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The microbial fuel cell

Electricity from yeast cells

For decades, microbes that produce electricity were a biological curiosity. Now, researchers foresee a use for them in watches and cameras, as power sources for the Third World and for bioreactors to turn industrial waste into electricity. The microbial fuel cell described here generates a small electrical current by diverting electrons from the electron transport chain of yeast (Figure 1). It may be used to study respiration in a novel and stimulating manner.

Aims

- To provide a stimulating introduction to the study of respiration
- To permit the study of some of the factors which influence microbial respiration
- To show how waste organic material may be used to generate electricity

Equipment and materials

Needed by each person or group

- *Perspex* fuel cell, cut from 4 mm thick sheet
- Neoprene gaskets, 2
- Cation exchange membrane, cut to fit between chambers of the fuel cell. *The membrane may be re-used indefinitely, but will melt if it is autoclaved.*
- Carbon fibre tissue electrodes, cut to fit, 2 (see Figure 2)
- *J-Cloth*, cut to fit inside cell, 2 pieces
- 10 ml plastic syringes, 2, for dispensing liquids

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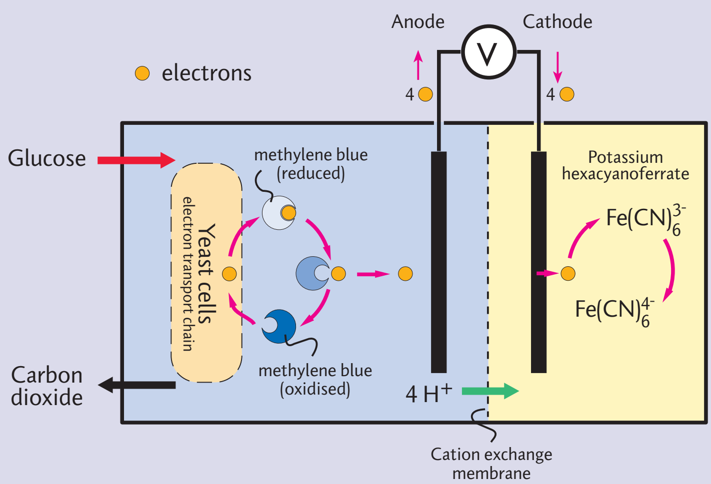
Fig. 1
How the microbial fuel cell works



- Petri dish base or lid on which to stand fuel cell
- Electrical leads with crocodile clips, 2
- 0–5 V voltmeter or multimeter and / or low current motor
- Scissors

All of the solutions listed below should be made up in 0.1 M phosphate buffer, pH 7.0, instead of water

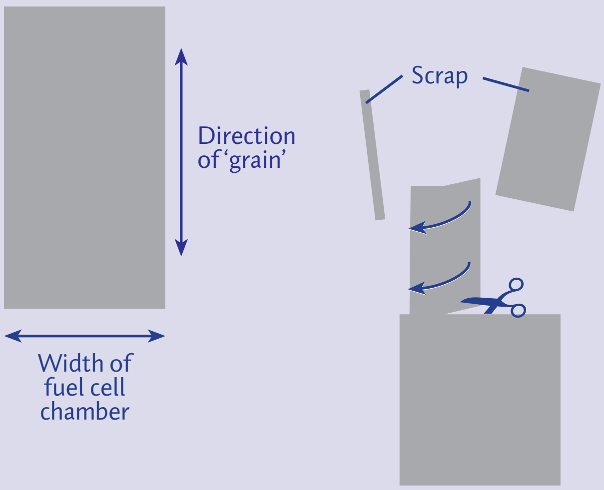
- Dried yeast, made into a thick slurry in 0.1M phosphate buffer (do *not* add glucose solution without first rehydrating the yeast in buffer)
- 10 mM methylene blue solution, 5 ml
- 1 M glucose solution, 5 ml
- 0.02 M potassium hexacyanoferrate (III) solution, 10 ml (also called potassium ferricyanide)

To make 0.1 M phosphate buffer, pH 7.0

- Dissolve 4.08 g Na_2HPO_4 and 3.29 g NaH_2PO_4 in 500 ml distilled water.

