Rate of photosynthesis: limiting factors

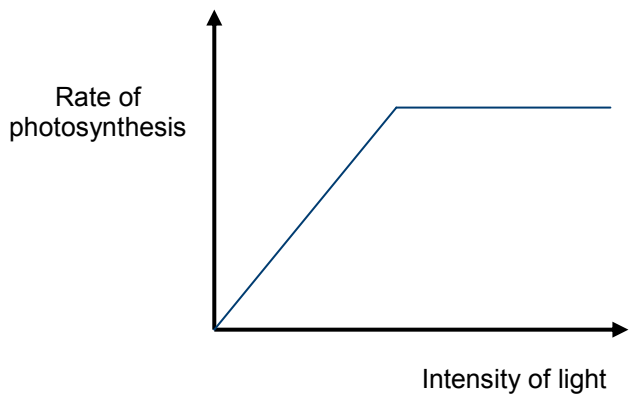
Limiting factors

The main factors affecting rate of photosynthesis are light intensity, carbon dioxide concentration and temperature.

In any given situation any one of these may become a limiting factor, in other words the factors that directly affects the rate at which photosynthesis can take place masking the effects of the other factors.

Light and rate of photosynthesis

At low light intensities, as light intensity increases, the rate of the light-dependent reaction, and therefore photosynthesis generally, increases proportionately (straight line relationship). The more photons of light that fall on a leaf, the greater the number of chlorophyll molecules that are ionised and the more ATP and NADPH are generated. Light dependent reactions use light energy and so are not affected by changes in temperature.



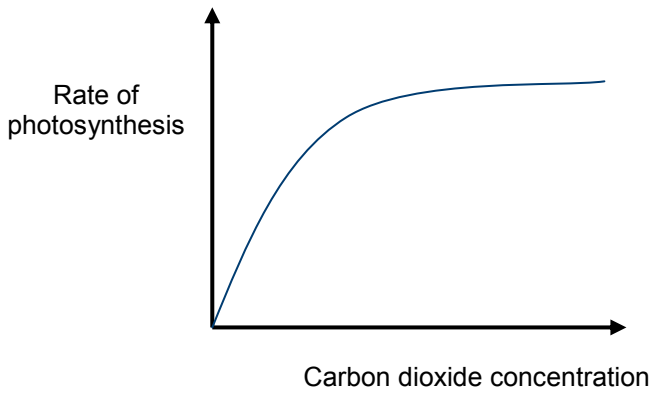
As light intensity is increased further, however, the rate of photosynthesis is eventually limited by some other factor. So the rate plateaus. At very high light intensity, chlorophyll may be damaged and the rate drops steeply (not shown in the graph).

Chlorophyll a is used in both photosystems. The wavelength of light is also important. PSI absorbs energy most efficiently at 700 nm and PSII at 680 nm. Light with a higher proportion of energy concentrated in these wavelengths will produce a higher rate of photosynthesis.

Carbon dioxide and rate of photosynthesis

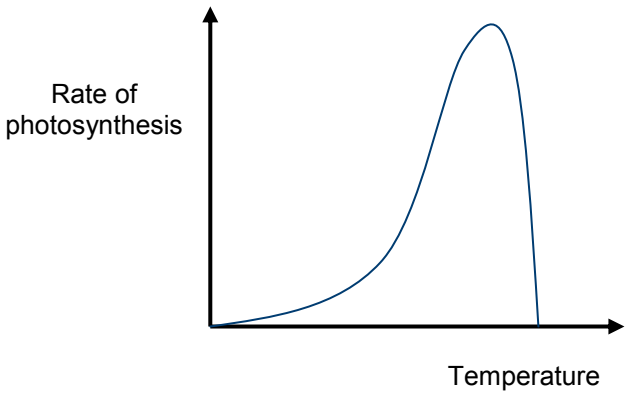
An increase in the carbon dioxide concentration increases the rate at which carbon is incorporated into carbohydrate in the light-independent reaction, and so the rate of photosynthesis generally increases until limited by another factor.

As it is normally present in the atmosphere at very low concentrations (about 0.04%), increasing carbon dioxide concentration causes a rapid rise in the rate of photosynthesis, which eventually plateaus when the maximum rate of fixation is reached.



Temperature and rate of photosynthesis

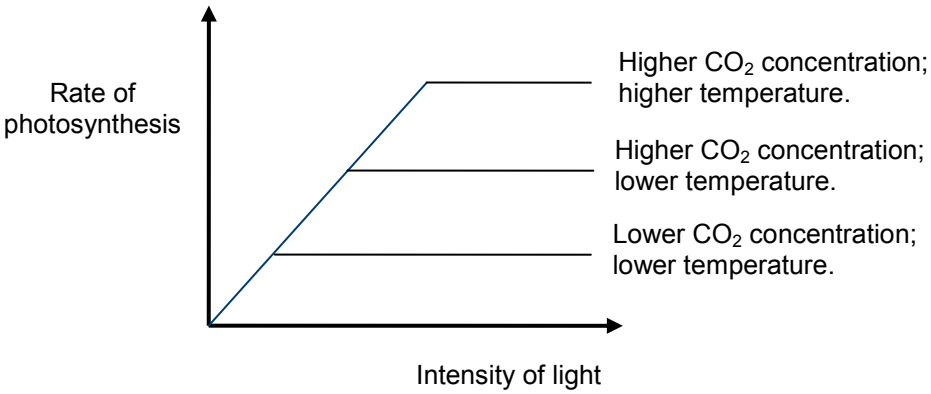
Although the light dependent reactions of photosynthesis are not affected by changes in temperature, the light *in*dependent reactions of photosynthesis *are* dependent on temperature. They are reactions catalysed by enzymes. As the enzymes approach their optimum temperatures the overall rate increases. It approximately doubles for every 10 °C increase in temperature. Above the optimum temperature the rate begins to decrease, as enzymes are denatured, until it stops.



Limiting factors

In 1905, when investigating the factors affecting the rate of photosynthesis, Blackmann formulated the Law of limiting factors. This states that the rate of a physiological process will be limited by the factor which is in shortest supply. Any change in the level of a limiting factor will affect the rate of reaction.

For example, the amount of light will affect the rate of photosynthesis. If there is no light, there will be no photosynthesis. As light intensity increases, the rate of photosynthesis will increase as long as other factors are in adequate supply. As the rate increases, eventually another factor will come into short supply. The graph below shows the effect of low carbon dioxide concentration. It will eventually be insufficient to support a higher rate of photosynthesis, and increasing light intensity will have no effect, so the rate plateaus.



If a higher concentration of carbon dioxide is supplied, light is again a limiting factor and a higher rate can be reached before the rate again plateaus. If carbon dioxide and light levels are high, but temperature is low, increasing temperature will have the greatest effect on reaching a higher rate of photosynthesis.

Finding out

How might the factors that affect the rate of photosynthesis be investigated?

Design a suitable series of experiments.