Possible Extension of the Demonstration

The demonstration as described has been designed to best serve the needs of students as well as considering the limitations of time and facilities. There are a number of ways in which the demonstration could be extended for different circumstances; it would be possible to cannulate the carotid artery of the rats and thus to monitor blood pressure, to remove blood samples for pH and gas analysis during the experiment, and even perhaps to monitor an electroencephalogram. Also, pH can be measured at ambient temperatures that are comparable to body temperatures, thus eliminating correction factors (8).

It would also be possible to further assess whether the collapse of blood pressure during cooling in unrespired rats can be prevented with vasoactive substances and if so, whether this improves the chances of resuscitation.

References

1. Andjus, R. K., and A. U. Smith. Reanimation of adult rats from body temperatures between 0° and 2°C. *J. Physiol. London* 128: 446-472, 1955.
2. Bender, H. W., R. D. Fisher, W. E. Walker, and T. P. Graham. Reparative cardiac surgery in infants and small children. Five years experience with profound hypothermia and circulatory arrest. *Ann. Surg.* 190: 437-443, 1979.
3. Bigelow, W. G., W. K. Lindsay, R. C. Harrison, R. A. Gordon, and W. C. Greenwood. Oxygen transport and utilization in dogs at low body temperature. *Am. J. Physiol.* 160: 125-137, 1950.
4. Hillman, H., and P. Rogers. Recovery of spontaneous respiration in rats following hypothermia. *J. Physiol. London* 204: 87:88, 1969.
5. Howell, B. J., F. W. Baumgardner, K. Bondi, and H. Rahn. Acid-base balance in cold-blooded vertebrates as a function of body temperature. *Am. J. Physiol.* 218: 600-606, 1970.
6. Kent, K. M., and E. C. Pierce. Acid-base characteristics of hibernating animals. *J. Appl. Physiol.* 23: 336-340, 1967.
7. Lyman, C. P., and D. C. Blinks. Effects of temperature on the isolated hearts of closely related hibernators and nonhibernators. *J. Cell. Comp. Physiol.* 54: 53-63, 1959.
8. Musacchia, X. J., and W. A. Volkert. Blood gases in hibernating and active ground squirrels. HbO_2 affinity at 6 and 38C. *Am. J. Physiol.* 221: 128-130, 1971.
9. Pickering, B. G., G. K. Bristow, and D. B. Craig. Case history number 97. Core rewarming by peritoneal irrigation in accidental hypothermia with cardiac arrest. *Anesth. Analg.* 56: 574-577, 1977.
10. Rahn, H. PCO_2, pH and body temperature. In: *Carbon dioxide and Metabolic Regulation,* edited by G. Nahas and K. E. Schaefer. New York: Springer-Verlag, 1974, p. 152-162.
11. Rogers, P. Cooling of rats and their recovery from deep hypothermia. *J. Physiol. London* 207: 19p, 1970.
12. Rogers, P. D. *Deep Body Cooling of Anaesthetised Rats and Subsequent Resuscitation* (Ph.D. thesis). Guildford, UK: University of Surrey, 1971.
13. Rogers, P. D., and H. Hillman. Increased recovery of rat respiration following profound cooling. *J. Appl. Physiol.* 29: 58-63, 1970.
14. Rogers, P., and H. Hillman. Increased recovering of anaesthetised hypothermic rats induced by intracarotid infusion. *Nature London* 228: 1314-1315, 1970.

Suggested Further Reading

15. Blair, E. *Clinical Hypothermia.* New York: McGraw, 1964.
16. Hardy, R. N. *Temperature and Animal Life.* London: Arnold, 1979.
17. Keatinge, W. R. *Survival in Cold Water.* Oxford, UK: Blackwell, 1969.
18. Popovic, V., and P. Popovic. *Hypothermia in Biology and in Medicine.* New York: Grune & Stratton, 1974.
19. Wang, L. C. H., and J. W. Hudson (Editors). *Strategies in Cold.* New York: Academic, 1978.

