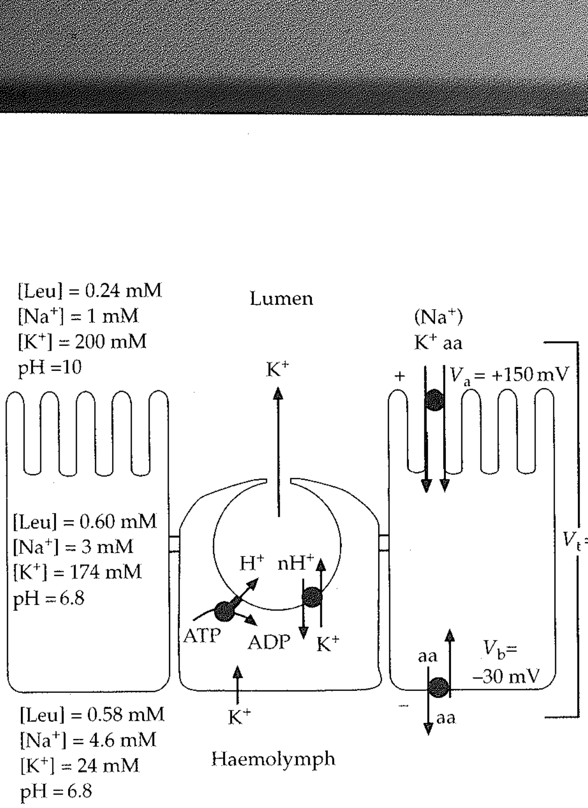

Figure 2.7 Model of amino acid absorption in the midgut of a caterpillar (*Philosamia cynthia*).

Note: A goblet cell is shown between two columnar absorptive cells. The left columnar cell shows leucine, Na^+ and K^+ concentrations and pH values in the lumen, cell and haemolymph. The goblet cell shows mechanisms involved in K^+ transport. The right columnar cell shows mechanisms involved in amino acid (aa) absorption and apical (V_a), basal (V_b) and transepithelial (V_t) electrical potential differences. Basal exit mechanisms for amino acids are less well known.

Source: *Biology of the Insect Midgut*, 1996, pp. 265–292, Sacchi and Wolfersberger, with kind permission of Kluwer Academic Publishers.

Na^+/K^+-ATPase are located on apical and basal membranes, respectively.

The plasma membrane V-ATPase of *M. sexta* is well characterized (Harvey *et al.* 1998). When feeding ceases in preparation for a larval–larval moult, downregulation of the V-ATPase is thought to be achieved by reversible dissociation of the peripheral ATP-hydrolysing complex from the membrane-bound H^+-translocating complex (Sumner *et al.* 1995). Expression of V-ATPase genes is also downregulated at this time, under the control of ecdysteroids (Reineke *et al.* 2002). This economy is necessary because 10 per cent of larval ATP production is consumed by midgut K^+ transport, that is, by the V-ATPase.

The pH of the midgut lumen varies with phylogeny and feeding ecology, and extreme alkalinity occurs in several orders besides Lepidoptera (Clark 1999; Harrison 2001). Extreme pH has complex effects on the activity of ingested allelochemicals (Section 2.4.3 and see Appel 1994). For caterpillars, a disadvantage of high gut pH is that it facilitates activation of Bt toxin (Dow 1984). The midgut of mosquito larvae is highly alkaline, probably through similar molecular mechanisms, and this characteristic might provide a basis for disease vector control just as it has for control of agricultural pests (Harvey *et al.* 1998). Insect acid–base physiology was reviewed by Harrison (2001).

2.3.3 Absorption of nutrients

Gut absorption was reviewed by Turunen (1985). Absorption includes transport across both apical and basal membranes, but there is more information on apical mechanisms. These are usefully studied by using purified plasma membranes which form sealed vesicles containing fluid of known composition, and can be pre-loaded with ions or amino acids (Sacchi and Wolfersberger 1996).

Leucine absorption in the midgut of *Philosamia cynthia* larvae (Lepidoptera, Saturniidae) has been well studied, and a model for leucine uptake by columnar cells is shown in Fig. 2.7. Goblet and columnar cells cooperate in ionic homeostasis and absorption of nutrients: the V-ATPase and K^+/nH^+ antiporter on the apical membrane of the goblet cells energize K^+-amino acid symporters on the microvilli of columnar cells. Amino acid transport is coupled to the movement of K^+ down its electrochemical gradient from lumen to cell. This contrasts with the Na^+-cotransport system of vertebrates and some insects (e.g. cockroaches), involving the basolateral Na^+/K^+-ATPase and apical transport proteins in the same cell (Sacchi and Wolfersberger 1996). The affinity of the symporter for Na^+ is about 18 times that for K^+, but since the luminal K^+ concentration is 200 times