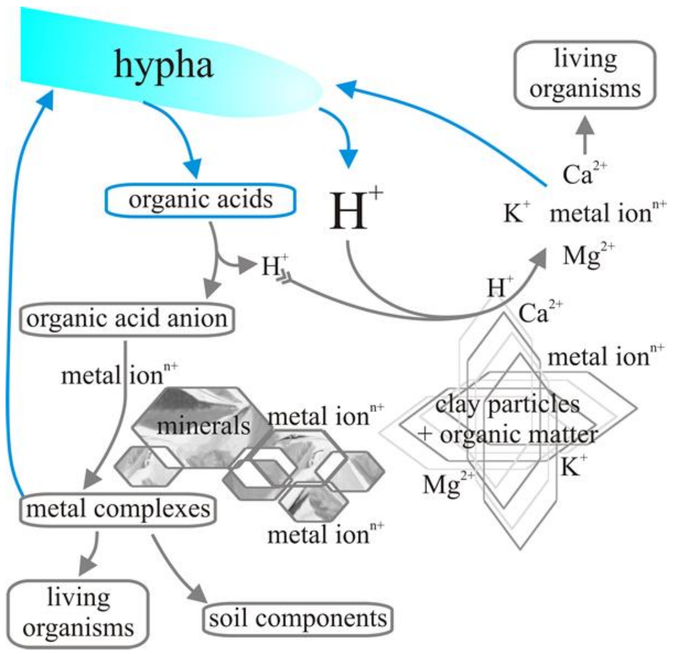

Fig. 1.5 (above). Proton- and organic acid-mediated dissolution of metals from soil components and minerals. Proton release from the hypha results in cation exchange with metal ions on clay particles, colloids etc. and metal displacement from mineral surfaces. Released metals can interact with biomass, can be taken up by other organisms, and can react with other environmental components. Organic acid anions, e.g. citrate, may cause mineral dissolution or removal by complex formation. Metal complexes can interact with live organisms as well as environmental constituents: in some circumstances complex formation may be followed by crystallisation, e.g. metal oxalate formation. Blue arrows indicate processes driven by the fungi. Modified from Gadd, 2004, 2016, 2017.

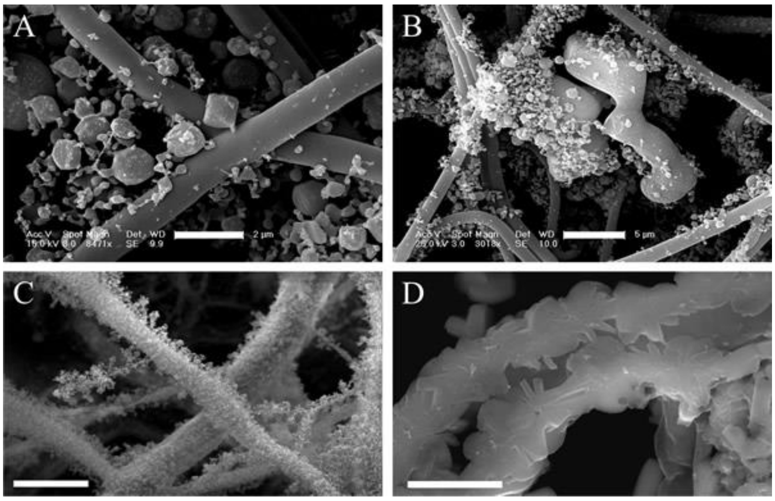

Fig. 1.6. Photomicrographs of fungal hyphae showing examples of minerals formed by hyphal growth; in these cases formation of uranium-containing biominerals following growth on medium containing uranium salts or uranium ore. Scale bars: **A**,2 µm; **B**, 5 µm; **C**, 20 µm; **D**, 5 µm. Modified from Gadd, 2007 using graphic files kindly supplied by Prof. G. M. Gadd, University of Dundee, UK. See Gadd, 2016, 2017.

These roles of fungi in soil geochemistry, especially metal cycling, have been included under the term ‘**geomycology**’, defined as ‘the study of the role fungi have played and are playing in fundamental geological processes’ (Burford *et al*., 2003; Gadd, 2004, 2007, 2016, 2017).

1.9 The origins of agriculture and our dependence on fungi

As the last ice-age came to an end, the consequential climatic and environmental changes forced humans to utilise an ever wider variety of food resources. Although hunting and gathering persisted (and still exists today in certain regions of the world), new food production techniques gained importance. The controlled cultivation of plants, what we might now call agriculture, began to be practiced in different parts of the world between 11,000 and 14,000 years ago. This was soon followed by the close management and eventual domestication of the animals that are common on farms today. The four major centres from which agriculture evolved were the Middle East and Europe, Africa, the Americas, and China and Southeast Asia.

European agriculture originated in the '**Fertile Crescent**', centred on the Tigris and Euphrates rivers. The region is also known as Mesopotamia, which refers to an area now occupied by modern Iraq, eastern Syria, south-eastern Turkey, and Southwest Iran (Riehl *et al*., 2013). Farmers in Mesopotamia were using irrigation to improve crop yields 8,000 years ago. This region saw the domestication of wild cereals like wheat (*Triticum*) and barley (*Hordeum*), as well as a number of legumes and fruit including grapes, melons, almonds and dates. The region also saw the first domestication of many of the animals with which we are familiar today: dogs, goats, sheep, pigs, cattle, horses, camels, were domesticated in succession from wild relatives indigenous to the region.

Plants and animals were domesticated through human-controlled selection (an unconscious use of applied genetics). Animals provided food resources in the form of meat, and a variety of secondary products including milk, dairy products, hides, wool, and other materials. Animals also provided traction and power, more extensive travel and new forms of energy. Improved crops gave greater surpluses and provided a source of wealth for economic exchange and trade; providing some release from the daily search for food and the opportunity to develop a civilised way of life. Within just a few thousand years, farming lifestyles became a global phenomenon. The shift from hunting and gathering to agriculture spread quite rapidly from the various originating centres by both migration with colonisation, and adoption of new technologies.

Agriculture reached the central Mediterranean region about 8,000 years ago; most of Western Europe about 7,500 years ago; and the Iberian Peninsula and British Isles about 7,000 years ago (Whittle, 2001; Renfrew & Bahn, 2016).

With the spread of agricultural civilisation went the spread of **agricultural fungi,** good and bad. Fungi have always accompanied the steady march of civilisation across human settlements - the animals and plants were accompanied by their fungal parasites and commensalisms, and fungi accompanied technologies like baking, brewing and cheese-making. We have been dependent on fungi since we became human. That observation raises the question of how long the fungi have been on Earth and where they came from. And those topics are dealt with in Chapter 2.

1.10 Chapter 1 References and further reading

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