

WASTE PRODUCTS OF NITROGEN METABOLISM

Proteins and nucleic acids are the two main sources of nitrogenous wastes. Proteins are the source of over 95% of the total amount of excreted nitrogen; nucleic acids make up the remaining 5%. The major problem is to get rid of the ammonia (NH_3) that forms when amino groups ($-\text{NH}_2$) are split from amino acids derived from the metabolized protein or from excess dietary protein. Because ammonia is toxic to most vertebrates, it is kept in low concentrations (0.0001 to 0.003 mg/100 ml) in the blood; higher concentrations can be lethal. For example, a mouse will die if the ammonia concentration in its blood reaches 5 mg/100 ml.

Most vertebrates convert ammonia to a less-toxic form immediately after it forms—thus, allowing it to be retained until it can be excreted. Exceptions are teleost fishes, which excrete almost all of their nitrogen as ammonia through the gills and in the urine. Excretion of most of the nitrogen as ammonia is called **ammonotelic excretion**.

As noted in the text, most mammals need to drink water or eat food containing water to maintain a water balance. Mammals produce only a moderate amount of urine—not the quantities necessary to dilute the toxic ammonia. Most of the ammonia formed from amino acid metabolism is therefore converted to urea, which is less toxic than ammonia. Excretion of urea as the primary nitrogenous waste is called **ureotelic excretion**.

In a third category are animals that, because they inhabit dry habitats or for other reasons of water conservation, excrete a minimal amount of urine that contains little or no water. These animals

(e.g., reptiles, some frogs, and birds) convert ammonia to uric acid or another highly insoluble substance. Because the substances are insoluble in water, only small amounts are retained in solution—thus, greatly limiting their toxicity. (For any substance to be toxic and achieve a biological effect, it must be in solution.) Excretion of nitrogen in the form of uric acid is called **uricotelic excretion**. Most uricotelic animals excrete their nitrogenous waste as a solid or semi-solid urine, or as uric acid crystals.

Ammonia, urea, and uric acid are the most common nitrogenous waste products, but not the only ones. Some sharks secrete trimethylamine oxide (TMO). A variety of animals also excrete small quantities of creatine and creatinine. Some animals even wastefully excrete some of their excess amino acids.

Because urea, uric acid, and TMO are less toxic than ammonia, why don't more animals excrete most of their nitrogen in these forms? The answer is in the form of biological economics. The synthesis of these compounds from urea requires an expenditure of ATP energy. **An animal using energy for an unnecessary function might be selected against during evolution.** Therefore, an animal usually excretes its nitrogen in the form requiring the least expenditure of energy, given the environment in which it lives.

A few animals excrete nitrogen that comes from the metabolism of purines (e.g., adenine and guanine). Purines can be broken down to ammonia only if the animal has the enzymes. Most animals excrete purine nitrogen as uric acid or as one or more intermediate products.