Fig. 2

The carbon fibre used to make the electrodes has a 'grain'. To ensure that the long 'tail' of the electrode does not tear and fits easily through the hole in the fuel cell, it is necessary to cut and fold the electrode as shown here.



Cut about half-way through the upper piece as shown, then fold it in half then half again to form a 'tail' on the electrode.

Procedure

1. Cut out two carbon fibre electrodes as shown (Figure 2).
2. Cut out two pieces of *J-Cloth* to fit inside the fuel cell.
3. Assemble the fuel cell as shown (Figure 3).
4. Stand the assembled fuel cell on a Petri dish base or lid to catch any liquid which may leak.
5. Combine the yeast slurry, glucose and methylene blue solutions. Syringe the mixture into one chamber of the fuel cell.

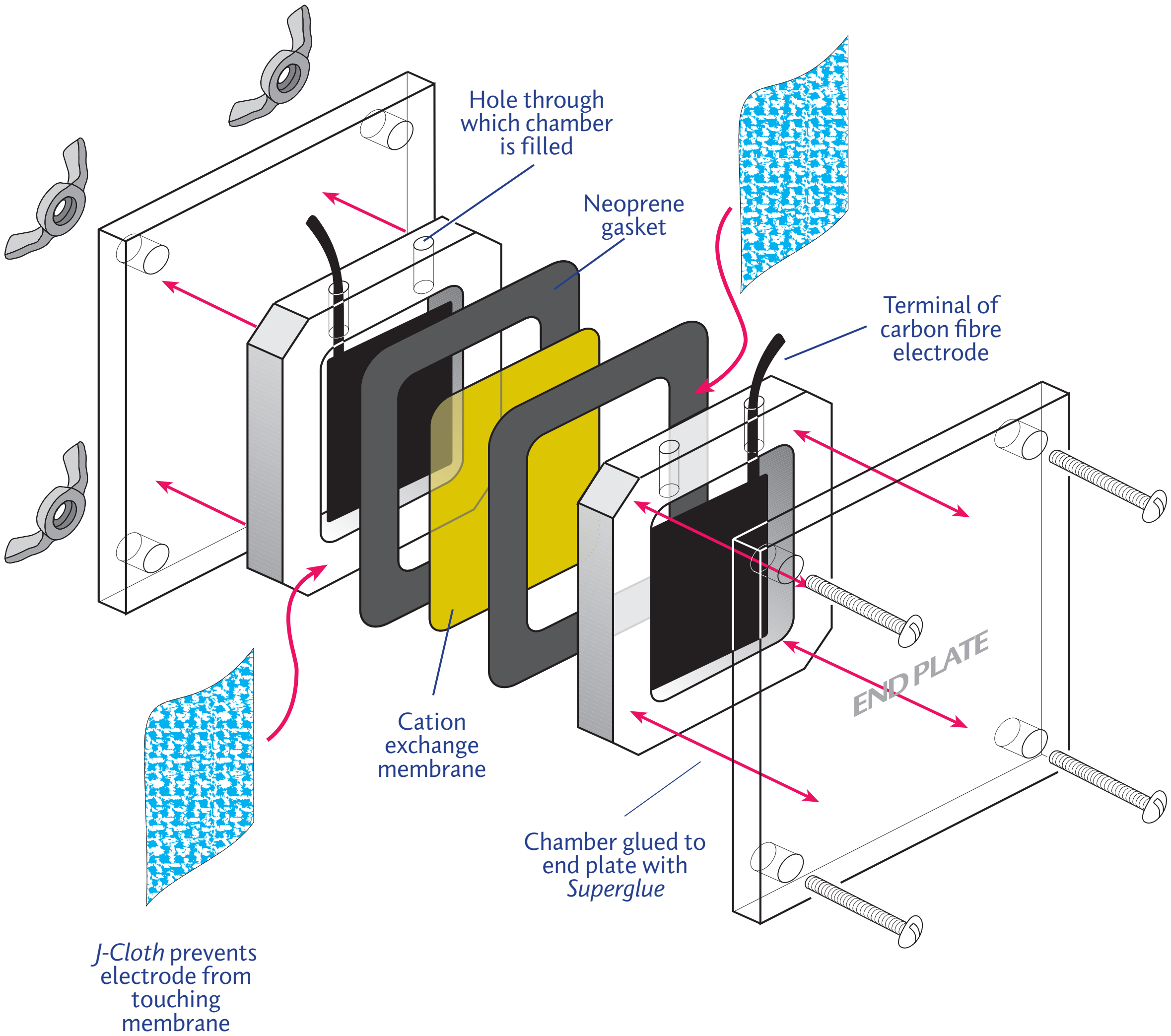


Fig. 3
How to assemble a microbial fuel cell (the exact dimensions are unimportant — the one shown here is roughly 55 mm x 55 mm).

6 Syringe potassium hexacyanoferrate (III) solution into the other side of the cell.

7 Connect a voltmeter or multimeter (*via* the crocodile clips) to the electrode terminals. Fuel cells of this type typically generate between 0.4–0.6 V and 3–50 mA. A current should be produced immediately — if the meter registers zero, check the connections and ensure that the carbon fibre electrodes are not touching the cation exchange membrane.

Safety

Potassium hexacyanoferrate (III) is poisonous. Eye protection should be worn when handling this material. If the solution comes into contact with the eyes, flood them with water and seek medical attention. If swallowed, give plenty of water to drink and seek medical attention. Local regulations should be observed when disposing of used solution.

Preparation

