

## Rate of photosynthesis: environmental factors

### Environmental factors

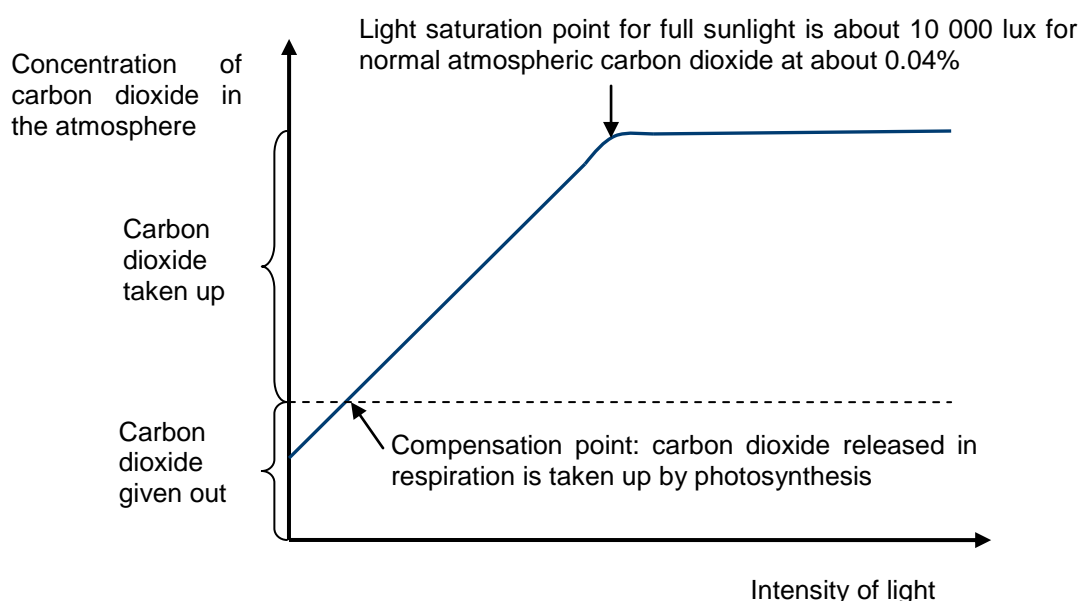
Each species is adapted to live in a particular set of conditions. It is said to have an environmental niche. Each species has evolved to suit its own unique niche, which allows it to exist with the minimum amount of competition with other species. According to the competitive exclusion principle, if two species share the same niche, one will be better adapted than the other, outcompete it and eventually drive it to extinction.

So plants show different adaptations for photosynthesis, according to the conditions to which they are best adapted.

### Shade or sun?

Shade-tolerant plants are able to photosynthesise in light of relatively low intensity and can grow in shady places such as woodland floors. Shade-intolerant plants are unable to carry out photosynthesis at a high enough rate to sustain growth in low light conditions.

Respiration and photosynthesis are opposites. Aerobic respiration continues all the time in plant cells, using up oxygen and making carbon dioxide. Photosynthesis, in contrast, occurs only in light and uses up carbon dioxide and makes oxygen. There is a light intensity at which respiration and photosynthesis cancel each other out. This is called the compensation point. Below this level carbohydrates are used up and the plant cannot grow.



**Figure** Compensation point: rate of carbon dioxide release = rate of carbon dioxide uptake.

Shade plants tend to have lower compensation points than sun plants because they have lower respiration rates and can absorb light more efficiently. To do this they have thinner leaves which spread to catch light over a wider area and have fewer deep cells to reduce the respiration rate.

In deep shade, light is more likely to be the limiting factor than carbon dioxide. So shade plants tend to have chloroplasts packed with thylakoids to make maximum use of the limited available light. They have more photosystems to funnel electrons into the same number of electron transport complexes.

Wavelength of light also affects the rate of photosynthesis. Shade plants most often live in shade created by other plants, especially trees. The leaves of trees absorb red and blue wavelengths, allowing mainly green light through. This is of little use to most plants which have limited ability to survive on woodland floors. However, far red light (long wavelength) passes through the tree canopy more than near red light. PSI absorbs this light better than PSII, so shade plants compensate by having slightly more PSII complexes to restore the balance.

### Dry or wet?

Water shortage is greatest in deserts. Here, CAM plants are most abundant (See *Rubisco and C<sub>4</sub> plants*). Being able to keep their stomata closed during the day when transpiration losses would be high allows them to survive in areas of extreme water shortage.

### Cold or hot?

Plants are able to acclimatise and adapt to cold or hot environments, both by suiting the climates in which they live and by adjusting to changes through the year.

Plants from hot climates tend to have higher optimum temperatures for photosynthesis and optimum temperatures tend to be higher in plants during the warmer seasons. As temperatures fall, plants can adjust the composition of membranes to make them more fluid, for example by increasing the polyunsaturated fat content. Some enzymes appear to exist in different forms which have different optimum temperatures.

### Hot, sunny and wet?

In ideal conditions for photosynthesis – bright light, high temperatures and plentiful water – photosynthesis tends to reduce carbon dioxide concentration and raise oxygen concentration, favouring photorespiration (high temperatures also help) and greatly reducing the rate of photosynthesis. So many tropical plants use the C<sub>4</sub> pathway to reduce photorespiration.

Water is an essential donor of electrons in photosynthesis, but severe water loss affects most of a plant's metabolism, making it very difficult to establish any direct effects on photosynthesis. However, C<sub>4</sub> also helps in dry conditions where the stomata are partially closed to conserve water, reducing carbon dioxide supply. The increase in photorespiration is much less than would occur in a C<sub>3</sub> plant.

### Other factors

Pollutants such as sulfur dioxide inhibit photosynthesis. Some herbicides (weedkillers) inhibit certain enzymes used in photosynthesis. PSII inhibitors such as the triazine herbicides and urea derivatives (like DCMU, dichlorophenyl methyl urea or CMU, p-chlorophenyl dimethyl urea) block electron flow to NADPH, causing electrons from water to accumulate on chlorophyll. PSI inhibitors (bipyridyliums like paraquat and diquat) steal electrons from the transfer chains. Both cause excessive oxidation reactions to occur. For example, hydroxyl radicals may form, which disrupt the phospholipids in membranes causing them to become leaky, and prevent the plant from obtaining energy, causing it to die.

A variety of inorganic ions are needed to make chlorophyll pigments. Magnesium and nitrogen are constituents of chlorophyll molecules and chlorophyll cannot be synthesised without the presence of iron. Soils deficient in nitrate, magnesium or iron will give rise to plants that are deficient in chlorophyll, usually with yellow rather than green leaves. The resulting reduction in the rate of photosynthesis causes stunted growth.