A Pen-Vibrator Adapter to Increase the Sensitivity of an Ink-Writing Kymograph

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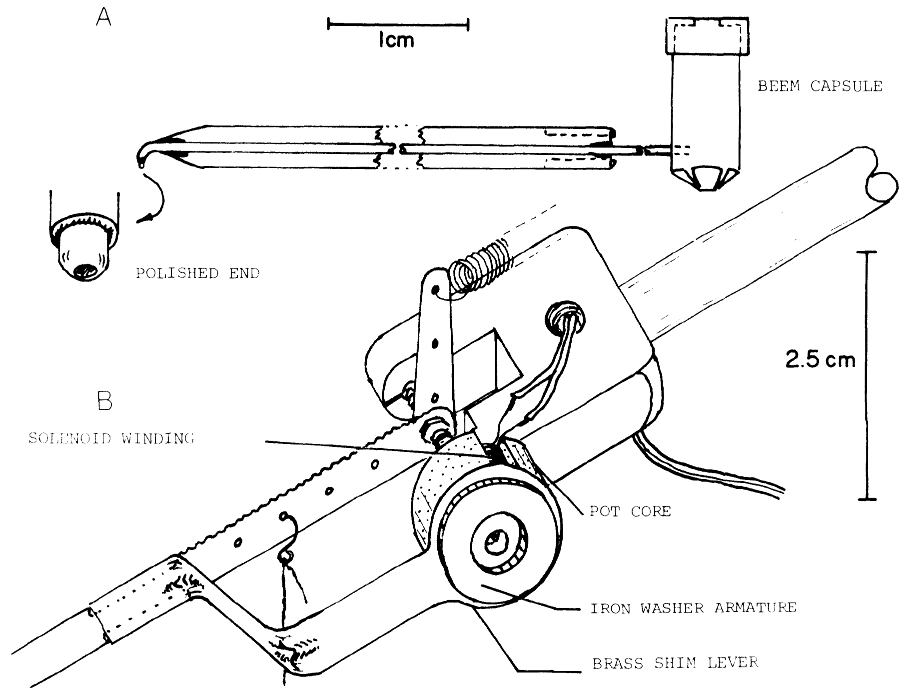
Recent years have seen a gradual displacement of the direct-writing kymograph and lever system in favor of electronic polygraphs and their associated transducers. This is partly because they are "more modern," and hence indicate progressive teaching methods, and partly because of well-justified frustration with smoked drums and messy and inefficient kymograph inking systems. Nevertheless, for freshman courses, the kymograph offers unparalleled simplicity of operation. Its use prevents the considerable complexities of electronic transducers and their associated amplifiers and controls, distracting the student from the object of the laboratory exercise. Needless to say, this does not only apply to freshman courses.

When it was acceptable to use smoked paper and styli, the sensitivity of the kymograph for smooth muscle work often rivaled that of present electronic systems, and in addition the equipment was almost immune from the effects of extraneous vibration. However, ink-writing systems are far more aesthetically acceptable; attempts to use ink with kymographs, while resulting in clearer and more readily copied traces, have led to a further decline in their use. This is because a new problem was introduced: the capillary attraction between the pen and the paper, amplified by the lever, drastically reduced the sensitivity of the system. Attempts have been made to overcome this problem, such as the use of gimbaled levers, electrosensitive paper, and so on, but these do not appear to have been particularly successful.

The approach outlined here, using a coaxial vibrator built into the lever system, has completely overcome these limitations, resulting in traces of equal sensitivity to those produced using a smoked drum and at the same time retaining the marvellous simplicity of operation of the direct-writing kymograph. Essentially, the device consists of a low-voltage AC-energized solenoid mounted coaxially with the axis of the pen-lever pivot. An iron washer, which acts as an armature, is connected to the pen-lever by a rigid arm constructed out of shim brass; movement of the armature toward the solenoid results in the pen tip flexing off the paper, thereby breaking the capillary adhesion between pen tip and paper. No rotational force is developed, so that the vibration is not transmitted to the preparation.

