Environmental conditions for fungal growth

In common with all microorganisms, fungi are profoundly affected by physical and physicochemical factors, such as temperature, aeration, pH, water potential, and light. These factors not only affect the growth rate of fungi but also can act as triggers in developmental pathways. In this chapter we consider the effects of environmental factors on fungal growth, including the extremes of adaptation to environmental conditions which are:

- **temperature and fungal growth**
- **pH and fungal growth**
- **oxygen and fungal growth**
- **water availability and fungal growth**
- **effects of light on fungal growth**

Temperature and fungal growth: Microorganisms are often grouped into four broad categories in terms of their temperature ranges for growth: **psychrophiles** (cold-loving), **mesophiles** (which grow at moderate temperatures), **thermophiles** (heat-loving), **Psychrophilic** fungi are defined as having optimum growth at no more than 16°C and maximum growth of about 20°C. In many cases they would be expected to grow down to 4°C or lower, whilst **psychrotrophic fungi** would be those that can grow at low temperatures but also above 20°C. There are many environments that could suit these organisms, including the polar and alpine regions.

Most fungi are **mesophilic**: commonly growing within the range 10–40°C, though with different tolerances within this range. For routine purposes these fungi can usually be grown at room temperature (22–25°C). Two important examples shown in Fig. 1 are *Aspergillus flavus*, which produces the potent aflatoxins in stored grain products, and *Penicillium chrysogenum*, used for the commercial production of penicillins

thermophilic fungi are defined as having a minimum growth temperature of 20°C or above, a maximum growth temperature of 50°C or above, and an optimum in the range of about 40–50°C. Cooney & Emerson, in 1964, described all the thermophilic fungi that were known at that time.

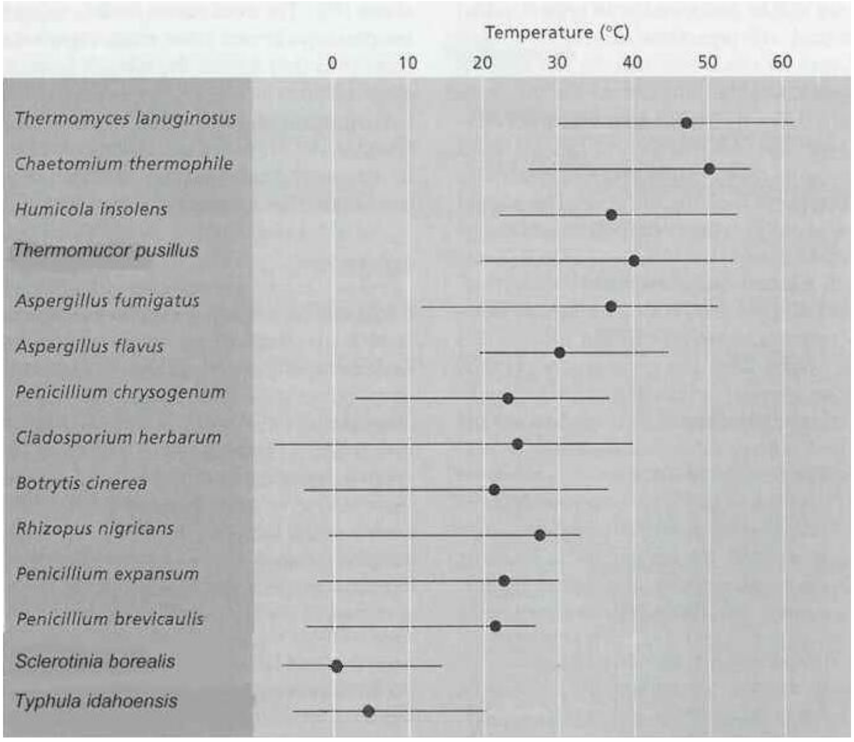

Fig.1: Approximate temperature ranges and optima (black circle) for growth of some representative fungi.

Hydrogen ion concentration and fungal growth

The responses of fungi to culture pH need to be assessed in strongly buffered media, because otherwise fungi can rapidly change the pH by selective uptake or exchange of ions. Mixtures of KH2PO4 and K2HPO4 are commonly used for this purpose. It is then found that many fungi will grow over the pH range 4.0–8.5, or sometimes 3.0–9.0, and they show relatively broad pH optima of about 5.0–7.0. However individual species vary within this "normal" range, as shown by the three representative examples in Fig. 2. Several fungi are **acid-tolerant**, including some yeasts which grow in the stomachs of animals and some mycelial fungi (*Aspergillus, Penicillium*, and *Fusarium* spp.) which will grow at pH 2.0. But their pH optimum in culture is usually 5.5–6.0. Truly **acidophilic** fungi, able to grow down to pH 1 or 2, are found in a few environments such as coal refuse tips and acidic mine wastes; many of these species are yeasts.

