INTRODUCTION

Urolithiasis denotes the pathological crystallization of minerals that are deposited in the form of calculi or “stones” in the urinary tract, especially in the kidney. In contrast to the biologically controlled formation of bone and teeth, urolithiasis is a spontaneous process resembling the formation of minerals in low-temperature, aqueous geochemical environments. This review explores the thermodynamic and kinetic aspects of mineral-urine interactions, together with pathological preconditions of urolithiasis. Various calcium phosphate minerals are crucially involved in kidney stone pathology, but many chemical and mineralogical issues relating to them remain unclear. We summarize what is currently known and identify the most important areas for future work. Progress is unlikely unless current understanding can be made more quantitative.

Kidney stone formation is a worldwide problem (Linder and Little 1986; Grases et al. 1999; Moe 2006) and is very painful (Grases et al. 1998; Thomas and Hall 2005). There is a high economic cost associated with the condition as a result of hospitalization and days taken off work (Linder and Little 1986; Grases et al. 1998, 1999; Parks and Coe 1996). Although surgical treatments have improved, there is a high, and increasing, incidence of the pathology (Romero et al. 2010; Tiselius 2011b). Despite much research, the underlying causes are still not well understood; prevention has therefore proved difficult (Söhnle and Grases 1995; Grases et al. 1998; Grases and Costa-Bauza 2006; Evan et al. 2015; Tiselius 2015).

Some risk factors, however, are well known. Incidence is age and gender dependent, being twice as common in males than in females (Hesse et al. 1986; Moe 2006; Hughes 2007; Romero et al. 2010; Tiselius 2011b), with a peak age of presentation at 20 to 50 yr (Robertson et al. 1981; Hesse et al. 1986; Hughes 2007). Dietary factors are significant, especially increasing risk are diets high in animal protein (Abdel-Halim 2005; Tiselius 2011b) and fat (Tiselius 2011b). Insufficient fluid intake, resulting in a more concentrated urine significantly exacerbates the problem (Tiselius 2011b). Obesity is another well known risk factor (Abdel-Halim 2005; Hughes 2007; Romero et al. 2010; Tiselius 2011b; Rendina et al. 2013). The environment also has an effect: risk is increased for those living in hot climates and in periods of hotter weather (Soucie et al. 1994; Moe 2006; Hughes 2007; Romero et al. 2010). Genetic influences are known to be important and differences have been noted in rates of urolithiasis between different racial groups. Incidence and prevalence is highest in Caucasians, decreasing in Hispanics and Asians and lowest in Africans (Soucie et al. 1994; Hughes 2007; Romero et al. 2010; Moran 2014). In fact, kidney stones are very rare in most of Sub-Saharan Africa (Kumar and Muchmore 1990; Rodgers 2006).

PHYSIOLOGY

The kidneys perform the vital function of removing unwanted substances from the blood. To understand kidney stone formation it is necessary to consider first the processes of filtration and reabsorption. The balance between these two plays a key role in the potential nucleation of stone forming minerals. Filtration starts with an unselective separation, where the fluid that is blood plasma passes through an ultrafiltration membrane into the tubules of the kidney. This is then followed by (1) a selective reabsorption process, in which metabolically useful substances are returned from the filtrate back into the blood, and (2) secretion, in which unwanted substances are transferred into the fluid in the tubule, and thus ultimately become excreted in the urine.

The basic functional unit of the kidney is called a nephron. A nephron is a tube, through which flows the fluid being processed by the kidney. Each nephron consists of several sections for add-