Note on a Method of demonstrating the Heat of Respiration.

BY

M. C. POTTER.

With one Figure in the Text.

THE method of demonstrating the heat of respiration described in most text-books follows that devised by Sachs and, one is tempted to think, is frequently quoted without practical trial. In this method a number of germinating seeds are placed in a funnel supported in a beaker which contains an alkaline solution to absorb the CO_2. The funnel and seeds are covered by a bell-jar to protect them from external variations of temperature, a tubule at the summit of the bell-jar serving for the introduction of a thermometer and for ventilation. A similar apparatus with a thermometer plunged in seeds which have been killed by boiling is used as a control. This contrivance is very inconvenient. A funnel sufficiently large for the purpose of the experiment necessitates a large bell-jar, and thus the apparatus becomes both expensive and cumbersome. For various reasons it cannot always be depended upon to give satisfactory results, and, as the heat of respiration is an important laboratory experiment, it may be of some interest to describe a simple apparatus which I devised and have used for many years with success.

In every experiment certain precautions must be taken to guard against experimental error. In the directions usually given to demonstrate the rise of temperature consequent upon respiration, the calibration of the thermometers and the necessity for guarding against the variations of temperature of the surrounding air are generally noted. But no account is taken of any increase of temperature due to fermentation or putrefaction. This calls for special comment, and neglect of this factor may give rise to serious error. Thus when seeds merely killed by boiling are used as the control (as is commonly recommended) putrefaction generally takes place, and it is often found that the experiment apparently does not succeed as the control registers the higher temperature.

[Annals of Botany, Vol. XXXI. Nos. CXXIII and CXXIV. July and October, 1917.]

For the success of this particular experiment under any method, the following conditions must be satisfied:

(*a*) a sufficiently large number of seeds so that the heat produced may not be dissipated;

(*b*) a supply of oxygen;

(*c*) a means of escape for the CO_2;

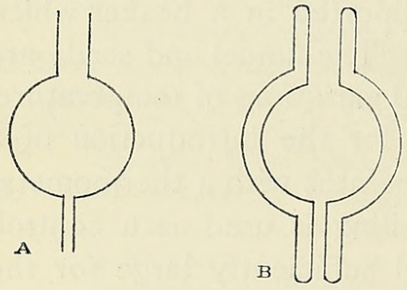
(*d*) screening from the changes in temperature of the surrounding air;

(*e*) efficient control;

(*f*) the prevention of putrefaction.

The form of apparatus which I have found convenient consists of flasks of about 500 c.c. capacity with a short ventilation tube fused at the base for the escape of the CO_2, these being enclosed in a box and packed with cotton-wool (in annexed figure, A). By this means the first four conditions enumerated can be satisfied.

I invariably employ three of these flasks. The first (I) contains living seeds thoroughly soaked before introduction into the flask. The second (II) contains seeds soaked and then boiled to destroy their power of germination. The third (III) contains seeds soaked and boiled in a solution of 0·5 per cent. mercuric chloride, with the object of killing the seeds and at the same time effectually sterilizing them.



To soak the seeds before introduction into the flasks is a necessary precaution, especially if peas are used, otherwise they would swell and break the flasks. The usual procedure is to soak the seeds for II and III and then effect the necessary boiling, and while these are cooling to soak the seeds for I. In this manner it is possible for the experiment to commence with the three flasks at the same initial temperature. Since the germinating seeds in I are damp, it is necessary that the control seeds should be damp also, in order to minimize any error due to the loss of heat from evaporation.

The three flasks thus prepared are placed in a box and packed round with felt or cotton-wool. It may be safely assumed that any variation of temperature due to evaporation or to changes of room temperature will be common to the three flasks.

Flask III is the control. In an ordinary room or laboratory its temperature will fluctuate, but does not rise above that of the room, and any rise above this room temperature in the other flasks will be due to respiration in I or putrefaction in II.

Flask I gradually rises in temperature as the activity of respiration proceeds, and in the course of about forty-eight hours (if peas are employed)

may register 2·0 centigrade above the control III. This may be taken as the rise of temperature due to the respiration.

The behaviour of Flask II is most instructive. Its temperature gradually rises, but more slowly than is the case with I, and after two days or so it will be found to possess a higher temperature than that of I. This rise of temperature is due to the action of various fungi and bacteria which invariably gain a footing on the dead unsterilized seeds.

As the experiment proceeds it is often found, after about a week, that the seeds in I are attacked by moulds and bacteria, and hence the later temperature difference is due partly to the seed-respiration and partly to putrefaction. It is only in the initial stages that the experiment gives a true indication of the heat evolved during respiration, unless the seeds have been sterilized before insertion.

The experiment is usually kept under observation for about fourteen days. By taking readings at frequent intervals, say twice a day, of the differences of temperature between I and II and between II and III, and employing them as ordinates, very instructive graphs can be obtained showing the progress of the heat of respiration and that of the heat of putrefaction.

A very simple method which yet gives excellent results and would be useful in school work may also be mentioned. The seeds are placed in three boxes instead of three flasks: ordinary chalk boxes placed upright answer admirably. A small hole is made at the top to serve for the introduction of the thermometer and suitable perforations at the opposite end for the escape of the CO_2. By this extremely simple means results similar to those given by Sachs's method may readily be obtained.

A more refined experiment may be performed by using a modification of the Dewar flask (Fig. B). Since 1903 I have employed flasks of this description with the addition of a drainage tubule, the vacuum diminishing very considerably the loss of heat from radiation ('Proc. Roy. Soc., B.,' 1908). These flasks are somewhat expensive and hardly suitable for students' use. But they are excellent for research and demonstration purposes, and several sets of the simpler apparatus can easily be provided so that the students may set up and work out the experiments individually.

With this form of apparatus many instructive experiments may be carried out. Thus by closing the end of the drainage tube in I and allowing the CO_2 to accumulate the fall of temperature due to decrease of respiration under these conditions can be noted. Or by filling the flask I with CO_2 or hydrogen or nitrogen one may observe the failure of the seeds to germinate under such conditions and the consequent absence of any rise in temperature.

Ganong ('Plant Physiology') also recommends vacuum flasks, but uses an alkali to absorb the CO_2 in place of the drainage tubule.

Pierce (' Botanical Gazette,' 1908, 1912) has employed the Dewar flask with drainage tubule in his investigations on measuring the number of calories liberated by germinating peas, and has also emphasized the necessity of measuring the heat equivalent. In his experiments he has also avoided the error due to the heat of putrefaction by sterilizing the seeds.

Armstrong College,
Newcastle-upon-Tyne,
March, 1917.