JOSEPH PRIESTLEY AND THE EVOLUTION OF OXYGEN IN PHOTOSYNTHESIS

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Isaac Asimov wrote that one could scarcely think of a more important fact than that the Earth is bathed in light from the sun. He could have taken it a step further and added that when photosynthetic organisms are exposed to sunlight, they release oxygen into the Earth's atmosphere. The ability of plants, algae, and cyanobacteria to use light energy to split water molecules and generate O_2 is of fundamental significance, and without it the higher organisms that inhabit our planet would not have evolved.

Some of the earliest insights into this process, and its relevance for understanding the relationship between plants and animals, were gained through the work of an amateur chemist, religious nonconformist, political agitator, and general gadfly named Joseph Priestley.

Joseph Priestley by Ellen Sharples (1794)
National Portrait Gallery, London

Priestley was born in West Yorkshire, England in 1733 and educated in the classics and theology. He adhered to the Christian philosophy of Rational Dissent, which held, among other things, that religious beliefs could be scientifically evaluated. This was a view that strongly influenced his future work, but did not endear him to believers in the traditional teachings of the Church of England. He became a minister, but his interests and writings also encompassed science, history, education, and grammar.

When he was in his thirties, Priestley developed an interest in the little-understood phenomenon of electricity. His work in that area brought him to the attention of some of the leading natural philosophers of the day, including Benjamin Franklin, who was in Britain as a representative of the American colonies. Priestley frequented the London coffee houses where religious and scientific intellectuals met to exchange ideas, and in 1766 was accepted as a Fellow of the Royal Society.

Priestley's scientific interests expanded to include the study of various gases, or "airs," as they were called at the time. He is generally credited with the discovery of oxygen, although that honor should perhaps be shared with Antoine Lavoisier, who named the gas and correctly interpreted his results in modern chemical terms rather than the antiquated "phlogiston" theory still favored by Priestley. Recognition should also go to Carl Scheele, who actually isolated oxygen before either Priestley or Lavoisier, but made the fatal error of delaying publication. In any event, Priestley's involvement with the discovery of oxygen was primarily based on heating mercuric oxide and collecting the gas that was driven off, rather than on his experiments which were pertinent to photosynthesis.

It was well known that an animal placed in a closed container would soon die, and that the air in the container was rendered "noxious," i.e., unable to sustain animal life or the burning of a candle. In fact, Priestley may have performed some experiments along these lines as a child. The eventual breakthrough came when he included a plant in the container, after which he found that the air had somehow been restored. Priestley reported his photosynthesis (the term was not coined until much later) experiments in a paper published in the Philosophical Transactions of the Royal Society of London in 1772. In his own words:

" . . . plants, instead of affecting the air in the same manner with animal respiration, reverse the effects of breathing, and tend to keep the atmosphere sweet and wholesome, when it is become noxious, in consequence of animals living and breathing, or dying and putrefying in it.

In order to ascertain this, I took a quantity of air, made thoroughly noxious, by mice breathing and dying in it, and divided it into two parts; one of which I put into a phial immersed in water; and to the other (which was contained in a glass jar, standing in water) I put a sprig of mint. This was about the beginning of August 1771, and after eight or nine days, I found that a mouse lived perfectly well in that part of the air, in which the sprig of mint had grown, but died the moment it was put into the other part of the same original quantity of air; and which I had kept in the very same exposure, but without any plant growing in it." (Priestley,1772).

Did Priestley really understand what he had discovered? Yes and no. Ironically from the standpoint of photobiology, Priestley seems not to have grasped the significance of light in his results. He refers to some difficulty in replicating the experiments during the winter, but was able to do so convincingly in the summer, which may be significant. It remained for Jan Ingenhousz in 1779 to show that plants give off bubbles of oxygen in the light, but not in the dark. Perhaps more unfortunately, Priestley continued to interpret his results in terms of the phlogiston theory, and never really reconciled with the modern view of chemistry established by Lavoisier.

However, to his credit, Priestley did understand the significance of his findings in terms of the broad global relationship between plants and animals. Again in his own words:

" . . . the injury which is continually done to the atmosphere by the respiration of such a number of animals, and the putrefaction of such masses of both vegetable and animal matter, is, in part at least, repaired by the vegetable creation." (Priestley, 1772).

These insights, among others, led to his selection as recipient of the Copley Medal in 1773, the highest award bestowed by the Royal Society.

Priestley lived an eventful life outside the laboratory as well. He was an extremely controversial figure, more known to the general public for his nonconformist religious beliefs and seditious political opinions than for his scientific work. He was held in particular contempt for his outspoken support of the French Revolution, which enraged the British establishment. On the night of July 14, 1791 a drunken, riotous mob (possibly orchestrated by local authorities) attacked and burned his house and laboratory in Birmingham. As the French Revolution escalated into the Terror, hostility toward its sympathizers mounted and in 1794 Priestley fled with his family to America.

They settled in Northumberland, Pennsylvania, a rural area to the west of Philadelphia. Priestley was befriended by many prominent Americans, including Thomas Jefferson, whom he advised on establishing the University of Virginia. Priestley set up a laboratory in a wing of the house he occupied, but by that time little of his published work was in the realm of science.

Joseph Priestley died in 1804 at the age of 70 and was buried in Northumberland, where his restored house is now open for public tours. Much of his surviving laboratory equipment is displayed at nearby Dickinson College, where an endowed faculty chair and an annual award to a prominent scientist are named in his honor.

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