not shown (JGI = 2). Hematoxylin and eosin stain. × 1,900.

FIG. 8. Case 18133. Section through an afferent arteriole and *macula densa* with eccentric hyperplasia of juxtaglomerular cells. Hematoxylin and eosin stain. × 1,000.



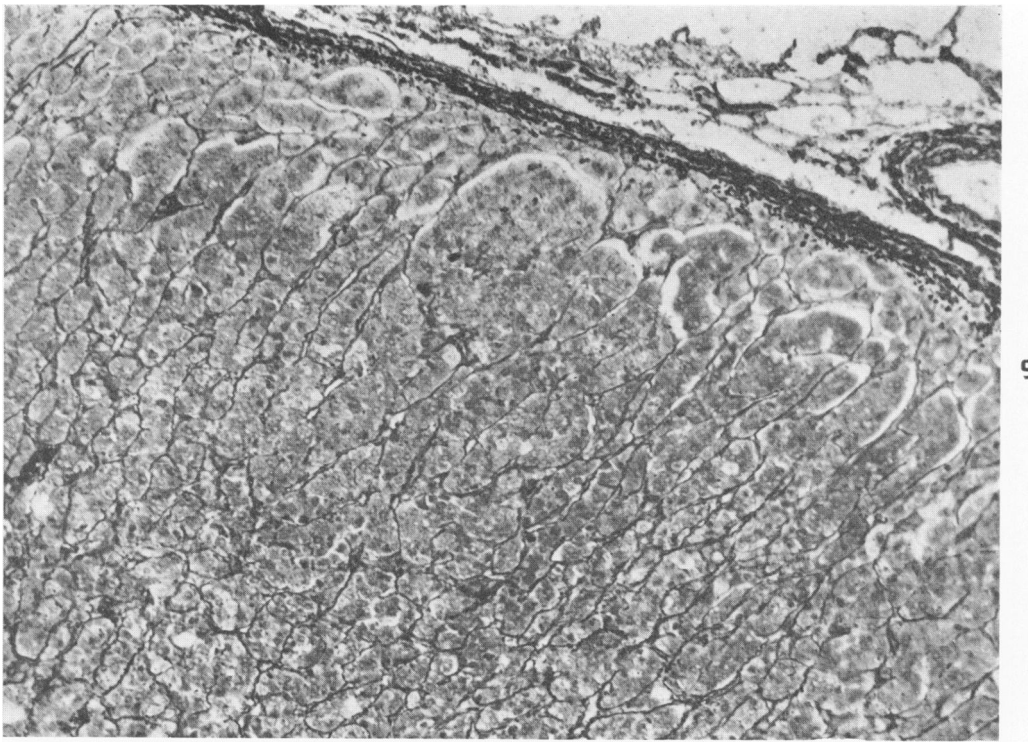
7



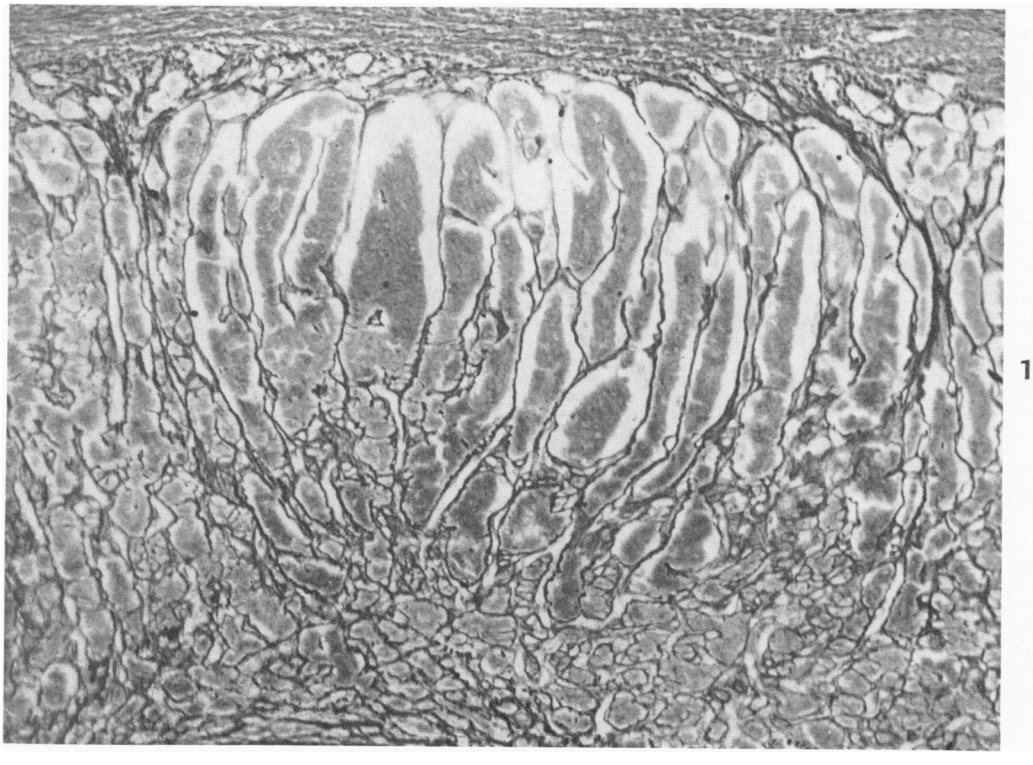
8

FIG. 9. Case 18114. Adrenal cortex from a case with normal plasma sodium level. Boundary between reticulum patterns of zona glomerulosa and zona fasciculata is irregular. Wilder reticulum stain. × 100.

FIG. 10. Case 18107. Adrenal cortex from a case with low plasma sodium level. Widening of the zona glomerulosa is apparent although the boundary with the zona fasciculata is irregular. Wilder reticulum stain. × 100.



9



10