Solutions of reagents should be prepared in advance. Pre-soak the cation exchange membrane in distilled water for 24 hours before use. The dried yeast can be resuscitated as the fuel cell is assembled.

Timing

Assembly (through to electricity generation) takes about 30 minutes.

Further investigations

1 Several fuel cells may be joined together to give a greater voltage. Increasing the size of the cell (or the electrode area) will increase the current generated (but not the voltage).

2 Different mediators and/or types of yeast *e.g.*, wine-makers' or bakers' yeast may be used. Note: For safety reasons, the use of this fuel cell with other microorganisms is *not* recommended.

3 Investigate the effect of temperature on the action of the fuel cell (remember to consider what 'controls' are necessary when making comparisons of this type).

Suppliers

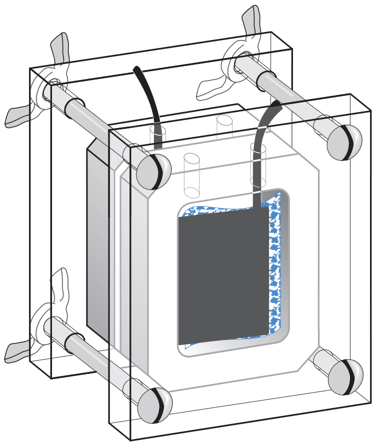
Microbial fuel cells suitable for school investigations as described here are available from the National Centre for Biotechnology Education at the University of Reading: http://www.ncbe.reading.ac.uk.

Further reading

Bennetto, P. (1987) Microbes come to power *New Scientist* 16 April (**114**) 36–40

Bennetto, H. P. (1990) Electricity generation by micro-organisms *BIO/technology Education*, 1 (4) 163–168. Note: This journal is now defunct. However, you may download a PDF copy of this paper from here.

Sell, D. (2001) Bioelectrochemical fuel cells. In *Biotechnology. Volume 10: Special processes* (Second edition) Rehm, H.-J. and Reed, G. [Eds] Frankfurt am Main: Wiley-VCH.



Acknowledgement

The microbial fuel cell was developed by Dr Peter Bennetto, formerly of the Department of Chemistry, King's College, London. It has been adapted for school use by Dean Madden and John Schollar.

