Box 3.2 Fritz Haber Changes the Global Nitrogen Cycle

Until the end of the industrial revolution, plants and plant communities depended upon two natural sources of nitrogen: biologically fixed nitrogen and nitrogen fixed by lightning discharges. All of this changed in the early 1900s. The first driving factor was gunpowder, the production of which also required nitrogen. The Germans knew that in the case of war, access to the rich beds of guano in Chile would be cut off by the British navy. The second driving factor was also related to military matters. In the case of war, German supplies of fertilizer (and hence food) would also be at risk. There had to be a way to extract nitrogen directly from the atmosphere.

This process was discovered by a German chemist named Fritz Haber (Figure B3.2.1) in 1909, and it is still named the Haber process in his honour (Oakes 2002). At high temperature and pressure, a metal catalyst is used in converting nitrogen to ammonia. So long as there are sufficient supplies of fuel, such as natural gas, the supplies of nitrogen are now nearly endless.

At very least, Dr. Haber prolonged the cataclysmic First World War by ensuring that both gunpowder and food would be amply available for the German war machine. Sadly, Haber was unable to stop there. He became further involved with chemical warfare, and introduced poison gas attacks, personally supervising them and refining the methods (Figure B3.2.2). Hundreds of thousands of soldiers from Russia, France, Britain and Canada, among others, were blinded, crippled or killed (Haber 1986; Stoltzenberg 2004).

Haber married in 1901, his wife Clara being the first woman in Germany to have earned a PhD in chemistry. Horrified by his involvement in chemical warfare, she shot herself in 1915. Haber continued his poison gas research and married an apparently less squeamish woman in 1917.

**Figure B3.2.1** Fritz Haber was awarded the 1918 Nobel Prize for chemistry for the synthesis of ammonia from its elements. (Photograph from Wikimedia Commons)

**Figure B3.2.2** A poison gas attack on the eastern front during the First World War. As the gas drifts downwind to the left, the shadows of advancing German troops can be seen on the upper right. Fritz Haber helped develop and refine methods of gas warfare that killed or injured more than a million soldiers. (Photograph from www.ga.k12.pa.us, accessed 15 February 2005).
the energy costs of supporting mycorrhizae. It is logical to assume that evolutionary solutions arise only in response to a pressing problem in survival. Increasingly it appears that the symbiotic relationship between plants and fungi is not some bizarre aberration but rather a general phenomenon. Terrestrial plants with mycorrhizae might be viewed as large lichens in which the single-celled alga has been replaced by a multicellular plant. It is even possible that the association between algae and fungi was essential for the earliest invasion of land; this is supported not only by the ubiquity of the alga–fungus relationship but by the presence of apparent fossilized mycorrhizae in early land plants such as *Rhynia* (Figure 1.5), as well as the mycorrhizal gametophytes of fern allies today.

### 3.4.4 Experimental Tests for Nitrogen and Phosphorus Limitation

One direct way to assess the relative importance of a mineral element in controlling plant growth is to