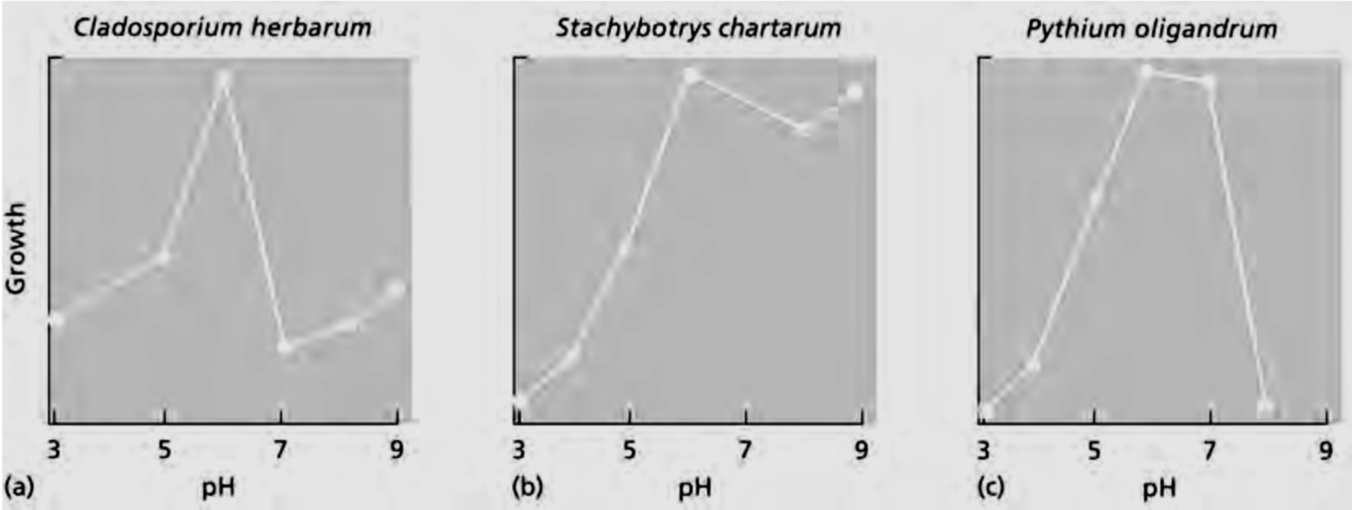

Fig.2 (a–c) pH growth response curves of three representative fungi in laboratory culture (*Pythium oligandrum* is a member of the cellulose-walled Oomycota).

Oxygen and fungal growth

Most fungi are strict aerobes, in the sense that they require oxygen in at least some stages of their life cycle.

Even *Saccharomyces cerevisiae*, which can grow continuously by fermenting sugars in anaerobic conditions, needs to be supplied with several preformed vitamins, sterols and fatty acids for growth in the absence of oxygen. *Saccharomyces* also requires oxygen for sexual reproduction. Having established these points, we can group fungi into four categories in terms of their oxygen relationships.

1 Many fungi are **obligate aerobes**: their growth is reduced if the partial pressure of oxygen is lowered much below that of air. For example, growth of the take-all fungus of cereals is reduced. The thickness of water films around the hyphae can be significant in such cases, because oxygen diffuses very slowly through water, as we saw for the rhizomorphs of *Armillaria mellea* Aerobic fungi typically use oxygen as their terminal electron acceptor in **respiration**. This gives the highest energy yield from the oxidation of organic compounds.

2- Many yeasts and several mycelial fungi (e.g. *Fusarium oxysporum, Mucor hiemalis, Aspergillus fumigatus*) are **facultative aerobes**. They grow in aerobic conditions but also can grow in the absence of oxygen by fermenting sugars. The energy yield from **fermentation** is much lower than from aerobic respiration, and the biomass production is often less than 10% of that in aerobic culture. However, a few mycelial fungi can use nitrate instead of oxygen as their terminal electron acceptor. This

anaerobic respiration can give an energy yield at least 50% of that from aerobic respiration.
3 -A few aquatic fungi are **obligately fermentative**, because they lack mitochondria or cytochromes (e.g. *Aqualinderella fermentans*, Oomycota) or they have rudimentary mitochondria and low cytochrome content (e.g. *Blastocladiella ramosa*, Chytridiomycota). They grow in the presence or absence of oxygen, but their energy always comes from fermentation.
4- A few **obligately anaerobic** Chytridiomycota occur in the rumen and are discussed below.

Water availability and fungal growth

All fungi need the physical presence of water for uptake of nutrients through the wall and cell membrane, and often for the release of extracellular enzymes. Fungi also need intracellular water as a milieu for metabolic reactions. However, water can be present in an environment and still be unavailable because it is bound by external forces.

Light

Light in the near-ultraviolet (NUV) and visible parts of the spectrum (from about 380 to 720 nm) has relatively little effect on vegetative growth of fungi, although it can stimulate **pigmentation**. In particular, blue light induces the production of carotenoid pigments in hyphae and spores of several fungi, including *Neurospora crassa*. These carotenoids, which also occur in algae and bacteria, are known to quench reactive oxygen species, discussed earlier. The pigments serve to minimize photo-induced damage. Melanins similarly protect cells against reactive oxygen species and ultraviolet radiation.