Figure 1



A: Pen and ink reservoir. In the illustration, the pen tip is shown twisted down by 90°, whereas in fact it lies perpendicular to the pen web. *B*: Vibrator adapter mounted on the pivot assemble of a standard isotonic lever (in this case Palmer Instr.). The iron washer armature is soldered onto the key-shaped brass shim bracket. The corners of the bracket are folded slightly, and a small fillet of solder is applied to the corners to increase rigidity. The solenoid assembly is cemented onto the lever yoke in such a way that the central hole in the half-pot core surrounds the pivot screw. The leads to the transform should be anchored as that they cannot be accidentally removed. (Scale 2.5 cm.)

Constructional details are given in Fig. 1. The actual magnetic material from which the pot core is made is not critical for this purpose. [A 14-mm-diameter 3B7 pot core (Philips-Norelco) was used in our version.] The solenoid coil must be wound as a "pancake" on a form consisting of a suitably sized rod (e.g., of nylon) fitted with removable facing washers between which the insulated coil wire (approx 40 gauge) is wound. Before removal, the coil is coated with diluted polyvinyl acetate (white) glue and baked dry. The coil must fit snugly into the cavity of the pot core and must not protrude beyond the face. The coil must be cemented in place inside the pot core, otherwise it will tend to move as well. The gap between the steel washer and the face of the solenoid pot core should be about 0.25 mm for optimum operation.

The pen used consists of a 14-cm length of 22-gauge thin-walled hypodermic tubing connected to an ink reservoir situated near the rotational axis to allow ready filling of the pen while the kymograph is in use. The ink reservoir is constructed from a BEEM electron-microscopy embedding capsule that has a hole punched in the cap to allow refilling. A short length of 27-gauge hypodermic tubing is used as the pen tip. It is soldered in place, and the writing tip is rounded and polished with an Arkansas stone.

The transformer powering the solenoid can be mounted within the kymograph body (and in the case of kymographs that have intergral stimulators, it can be omitted and the solenoid energized from the low-voltage AC output of the power transformer through a suitable current-limiting resistance). The low-voltage side of the transformer can be connected to two banana jacks mounted on the kymograph body to allow ready connection of the pen unit. For a coil resistance of 8-10 Ω an excitation voltage of 4 V AC was found to be adequate.

In operation the pen pressure and the distance between the iron washer and the pot core should be adjusted so that the pen can be seen to be just tapping, at mains frequency, on the surface of the paper (see Fig. 2). This vibration achieves two effects. First it continually breaks the surface tension between the pen and paper, thereby allowing the preparation to move the pen to the new position. In addition, the vibrator "loosens" the bearings of the lever system, thus further increasing the sensitivity of the lever arm.

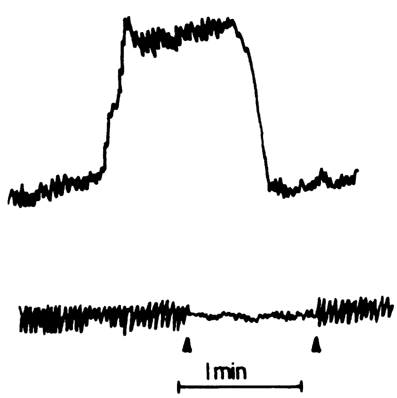


Figure 2

Two traces made using the vibrator and an isotonic writing-lever system. *Upper trace* is the response of rat intestine to an addition of 10^{-6} M norepinephrine to the organ bath. *Lower trace* illustrates the effect of tip adhesion to the paper. Between the two arrows the vibration was turned off (with the pen tip just touching the paper). As is evident, there is an approximately 10-fold decrease in the size of the trace due to tip capillary adhesion. (Paper speed 2.5 cm/min.)