Embryology

The kidneys develop from an intermediate mass of mesoderm (the nephrogenic cord) situated on the posterior wall of the intraembryonic coelom between the dorsal somites and the lateral plate mesoderm. Three successive excretory organs develop in the early human embryo—the pronephros, the mesonephros and the metanephros. These three “kidneys” form sequentially and progressively and more caudally, but there is considerable overlap both chronologically and topographically. The pronephros and mesonephros are transient vestigial structures, and the definitive kidney forms from the metanephros. The mesonephric (or Wolffian) duct persists in male embryos as the duct of the epididymis, the vas deferens, and the ejaculatory duct.

The metanephros develops in two parts; the nephrons (glomeruli and tubules) from the nephrogenic cord caudal to the mesonephros (the metanephric blastema) and the excretory system (the ureter, pelvis, calyces and collecting ducts) from the ureteric bud, which develops as a branch of the Wolffian duct near its distal end. During early development the ureteric bud growscranially and impinges on the metanephric blastema, where it begins a process of rapid dichotomous branching. Our understanding of the differentiation of the metanephros has been greatly extended by the microdissection studies of human fetal kidneys by Osthannondh and Potter (1963a–c, 1966a,b). These authors recognized two parts of the ureteric bud and each of its branches:

1. The dilated tips, or ampullae, which are capable of dichotomous branching and the induction of nephron formation in the related metanephric blastema
2. Tubular, or interstitial, portions behind the ampullae, which are capable of growth by elongation.

Rapid branching of the ureteric bud on reaching the metanephric blastema results in a large number of ampullae with short interstitial portions. Nephron formation and subsequent urine secretion causes their dilatation and coalescence to form the renal pelvis and calyces. The renal pelvis and major calyces are derived from the first three to five branches and the minor calyces from the next three to five branches of the ureteric bud. Urine production causes dilatation and coalescence of the generations of branches forming the minor calyces, but the differentiation of nephrons around the calyces limits the dilatation of adjoining calyces and results in the invagination of overlying parenchyma to produce the renal papillae surrounded by flask-shaped calyces.

During the early phase of nephron production branching of the ureteric bud continues. Condensations of metanephric blastema, from which the nephrons develop, become related to the ampullae. As the nephrons form they quickly become attached to the ampullae, which in turn develop into collecting ducts. This rapid attachment to the growing tips of the ureteric bud ensures that the nephrons are carried outwards as the ureteric bud grows and branches. Figure 8.1 illustrates the process of nephron formation. Subsequently (from about the 14th week of gestation onwards) branching of the ureteric bud ceases and each ampulla becomes capable of inducing the formation of a number of new nephrons. Each of these becomes attached in turn to the previously formed nephrons, to form a chain,
Fig. 8.1. Nephron formation: 1. nephrons formed during initial phase of ureteric bud branching; 2. nephron arcade; 3. nephrons added singly till nephronogenesis ceases (32–36 weeks). (After Ostanondh and Potter 1963c)

or nephron arcade. The inner members of the arcade are formed first, and the innermost nephron in the chain is one of those formed during the first phase when the ureteric bud was branching.

After about the 22nd week of gestation the ampullae advance outwards beyond the point where nephron arcades are formed, and subsequently new nephrons are added singly. At this stage the nephrons become attached just behind the zone of active ampullary growth, and are not, therefore, carried outwards as the ampullae advance. By the 36th week of gestation ampullary growth and new nephron induction cease (Fig. 8.2).

Individual nephrons form from oval condensations of metanephric blastema, which rapidly develop a lumen that elongates and become S-shaped. The lumen of the developing nephron rapidly connects with the lumen of the ureteric bud. The proximal part of the S-shaped nephron becomes concave around the capillaries that form the glomerular tuft, which are derived from capillary sprouts arising from arteriovenous shunts adjacent to the glomeruli. The walls of the proximal limb of the developing nephron become stretched over the tuft to form the epithelial cells covering the glomerular tuft capillaries (the podocytes) and the lining cells of Bowman’s capsule, with the lumen between them forming the urinary space. The rest of the curved tubular portions of the developing nephron elongate and differentiate into the various parts of the nephronic tubules (proximal and distal convoluted tubules and the loop of Henle).

**Congenital Anomalies**

The commoner congenital abnormalities of the kidneys can conveniently be divided into (1) anomalies of position and form, and (2) parenchymal maldevelopments.

**Renal Ectopia**

During its development, the metanephros ascends to its ultimate level (between the 12th thoracic and 3rd lumbar vertebrae). This apparent upward migration is largely due to differential growth of the caudal part of the embryo, and is accompanied by medial rotation of the kidney so that the hilus and renal pelvis, which are at first located anteriorly, come to lie on the anteromedial aspect. Interference with, or arrest of, this process results in an abnormal position and often in an abnormal shape of one or both kidneys, or to their fusion across the midline.

Ectopic kidneys are most commonly found at the pelvic brim or in the pelvic cavity. They are usually malrotated with the renal pelvis pointing forward, are rounded or lobulated rather than reniform, and have an ectopic blood supply. Commonly a number of small arteries supply the kidney rather than a single large renal artery; these arise from the aorta near the bifurcation, or from the iliac arteries. It is not uncommon for ectopic kidneys to exhibit parenchymal maldifferentiation (renal dysplasia), and distortion or kinking of the renal pelvis may cause hydronephrosis predisposing to renal infection. Ectopia may be unilateral or bilateral and its incidence is about 1 in 800; it is slightly commoner in females and on the left. Occasionally unilateral